Swansea University
Prifysgol Abertawe

Cronfa
Setting Research Free

Swansea University E-Theses

Reading and recognising acronyms: Insights from behavioural, electrophysiological and neuropsychological investigations.

Playfoot, David Ross

How to cite:

Playfoot, David Ross (2011) *Reading and recognising acronyms: Insights from behavioural, electrophysiological and neuropsychological investigations.*. thesis, Swansea University.
http://cronfa.swan.ac.uk/Record/cronfa43197

Use policy:

This item is brought to you by Swansea University. Any person downloading material is agreeing to abide by the terms of the repository licence: copies of full text items may be used or reproduced in any format or medium, without prior permission for personal research or study, educational or non-commercial purposes only. The copyright for any work remains with the original author unless otherwise specified. The full-text must not be sold in any format or medium without the formal permission of the copyright holder. Permission for multiple reproductions should be obtained from the original author.

Authors are personally responsible for adhering to copyright and publisher restrictions when uploading content to the repository.

Please link to the metadata record in the Swansea University repository, Cronfa (link given in the citation reference above.)

http://www.swansea.ac.uk/library/researchsupport/ris-support/

READING AND RECOGNISING ACRONYMS: INSIGHTS FROM BEHAVIOURAL, ELECTROPHYSIOLOGICAL AND NEUROPSYCHOLOGICAL INVESTIGATIONS.

DAVID ROSS PLAYFOOT

Submitted to the University of Wales in fulfilment of the requirements for the Degree of Doctor of Philosophy

Swansea University

2011

SWANSEA UNIVERSITY
LIBRARY

R

NOT TO BE
REMOVED FROM
THE LIBRARY

ProQuest Number: 10821589

All rights reserved

INFORMATION TO ALL USERS
The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript
and there are missing pages, these will be noted. Also, if material had to be removed,
a note will indicate the deletion.



ProQuest 10821589

Published by ProQuest LLC (2018). Copyright of the Dissertation is held by the Author.

All rights reserved.
This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 – 1346

ABSTRACT

This thesis examined the processes involved in reading and recognising acronyms (e.g. BBC, HIV, NATO). Normative values for frequency, age of acquisition, imageability, length, bigram and trigram frequency and orthographic neighbourhood size have been collected, and the influence of these factors on reading, recognition (Chapter 3) and word association responses (Chapter 4) has been assessed. Findings suggest that acronyms are integrated alongside words in the mental lexicon, and that meaning and phonology are particularly important in acronym processing. Chapter 5 extended these findings by investigating the performance of a patient with a specific deficit in semantic processing (semantic dementia). Some acronyms, specifically those which are pronounced by naming each letter in turn, were found to pose few problems for this patient even after her semantic system had been adversely affected by her disorder. Chapter 7 reported an event-related potential study of acronyms, with reference to the N170 and Recognition Potential components. The electrophysiological data supported the interpretation of acronyms as lexical, and particularly influenced by print to pronunciation factors. Findings of the thesis as a whole were discussed in relation to the Dual Route Cascaded model (Coltheart, Perry, Rastle, Langdon & Ziegler, 2001) and the Triangle model (Plaut, Seidenberg & Patterson, 1996). It was concluded that neither model could adequately accommodate acronym reading and recognition processes as they currently stand. Suggestions for amendments to word reading models were made. Potential future research directions are also discussed.

SWANSEA LIBRARY UNIVERSITY

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed.....(candidate)

Date.....

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

Other sources are acknowledged giving explicit references. A bibliography is appended.

Signed.....(candidate)

Date.....

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed.....(candidate)

Date.....

SWANSEA UNIVERSITY LIBRARY

Contents

PAGE

Abstract 2

Declarations and statements 3

Contents 4

Acknowledgements 12

List of Tables 13

List of Figures 17

Chapter 1 – Reading and recognising acronyms: Insights from behavioural, electrophysiological and neuropsychological investigations. 20

1.1 Introduction 20

1.2 Word recognition 23

1.3 Word comprehension 25

1.4 Word naming 27

1.4.1 The Dual Route Cascaded model 27

1.4.2 The Triangle model 29

1.4.3 Developing model 31

1.5 Important characteristics of words and acronyms 31

1.5.1 Age of acquisition 31

1.5.2 Bigram and trigram frequency 34

1.5.3 Imageability 35

1.5.4 Number of orthographic neighbours 37

1.5.5 Word frequency and Word familiarity 40

1.5.6 Letter and syllable length 42

1.6 Semantic Dementia and Surface Dyslexia 44

1.6.1 Description of the disorder 44

1.6.2 Modelling semantic dementia and surface dyslexia 45

1.6.2.1 DRC account 45
1.6.2.2 Triangle account 45
1.7 EEG and ERP methods 46
1.8 Aims and outlines of the experimental Chapters 47
1.8.1 Are acronyms processed like mainstream words? 47
1.8.2 Do acronyms require processing similar to that required by irregular words? 51
1.8.3 Can currently influential models of word reading accommodate acronym performance? 52

Chapter 2 – Investigating frequency in acronym recognition and reading. 54

2.1 Introduction 54
2.2 Experiment 2.1 methods 61
2.2.1 Participants 61
2.2.2 Materials 62
2.2.3 Procedure 62
2.3 Experiment 2.1 results 63
2.4 Experiment 2.1 discussion 66
2.5 Experiment 2.2 methods 68
2.5.1 Participants 68
2.5.2 Procedure 68
2.6 Experiment 2.2 results 69
2.7 Experiment 2.2 discussion 71
2.8 Experiment 2.3 introduction 72
2.9 Experiment 2.3 methods 74
2.9.1 Participants 74

SWANSEA UNIVERSITY LIBRARY

2.9.2 Materials 74

2.9.3 Procedure 74

2.10 Experiment 2.3 results 75

2.11 Discussion 77

2.12 General discussion 77

Chapter 3 – A normative study of acronyms 82

3.1 Introduction 82

3.2 Acronym characteristics 85

3.2.1 Age of acquisition 85

3.2.2 Number of orthographic neighbours 87

3.2.3 Bigram and trigram frequency 88

3.2.4 Imageability 89

3.2.5 Frequency and familiarity 90

3.2.6 Length 91

3.2.7 Print to pronunciation characteristics 92

3.2.8 Word's initial sound 96

3.3 Results 96

3.3.1 Participants 96

3.3.2 Materials 97

3.3.3 Database variables 98

3.3.3.1 Procedure 99

3.3.3.1.1 Rated frequency 99

3.3.3.1.2 Printed frequency 99

3.3.3.1.3 Imageability 99

3.3.3.1.4 Age of acquisition 100

3.3.3.1.5 Number of orthographic neighbours 100

3.3.3.1.6 Length 100

3.3.3.1.7 Bigram and trigram frequency 100

3.4 Results and discussion 101

3.5 Word naming experiment 104

3.5.1 Participants 104

3.5.2 Procedure 104

3.6 Results 107

3.6.1 RTs 107

3.6.2 Errors 115

3.7 Discussion 116

3.8 Lexical decision experiment 120

3.8.1 Participants 120

3.8.2 Materials 120

3.8.3 Procedure 120

3.9 Results 121

3.9.1 RTs 121

3.9.2 Errors 126

3.10 Discussion 128

3.11 General discussion 131

Chapter 4 – The role of imageability, age of acquisition and frequency in acronym comprehension **138**

4.1 Introduction 138

4.2 Methods 145

4.2.1 Participants 145

4.2.2 Procedure 145

4.3 Results 146

4.3.1 RTs 146

4.3.2 Distribution analyses 148

4.3.3 Categorisation analyses 150

4.4 Discussion 153

Chapter 5 – Acronym processing in semantic dementia **158**

5.1 Introduction 158

5.2 Methods 165

5.2.1 Patient JD 165

5.2.2 Semantic categorisation 165

5.2.2.1 Control participants 165

5.2.2.2 Materials 166

5.2.2.3 Procedure 168

5.2.3 Results 168

5.2.4 Discussion 169

5.2.5 Lexical decision 170

5.2.5.1 Control participants 170

5.2.5.2 Materials 170

5.2.5.3 Procedure 171

5.2.6 Results 172

5.2.7 Discussion 173

5.2.8 Naming 174

5.2.8.1 Control group 176

5.2.8.2 Procedure 176

5.2.9 Results 177

5.2.10 Discussion 178

5.3 General discussion 179

Chapter 6 – The effect of context on acronym naming performance 184

6.1 Introduction 184

6.2 Method 188

6.2.1 Participants 188

6.2.2 Materials 188

6.2.3 Procedure 189

6.3 Results 190

6.4 Discussion 192

Chapter 7 – The effect of repetition on acronym naming and lexical decision and an investigation of lexicality effects in event related potentials **198**

7.1 Naming introduction 198

7.2 Methods 201

7.2.1 Participants 201

7.2.2 Materials 201

7.2.3 Procedure 201

7. 3 Results 202

7.3.1 RT analyses – Block 1 202

7.3.2 Accuracy analyses – Block 1 203

7.3.3 RT analyses – All blocks 204

7.3.4 Accuracy analyses – All blocks 206

7.4 Discussion 207

7.5 Lexical decision introduction 209

7.6 Methods 216

7.6.1 Participants 216

7.6.2 Materials 216

7.6.3 Procedure 217

7.6.4 Electrophysiological recording 218

7.7 Results 218

7.7.1 Behavioural analyses 218

7.7.1.1 RT analyses – Block 1 219

7.7.1.2 Accuracy analyses – Block 1 220

7.7.1.3 RT analyses – All blocks 221

7.7.1.4 Accuracy analyses – All blocks 223

7.7.2 Electrophysiological data 224

7.8 Discussion 225

7.9 General discussion 232

Chapter 8 – Acronym naming and recognition processes: Implications for current models of reading and recognition 235

8.1 Introduction and summary of main findings 235

8.2 Addresssing the research questions 250

8.2.1 Are acronyms processed like mainstream words? 250

8.2.2 Do acronyms require processing similar to that required by irregular words? 252

8.3 Acronyms and models of reading 253

8.4 Future directions 256

References 260

Acknowledgements

I would like to acknowledge the contributions of the following people in the completion of this thesis. First and foremost, I would like to express my gratitude to Dr Cristina Izura for her patience and guidance over the last 4 years. I appreciate all of her efforts in getting me his far, and for making me feel like her door was always open if I needed it to be. I would also like to thank her for the support she has given me and my new family. I thank Dr Jeremy Tree for his help in completing the data collection for Chapter 5 of this thesis, and for his general input on the ideas for, and interpretation of, the rest of my work. I also appreciate the comments on portions of this thesis received at conferences over the last three years. I am particularly grateful to Ilhan Raman, Friedemann Pulvermuller, Catriona Morrison and Andy Ellis, and to Alan Rudell and Max Coltheart for their informative email correspondence. Dr Tess Fitzpatrick deserves an honourable mention for employing me over the past 12 months, for recognising that I still had work to do on this thesis and for being flexible enough to allow me to complete in time. There are times when she seems much more certain of my abilities than I am, as indeed are my parents, but it's always nice to have a cheerleading section.

Finally, I would like to thank Rebecca Batchelor (soon to be Playfoot) for having faith in me even when I had lost mine. Without her I may have given up on the PhD long ago. Her ability to pick me up when I was down and keep me grounded when I got ahead of myself has been a major factor in the completion of this thesis. I love the way she pretended to be interested when I waffled on, in depth, about regression analyses over dinner, or about the arbitrary mappings hypothesis while en route to visit family.

For Oscar Elliott Playfoot (born. 26 February 2011).

"He who has a why to live can bear almost any how."

LIST OF TABLES

Table 2.1 –Mean response times (M), standard deviations (SD) and percentage of errors (Errors (%)) for Experiment 2.1

Page 58

Table 2.2 – Mean response times (M), standard deviations (SD) and percentage of errors (Errors (%)) for Experiment 2.2.

Page 63

Table 2.3 – Response naming times (M), standard deviations (SD) and percentage of errors (Errors (%)) for Experiment 2.3

Page 69

Table 3.1 – Descriptive statistics for each continuous variable

Page 93

Table 3.2 – Correlation Matrix for fourteen variables and 146 acronyms.

Page 95

Table 3.3 – Percentage of correct and incorrect naming responses to known and unknown acronyms.

Page 98

Table 3.4 – Correlations between predictor variables, reaction times and accuracy.

Page 100

Table 3.5 – Acronym printed frequencies comparisons

Page 101

Table 3.6 – Standardized regression coefficients (β) for the four multilevel analyses carried out on acronym naming times.

Page 103

Table 3.7 – Wald statistic the four multilevel analyses carried out on acronym accuracy.

Page 108

Table 3.8 – Correlations between predictor variables, reaction times and accuracy.

Page 113

Table 3.9 – Acronym printed frequencies comparisons

Page 114

Table 3.10 – Standardized regression coefficients (β) for the four multilevel analyses carried out on acronym recognition times.

Page 115

Table 3.11 – Wald statistics for the four multilevel analyses carried out on acronym lexical decision accuracy.

Page 118

Table 4.1 – Pearson's correlation coefficients between lexical variables and word association response latencies.

Page 138

Table 4.2 – Regression coefficients for the multiple regression carried out on word association latencies.

Page 138

Table 4.3 – Pearson's correlation coefficients between lexical variables and measures of the distribution of word association responses.

Page 140

Table 4.4 – Standardised (β) regression coefficients for the four analyses concerning word association response distribution.

Page 141

Table 4.5 – Pearson's correlation coefficients between lexical variables and the numbers of responses categorised as being based on meaning, form and position.

Page 143

Table 4.6 – Standardised (β) regression coefficients for the five analyses concerning word association response categorisation.

Page 144

Table 5.1 – JD's performance in standard tests (% Accuracy) at two different points in time.

Page 157

Table 5.2 – Accuracy rates for JD in the semantic categorisation tasks.

Page 159

Table 5.3 – Percentage of correct lexical decision responses for each stimulus type in each of JD's test sessions.

Page 163

Table 5.4 – Accuracy rates for JD in the naming task.

Page 168

Table 6.1 – Mean response latencies (M) and standard deviations (SD) for ambiguous typical (HIV) and ambiguous atypical (NATO) acronyms presented in different contexts. Percentage accuracy is also included (Accuracy%).

Page 180

Table 7.1 – Descriptive statistics for RT and accuracy to targets in each condition (ms)

Page 190

Table 7.2 – Mean (M), standard deviation (SD) and percentage accuracy (Acc(%)) for each block and condition of Experiment 7.1.

Page 193

Table 7.3 – Mean, standard deviation (SD) and percentage accuracy (%) for all conditions in block 1 in Experiment 7.2

Page 207

Table 7.4 – Mean reaction times (M), standard deviations (SD) and percentage accuracy (Acc(%)) for all the conditions and repetitions in Experiment 7.2

Page 210

LIST OF FIGURES

Figure 1.1 – The Dual-Route Cascaded Model of word reading (Coltheart et al., 2001).

Page 28

Figure 1.2 – The Triangle model (Plaut et al. 1996).

Page 29

Figure 2.1 – Mean response times for correct lexical decision responses.

Page 59

Figure 2.2 – Mean number of errors for each stimulus type.

Page 60

Figure 2.3 – Mean naming times for each stimulus type

Page 64

Figure 2.4 – Mean naming times for each stimulus type

Page 70

Figure 3.1 – Regression lines between Reaction Times and Printed Frequencies for the different types of acronyms.

Page 104

Figure 3.2 – Regression lines between Reaction Times and Age of Acquisition for the different types of acronyms.

Page 105

Figure 3.3 – Regression lines between Reaction Times and Imageability for the different types of acronyms.

Page 106

SWANSEA UNIVERSITY LIBRARY

Figure 3.4 – Regression lines between Reaction Times and imageability for the different types of acronyms.

Page 116

Figure 3.5 - Regression lines between Reaction Times and age of acquisition for the different types of acronyms.

Page 117

Figure 3.6 – Mean printed frequency of correct and incorrect responses to each type of acronym.

Page 119

Figure 4.1 – Percentage of the total number of word association responses in each response category.

Page 142

Figure 6.1 – Interaction between acronym print to pronunciation pattern and the context of the presentation for reading in RT.

Page 181

Figure 6.2 – Interaction between acronym print to pronunciation pattern and the context of the presentation for reading in accuracy

Page 182

Figure 7.1 – Mean naming reaction times by subjects and by items for the five conditions of Experiment 7.1

Page 192

Figure 7.2 – Mean naming reaction times across block for the five conditions of Experiment 7.1

Page 194

Figure 7.3 – Mean latencies across repetitions and conditions for Experiment 7.2

Page 208

Figure 7.4 – Mean reaction time in milliseconds for each type of word in each presentation block.

Page 211

Figure 7.5 – Grand average ERP waves for the PO7 region of interest

Page 213

CHAPTER 1

READING AND RECOGNISING ACRONYMS: INSIGHTS FROM EXPERIMENTAL, ELECTROPHYSIOLOGICAL AND NEUROPSYCHOLOGICAL INVESTIGATIONS.

1.1 Introduction

Reading is a process of both recognition and comprehension. In skilled readers this process generally occurs quickly and accurately, but in some circumstances reading becomes more difficult. The wealth of literature on word reading that has provided evidence for the effect that semantic, phonological and orthographic factors have in the ease with which a stimulus is processed is large (see Balota, Yap, & Cortese, 2006; Gaskell, 2009). Of interest in this thesis is the way in which acronyms or initialisms are processed. While strictly speaking "acronym" refers to pronounceable abbreviations formed from the initial letters of a series of words and "initialism" refers to similarly created abbreviations that are unpronounceable. Many (if not most) people use the former term to refer to all such abbreviations. It is in this sense that the word "acronym" will be used here. The orthographic structure of acronyms often looks like that of non-words, while having similar semantic properties to mainstream words. The first time an acronym is used (e.g., HSKT) the letters do not make a 'real' word, and their combination tends to be orthographically and phonologically impossible, but when extended to the full words they correspond to, the letters gain meaning – "head, shoulders, knees and toes" – and with enough repetition they could substitute the full term. Acronyms are produced because they are "a convenient code for some particularly lengthy or cumbersome phrase," (Jamieson, 1968; p. 473-474). However, despite their conveniences, acronyms can also be ambiguous and meaningless (Jamieson, 1968). Regardless of their merits and disadvantages, acronyms proliferate in today's society, perhaps nowhere more so than in academic literature. Cheng (1992), for example, compiled a list of 244 acronyms referring to cardiological research trials. Two years later the number had almost quadrupled

(Cheng, 1994a). Cheng (1994b) indicated that some readers of medical journals "give up halfway through an article littered with unexplained acronyms" (pp.684). An examination of the ease at which acronyms are recognised and comprehended is invaluable to understanding the accessibility of an article, or any written text which contains a large number of acronyms.

A distinctive characteristic of acronyms is that their configuration does not obey the orthographic and/or phonological rules of English. They are often formed by a sequence of illegal letter strings that can become highly familiar to the language user (e.g., abc, BBC, CNN, FBI, fm, HIV, KFC, pm, TV, USB, etc). Due to this peculiar illegality, acronyms have been recently used in the study of two influential models of reading aloud; the triangle model and the dual route cascade model (Laszlo & Federmeier, 2007b). An important discrepancy between these two models lies in the relative relevance given to the frequency of the word in contrast to its regularity when reading aloud. One of the models under investigation in Laszlo and Federmeier (2007b) was the connectionist triangle model (Seidenberg & McClelland, 1989; Harm & Seidenberg, 2004). The model proposes a single processing system for reading all known words, irrespective of their frequency and regularity, and all unknown/novel words. This is achieved by means of a learning mechanism that extracts the statistically more reliable (frequent) spelling-sound relationships in English. Importantly, orthographic and/or phonological rules are redundant in the model and therefore they have not been specifically implemented. The other model investigated is the non-connectionist dual route cascaded model (Coltheart, Curtis, Atkins, & Haler, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). It proposes two reading routes or procedures: a lexical route and a non-lexical route. The lexical route entails direct connections between the mental representations of the written form of the word and the spoken form of the word and also detoured connections between written and spoken word forms with their corresponding conceptual representations in the semantic system. The non-lexical route converts letters into sounds applying the orthographic and phonologic rules of the language. This latter route is indispensable to read novel words and non-words since no mental representation for them has been formed. Non-lexical processing will also give the correct pronunciation of regular words, although this is not the only reading pathway available to them. Correct

reading of irregular words, however, needs to be accomplished via the lexical route since these words do not stick to the pronunciation rules of the language.

Laszlo and Federmeier (2007b) tested these models looking at the differential N400 repetition effect found for words (HAT) and pseudowords (e.g., DAWK) but not for orthographically illegal nonwords (MDTP). They argue that according to the dual route model, the sensitivity of the N400 component to the repetition of legal letter strings, for both words and pseudowords (Deacon, Dynowska, Ritter, & Gorse-Fifer, 2004; Rugg, 1990) could only reflect the performance of the non-lexical pathway since this is the only route available to read novel items such as the pseudowords. In consequence, no repetition effects in the N400 should be observed when reading acronyms since their irregularity precludes the use of the non-lexical route. It is important to note that it is not clear how the predicted and reported absence of repetition effects for illegal letter strings fits into the argument since illegal letter strings also make use of the non-lexical pathway. Connectionist models, alternatively, would predict repetition effects in the N400 for words, pseudowords and acronyms since the same process underpins the recognition of any type of letter string. Laszlo and Federmeier (2007b) found N400 repetition effects for words, pseudowords and acronyms and not for illegal non-words. They concluded that this outcome could only be accommodated by the connectionist account for oral reading. However, Lazlo and Federmeier (2007b) failed to notice that pseudowords, in particular pseudohomophones and those pseudowords extracted from high frequency words can generate activation in the lexical pathway (Coltheart, 2007). The lexical route will not produce the correct reading of pseudowords but can be, nevertheless, stimulated. Taking this into account their results can be perfectly explained by the dual route model through the activation of the lexical route by words, acronyms and pseudowords. This explanation also reconciles better with the lexico-semantic processing found to be associated with the N400 component (Sheehan, Namy, & Mills, 2007; van Elk, van Schie, & Bekkering, 2010). Equivalent N400 amplitudes were found for words and acronyms in a subsequent study (Laszlo & Federmeier, 2008) in which the N400 sentence anomaly paradigm was used. Here regular words, acronyms, legal and illegal letter strings were placed at the end of sentences in such way that they formed semantically congruent or incongruent statements. The authors conclude that this pattern of results is not reconcilable with the dual route model.

Acronyms have also played an important part in the investigation of the word superiority effect (WSE). Gibson, Bishop, Schiff, and Smith (1964), for example, investigated the relative contribution that meaningfulness and pronounceability had in the WSE. They devised two experimental conditions; one formed by meaningful but unpronounceable trigrams (these were all acronyms), and the other by meaningless but pronounceable trigrams (these were all pseudowords). They showed an advantage for acronyms in word recognition memory and recall suggesting that meaning rather than pronounceability had a more powerful influence in these processes. Similar results were reported by Henderson (1974) who also manipulated meaning and pronounceability using acronyms and pseudowords. She found that participants were faster at judging pairs of items as being the same (e.g., FBI-FBI; BLI-BLI) or different (e.g., FBI-IMB; BLI-LSF) if a meaningful item or acronym, was in the pair. A number of later studies have replicated the influence of meaning in the WSE using acronyms in their experimental sets (Lazlo & Federmeier, 2007a; Noice & Hock, 1987; Staller & Lappin, 1981).

In sum, a great part of the research on acronyms leads to the conclusion that although they are unusual in orthography and phonology, they are nevertheless representations of a specific meaning, and hence might be considered words. Findings such as those detailed above suggest that acronyms do indeed have lexicon entries, and that studies using acronyms have the potential to further understanding of reading processes and extend existing models of word reading. Three facets of word processing are commonly examined. The first is word recognition, which refers to the ability to determine that a word has been encountered before. The second is word comprehension which assesses knowledge of the meaning of the word, and its connection to other concepts. The third is word naming or the ability to read words out loud. A brief discussion of each of these and the techniques used to examine their processes follows below.

1.2 Word recognition

Perea, Rosa, and Gómez (2002) stated that the lexical decision task has been "the most widely used task in the study of visual word recognition" (p. 34). The task is

also used extensively in this thesis. The lexical decision task requires participants to distinguish words from non-words as quickly as possible. The nature of the task forces the use of two types of stimuli: real words and invented words. The processes engaged when individuals decide whether the target item is a word or a non-word appear to depend on the nature of the invented words (James, 1975; Richardson, 1976; Rubenstein, Lewis, & Rubenstein, 1971; Snodgrass & Jarvella, 1972). If all the non-words in the task are formed by groups of consonants (e.g. YHGB, PYTR, NBVGY) it may be possible to determine that an item is a word by a kind of visual familiarity check. In this case, the individual can develop a strategy of "every time I see a vowel I report it as a word." Employing this strategy will result in quick and accurate responses. In this instance, the task is based on a pure letter identification strategy. The processes involved in making a lexical decision response seem to be different in experiments where the non-words used are orthographically or phonologically similar to real words (e.g. BURF, MAVE, RINT). In these cases determining that a stimulus is a word is assumed to require lexical access (James, 1975; Richardson, 1976).

In order to frame the findings reported in the word recognition literature appropriately, it is pertinent to discuss the mechanisms by which a "yes" or "no" decision is reached. To make a "yes" response, the participant needs to acknowledge that they recognise the word in front of them. This is made possible by the existence of a mental lexicon which contains representations of all the known words in the participant's vocabulary. According to the architecture of the Dual Route Cascaded model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) a visually presented letter string elicits the activation of letter units and hence activation of whole word representations in the orthographic input lexicon. Once the level of activation has reached the criterion level, it is possible to make the assertion that the stimulus has a representation in the lexicon, and that it can be accepted as a word. The logical continuation of this view is that items which reach the threshold more easily are recognised with greater speed. For example, high frequency words are recognised more quickly than low frequency words, and this has been attributed to higher levels of resting activation for commonly occurring stimuli (Perea, Rosa, & Gómez, 2005). When participants are presented with a non-word the mechanism for deciding which

response to make is necessarily different, as it is not possible to activate a lexical representation for a stimulus that does not have one. In this instance, the common conception is that a processing deadline is imposed, and that if the recognition threshold has not been reached in time the stimulus is rejected as a non-word (Coltheart, Besner, Davelaar, & Jonasson, 1977). Importantly, this deadline can be altered depending on the task or the stimulus. The Dual Route Model proposes that the deadline may be lengthened in situations where there is a large amount of activation in the input lexicon, and that it is shortened when very little early activation is elicited (Coltheart et al., 1977; 2001). This conception of a flexible deadline for recognition supports the finding that non-words with large orthographic neighbourhoods are rejected slower than those with few similarly spelled words (e.g. Forster & Shen, 1996). It has been argued that the mechanisms for making "yes" and "no" responses in lexical decision tasks are fundamentally different and it may be therefore inappropriate to analyse reaction time data for words and non-words together.

Response times and accuracy are the measures more commonly used in lexical decision experiments. It is assumed that longer and less accurate responses reflect greater processing effort. Under this assumption, carefully designed experiments allow the examination of which characteristics of the words make them easier or more difficult to process. This provides a window into the structure of the lexical store.

1.3 Word comprehension

Over the course of their life, an individual learns a large number of words. Nagy and Anderson (1984) estimated that the average high school senior student had acquired around 45,000 words. Even with the large number of possible candidates, the appropriate word to describe an object or concept is available quickly. This has been taken as evidence that the lexicon is organised into networks of related words (Collins & Quillian, 1972; Collins & Loftus, 1975). A particularly useful technique to examine the links between concepts is word association. In Chapter 4 the discrete word association task is used to examine the role of acronym characteristics in a semantic task. In a discrete association task, the participant is presented with a single

word and required to produce the first word that comes to his/her mind. In order to achieve this, the participant is forced to activate a second lexical representation which is connected to the target word. Ordinarily, the majority of the associations generated in response to a cue share some kind of semantic relationship. However, it has been argued that these associations are not attributable to semantic similarity per se, and are instead made due to the co-occurrence of two words in text or speech (Fodor, 1983; Lupker, 1984; McKoon & Ratcliff, 1992). It should be noted that there have been a number of different interpretations of what constitutes semantic similarity (see McRae, de Sa & Seidenberg, 1997). Although the level of semantic overlap and associative relatedness between word pairs often co-vary, there are many instances in which word association norms represent highly probable responses which share few semantic features with the cue (e.g. *coat* and *rack*). By the same token, a large number of word pairs which are very closely related semantically are unlikely to appear as responses in word association tasks (e.g. *radish* and *beets*). This dissociation has been the subject of some debate in the automatic priming research. The full extent of this debate is beyond the remit of this thesis, but a cursory glance over the literature reveals evidence for priming effects when prime and target are a) linked associatively but not semantically and b) linked semantically but not associatively (e.g. Ferrand & New, 2003).

While the literature describes separate accounts of semantic priming and associative priming, both are reconcilable with network models of semantic memory (e.g. Collins & Quillian, 1969; Collins & Loftus, 1975). In these models, each word node has a number of other word nodes linked to it. The strength of the links between words determines the ease with which an association between the two concepts is made. Stronger links are easier to retrieve and result in faster responses. The strength of the link also determines the likelihood of the one word being generated as an associate of the other. It has been argued that a link between two nodes is strengthened every time it is activated. Frequency, imageability and age of acquisition are among the factors which seem to influence the strength of the lexico-semantic connections between representations, and are therefore important in word association behaviour (Altarriba, Bauer, & Benvenuto, 1999; Brysbaert, Van Wijnendaele, & De Deyne, 2000; de Groot, 1989; Hall & Ugelow, 1957; Postman, 1964; 1970). Examinations of word

association responses are useful in the examination of the organisation and structure of the lexicon.

1.4 Word naming and models of word reading

Naming tasks present participants with words (and sometimes non-words) to be read aloud. Response time and accuracy data has indicated that some words may be easier to process than others. In order to adequately discuss word naming data, it is necessary to describe the currently influential models of word reading. While there are numerous theories as to how reading is achieved, these can largely be placed into one of two camps. Connectionist models (Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989) argue that reading of words and non-words is possible using a single system. Non-connectionist models (Coltheart, Curtis, Atkins & Haller, 1993; Coltheart et al., 2001), on the other hand, propose two reading routes with different "specialities." These two types of models often predict distinct patterns of results on a given task based on the assumptions that each make about the structure of the reading system. Influential theories from each perspective will be examined in detail here – the connectionist Triangle Model (Plaut et al., 1996) and the Dual-Route Cascaded or DRC model proposed by Coltheart et al. (2001) from the non-connectionist group.

1.4.1 The Dual-Route Cascaded (DRC) Model

The Dual-Route Cascaded model (Coltheart et al. 2001) proposes three pathways from the written word to the spoken output. The first is a non-lexical and rule based route. This relies on converting what is written directly into sound using grapheme-phoneme correspondences (GPC). Each grapheme is related to the phoneme most commonly associated with it in English monosyllabic words, taking into account serial position where necessary. The GPC route allows any novel stimulus to be pronounced by the application of the rules, selecting the appropriate rule for each letter in turn until the last letter is reached, from left to right. However, not all words in the English language adhere to these grapheme-phoneme correspondence principles. Those words that flout the rules used by the non-lexical route can be read via a lexical non-semantic route. In this pathway, the orthography to phonology

conversion is made at a whole word level. Stored representations of the appropriate pronunciation of all known words are accessed, with high frequency items being accessed more quickly than low frequency items. The DRC model proposes a third route, the lexical semantic pathway, which has yet to be fully implemented. This route introduces meaning into the processing of written words. By definition the lexical routes cannot be used to pronounce novel items for which no representation has been stored. The routes in the model work in parallel. This can, in some cases, result in conflicting outputs being offered by the two routes and a slowing of the response while the conflict is resolved. The model architecture is shown below in Figure 1.1.

Activation of a unit in a given layer can make it more difficult for other units to be activated (inhibition) or contribute to the activation of other units (excitation). Lateral inhibition within a layer is also possible. Communication between layers is bi-directional for the most part, with the exception of the connections between feature and letter level units. The orthographic and phonological units in the lexical non-semantic route are only excitatory and mapped one to one. Letter position is implemented through the use of separate units for each input position. The orthographic lexicon contains units for almost 8000 monosyllabic words with corresponding units in the phonological lexicon. Simulations using this structure have successfully mimicked the results from a relatively large number of studies in the word recognition literature both in healthy participants and in participants with developmental or acquired dyslexia.

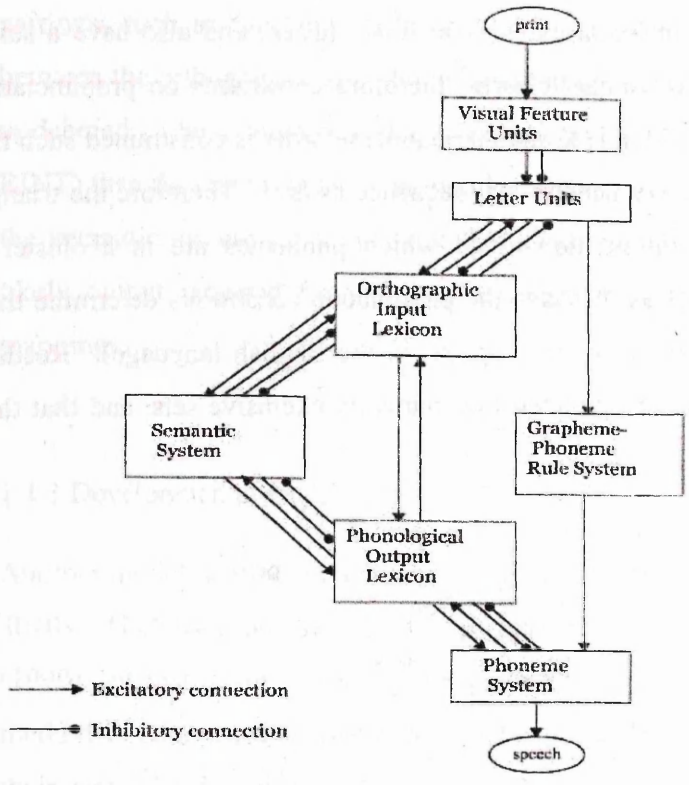


Figure 1.1 – The Dual-Route Cascaded Model of word reading (Coltheart et al., 2001).

1.4.2 The Triangle Model

Plaut et al's (1996) simulations of word reading using a triangle model (Figure 1.2) have also been successful in imitating participant response patterns. This model differs from the DRC in one major facet. The Triangle model proposes a single system for reading aloud rather than two (or three). In this model, orthographic, phonological and semantic inputs interact to determine the pronunciation of a word. The triangle model uses individual orthographic units for each letter of the alphabet and individual units for each phoneme. Mapping from all the letters in a word to all the phonemes in the word through simultaneous (yet weighted) connections would fail to preserve serial position information and would be unable to differentiate between "pit" and "tip." However, Plaut et al.'s (1996) model imposes a few constraints to overcome this potential flaw. They observed that monosyllabic words generally contain only one vowel and often a cluster of consonants in initial or final positions (e.g. CATCH, THROW). As a consequence of this there is a necessity to

group units of consonants in initial clusters, in final clusters and also have a set of units for vowels. Within consonant clusters there are constraints on pronunciation that stem from articulation. That is to say that phoneme order is constrained such that /s/ /t/ and /r/ can only be pronounced in that sequence as /str/. Therefore the triangle model suggests that only information about which phonemes are in a cluster is required for their pronunciation, because the phonotactic constraints determine their order (i.e. there are no examples of /rts/ or /trs/ in the English language). Reading requires only that phonemes are grouped into mutually exclusive sets, and that they are read from left to right.

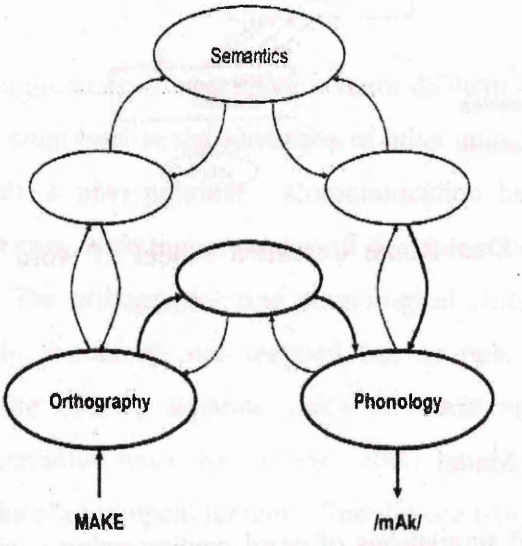


Figure 1.2. – The Triangle model (Plaut et al. 1996).

Simply put then, the triangle model implies that the pronunciation of a stimulus is achieved through the application of constraints imposed by the statistical structure of the English language and English phonology. The implementation of the model dictates that words with a higher frequency impact the knowledge learned more strongly than low frequency words. The triangle model is a learning model, unlike the DRC. Each encounter with a stimulus affects the weights of the connections between units in the model. Thus frequently occurring words influence the orthography to phonology pathway to a greater extent than unusual words. The same principle applies to spelling to sound consistency. Each time common spelling-sound

pairings, such as the "int" in "mint," are presented to the model the connection between the orthographic and phonological units increases in weight. Therefore /int/ is deemed to be a more probable pronunciation for a new word or non-word (e.g. RINT) than the relatively less common pronunciation of "int" as in "pint." Input from the semantic system serves to alter the phonological activation to produce the less likely output required for words with irregular or inconsistent spelling to sound mappings.

1.4.3 Developmental model

Another model worthy of mention is the Developmental Model (P. Monaghan & Ellis, 2010). They used the connectionist architecture described by Harm and Seidenberg (1999) but instead of presenting all the training materials en masse (as is the usual method in computational modelling) words were introduced into the model based on their age of acquisition as calculated from the Educators Word Frequency Guide (Zeno, Ivens, Hillard & Duvvuri, 1995). The model's performance was assessed based on the accuracy of the phonological output computed from the orthographic input after training. The model's response was considered accurate if all the phoneme units matched the target phonemes for the presented word. By presenting training words in different training epochs, the developmental model simulated the age of acquisition effects observed in human participants, as well as the commonly reported interactions between age of acquisition and orthography-phonology consistency (J.Monaghan & Ellis, 2002).

1.5 Relevant characteristics of words and acronyms in cognitive processing

1.5.1 Age of acquisition

Age of acquisition (AoA) refers to the moment in time in which words, objects and faces are first learned. Differences in order of learning or AoA have been shown to affect processing times, accuracy, amplitude of ERP components, eye fixation durations and spatially distinctive brain regions (Cuetos, Barbón, Urrutia, &

Dominguez, 2009; Ellis, Burani, Izura, Bromiley, & Venneri, 2006; Gilhooly & Logie, 1982; Juhasz & Rayner, 2006; Morrison & Ellis, 1995, 2000; Pérez, 2007; Weekes, Chan, & Tan, 2008). Evidence shows that early acquired material has an advantage over late acquired material in terms of processing time, accuracy and resistance to brain damage (see reviews in Johnston & Barry, 2006; Juhasz, 2005). Ratings have been the most common way of measuring AoA. Here participants are asked to estimate, on 7-point or 9-point scales, the age at which they believe they learned a list of words. Although these estimations might seem too subjective they have been shown to correlate highly with objective AoA values (Carroll & White, 1973; Gilhooly & Gilhooly, 1980; Morrison, Chappell & Ellis, 1997; Pérez, 2007).

The relevance of the AoA effect in cognitive processes lies in the wide range of tasks, languages and population samples influenced by it. AoA effects have been reported in lexical decision, word and object naming, word-associate generation, semantic categorisation, object and face recognition, written word production and repetition priming (Barry, Johnston, & Wood, 2006; Bonin, 2005; Brysbaert, Van Wijnendaele, & De Deyne, 2000; Catling, Dent, & Williamson, 2008; Gerhand & Barry, 1999; Holmes, Fitch, & Ellis, 2006; Monaghan & Ellis, 2002; Morrison & Ellis, 1995; Richards & Ellis, 2008). Also, evidence shows that AoA influences performance of healthy and brain damaged participants, bilingual speakers and monolingual speakers of a variety of languages such as English, Chinese, Dutch, French, Icelandic, Italian, Spanish and Turkish amongst others (Alija & Cuetos, 2006; Bonin, Barry, Meot, & Chalard, 2004; Izura & Ellis, 2002; Liu, Hao, Shu, Tan, & Weekes, 2008; Menenti & Burani, 2007; Pind & Tryggvadottir, 2002; Raman, 2006).

The arbitrary mappings hypothesis is one of the current explanations for the AoA effect. According to this hypothesis AoA is the result of arbitrary connections created between two representations in the learning process. Object naming is a good example of this type of unpredictable link because there is no information in the shape or intrinsic meaning of the object that could possibly predict its name. Conversely, when the mapping established between representations is consistent, AoA effects would not be noticeable since late acquired material will benefit from the regularities extracted

from the early acquired material. Research carried out on object and word naming supports the arbitrary mappings hypothesis showing larger AoA effects in object naming than in word reading since the nature of the connections between orthography and phonology is more or less consistent in alphabetic languages (Brysbaert & Ghyselinck, 2006; Ghyselinck, Lewis, & Brysbaert, 2004).

AoA effects are also prominent in studies using the lexical decision tasks (e.g. Butler & Hains, 1979; Morrison & Ellis, 1995; Morrison & Ellis, 2000; Whaley, 1978). Words which were learned early in life are recognised more quickly than late acquired words. A phonological explanation for this effect was offered by Morrison and Ellis (1995). They suggested that performing a lexical decision task makes use of all available sources of information to deduce whether the target is a word. Evidence for this position comes from the finding that participants take longer to reject pseudohomophones (non-words which sound like real words such as BOTE or BERN) than to reject nonhomophonic non-words (e.g. Besner & Davelaar, 1983). The pseudohomophone effect provides evidence that phonology may be used to inform lexical decision. Morrison and Ellis (1995) concluded that the phonological representations for early acquired words might be accessed more rapidly than that of late acquired words and that the AoA effect in lexical decision responses reflected the influence of lexically derived phonology.

Assuming that Morrison and Ellis' (1995) interpretation of the AoA effect in lexical decision holds, there should be no differences between early and late acquired words in circumstances where phonology is not informative. That is, when pseudohomophones are included in the lexical decision task, phonology does not help to differentiate between words and non-words. Thus the information from phonology would be discarded or suppressed, and the facility of the access of phonological representations would be of no consequence. However, Gerhand and Barry (1999) provided evidence that the AoA effect persisted even when the non-words were pseudohomophones. Subsequently, Brysbaert et al., (2000) discussed the proposition that AoA effects have a semantic root rather than a phonological one. They presented participants with a word association task and with a semantic categorization task, both

of which are specifically tailored to access the semantic system, and reported significant AoA effects. Brysbaert et al. (2000) suggested that the AoA effect could be a result of the interconnection between words and concepts. Specifically, it is proposed that late acquired words are learned by relating the new concept to a previously existing word representation. As a result of this learning process the representations for early acquired words are accessed more often, and therefore are recognised more quickly and accurately. A related hypothesis is offered by Steyvers and Tenenbaum (2005). Words are represented as nodes in their model network. New material was learned by this network in such a way that early acquired nodes had more semantic connections than late acquired nodes. As a consequence early acquired words are accessed more often than late acquired words.

1.5.2 Bigram and Trigram frequency

Bigram and trigram frequencies refer to the frequency at which pairs of letters or sets of three letters appear together in written words of any given length. Thus, from a word formed from *n* letters, *n*-1 bigrams and *n*-2 trigrams can be formed. Bigram and trigram frequencies are sub-lexical measures of what is known as orthographic redundancy or orthographic familiarity (Andrews, 1992; Graves, Desai, Humphries, Seidenberg, & Binder, 2010). Anisfeld (1964) proposed bigram and trigram frequencies as an alternative explanation to the consistency effects found in word processing. He argued that it could be that consistent words are processed more efficiently not because of their 'consistent pronounceability' but because they are formed by letters with higher bigram and trigram frequencies than inconsistent words. Bigram frequency has been reported to affect tasks involving word recognition for low frequency words (Biedermann, 1966; Broadbent & Gregory, 1968; Conrad, Carreiras, Tamm, & Jacobs, 2009; Massaro & Cohen, 1994; Owsowitz, 1963; Rice & Robinson, 1975; Rumelhart & Siple, 1974; Westbury & Buchanan, 2002), although the size and direction of this effect has not been consistent. Owsowitz (1963), Broadbent & Gregory (1968) and Rice & Robinson (1975) reported that low frequency words which contained low frequency bigrams elicited responses more quickly than those containing high frequency bigrams. The studies reported by Biedermann (1966) and Rumelhart & Siple (1974) showed that the advantage was for words with high bigram frequency over low bigram frequency. One study

(McClelland & Johnston, 1977) reported no effect of bigram frequency. Gernsbacher (1984) postulated that the equivocal findings concerning bigram frequency in word recognition could be a result of a confound with "experiential familiarity." She collected ratings for the familiarity of the words used in the studies listed above. For studies that reported an advantage for high versus low bigram frequency, high bigram words were rated as significantly more familiar. The converse was true for studies in which responses for low bigram frequency words were faster. The high and low bigram frequency stimuli used in McClelland and Johnston's (1977) experiment did not differ in familiarity. In her Experiment 3, Gernsbacher (1984) controlled the familiarity of high and low bigram frequency stimuli in a lexical decision task. Participants responded equally quickly regardless of bigram frequency. The few studies that have investigated the influence of bigram frequency in word naming have reported no effects (Andrews, 1992; Bowey, 1990; Strain & Herdman, 1999).

Although the reported evidence suggests that bigram and trigram frequencies have little impact on behavioural measures of word naming and word recognition, there is some evidence that the brain is sensitive to variations in experience with particular letter patterns. Recent EEG studies (Hauk, Davis, Ford, Pulvermuller, & Marslen-Wilson, 2006; Hauk, Patterson, Woollams, Watling, Pulvermuller, & Rogers, 2006) have offered evidence of "letter n-gram frequency" (a combination of bigram and trigram frequencies) effects appearing in event-related potential data at around 100 milliseconds after stimulus onset. Other studies using neuroimaging techniques have shown increased brain activity with increasing bigram frequency in the left mid-fusiform gyrus (Binder, Medler, Westbury, Liebenthal, & Buchanan, 2006; Vinckier, Dehaene, Jobert, Dubus, Sigman, & Cohen, 2007).

1.5.3 Imageability

Imageability refers to the ease with which a word evokes a mental image (Paivio, Yuille, & Madigan, 1968). The lexical relevance of imageability emerged in the 60's as an interpretation of the superiority of concrete over abstract nouns. This was supported by the fact that concrete words were rated as more imageable than abstract words (Paivio, 1965). Subsequent research has shown that highly imageable words

are better recognised and memorised than less imageable words in tasks of lexical decision, cued and free recall (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Kennet, McGuire, Willis, & Schaie, 2000; Paivio 1965). The dual-code hypothesis (Paivio, 1971; 1991), accounts for the imageability effect arguing that abstract words activate verbal codes while concrete words activate verbal and imagery codes. The hypothesis states that the assistance of the imagery system facilitates the processing of concrete words. A number of studies have also shown that highly imageable words are consistently better named by patients with a phonological impairment but some preservation of their reading ability (Hirsh & Ellis, 1994; Tree, Perfect, Hirsh, & Copstick, 2001; Weekes & Raman, 2008). The influence of imageability in unimpaired oral reading, however, is uncertain. Strain, Patterson, and Seidenberg (1995) argued that the imageability influence shown in patients implies a relationship between the semantic and phonological system that must be also present in normal reading. They argued that this relationship might be particularly marked when reading aloud words whose translation from orthography to phonology can be problematic such as low frequency exception words. They devised three experiments in which imageability, word frequency and consistency [1] were manipulated. In Experiments 2 and 3, they found significant interactions between imageability and consistency for low frequency words. This meant that reading speed and accuracy was very similar for all consistent words (irrespective of their imageability value) and also for those inconsistent and high imageability words. However, significantly longer times were required to read low imageability and inconsistent words. They account for these results arguing that translation from orthography to phonology is fast and efficient for words with regular and consistent spelling patterns (regardless of their frequency range or imageability value) because orthography-to-phonology correspondences are assisted by the regular/consistent connections established by high frequency words. However, low frequency inconsistent words (e.g., *dread, mischief*) fail to generate fast naming through the usual process because neither the regularity of the word or its frequency can aid their pronunciation. As a consequence, the

[1] Consistency refers to the degree of reliability of the spelling-to-sound correspondences in the English language. Thus, consistent words are those that ending with the same letters are pronounced the same (e.g., *cork, dork, fork, pork*, and *York*). Inconsistent words are those that share their letter ending but are pronounced different (e.g., *pear, bear* and *wear* are inconsistent with *dear, fear, hear, near, rear, sear* and *year*).

intervention of semantic information facilitates the reading processes of those inconsistent words with richer semantic representations or high imageability.

However, Gerhand (1998) failed to observe imageability effects in a reanalysis of Strain et al.'s (1995) results once age of acquisition was taken into account. Similar results were reported by Monaghan and Ellis (2002) in an independently designed experiment in which imageabilty and consistency were manipulated while controlling for AoA and frequency. An issue debated in two subsequent studies (Ellis & Monaghan, 2002; Strain, Patterson and Seidenberg, 2002) was whether these conflicting results could be due to the different criteria used by Strain et al., (1995) and Monaghan and Ellis (2002) to establish consistency. Strain et al., (1995) used a 'two-stage classification' by which regularity was considered first in relation to the pronunciation of single graphemes and then in terms of body neighborhood. Monaghan and Ellis (2002), in contrast, only considered body neighborhood when determining consistency.

1.5.4 Number of orthographic neighbours or neighbourhood size (N).

The role of lexical similarity in the process of word recognition and naming has been the subject of extensive investigation. One of the fundamental questions under examination is how the system distinguishes the word to be recognised (e.g., *word*) from a set of similar candidates (e.g., *ward, wore, warm, war*). One way in which the lexical similarity of a word has been operationalised is counting the number of words formed by changing one letter from the given word while keeping constant the position and identity of the rest of the letters (Coltheart, Davelaar, Jonasson, & Besner, 1977). For example, replacing the vowels from the word *peace* produces three neighbours: *'peach', 'pence,' 'pease,'* and *'place'*. It is often referred to as N and it is the more commonly used measure in studies of lexical similarity. A common finding in word naming is that words with high-N are named faster than words with low-N (Andrews, 1989; 1992; Mathey, 2001; Sears, Hino, & Lupker, 1995).

A further concern relates to the locus from which the N effect emerges. Andrews (1989) proposed an early origin, suggesting that the N effect is a product of the interaction between letter and lexical units (neighbour words receive and feedback activation from and to their constituent letters increasing the activation of the target

letters and accelerating the recognition of the correct word). In this case, an additional question is whether the N-effect is lexical in nature. The question arises because number of orthographic neighbours shows a positive correlation with orthographic regularity or consistency since words with many orthographic neighbours share more consistent pronunciations with other words than words with few orthographic neighbours. As a consequence, the facilitation observed in naming high-N words could emerge either from the lexical level through help received from lexically activated neighbours or it could be due to non-lexical processes as a confound with the orthographic regularity or consistency of the word. Peereman and Content (1995) addressed this issue by introducing non-words in a reading task. They argued that if N effects are non-lexically-based the inclusion of non-lexically-read-items, such as non-words, would only increase the size of the N effect by promoting the exploitation of non-lexical mechanisms. The results showed smaller N effects when reading mixed lists of words and non-words suggesting that the facilitatory effects of N were lexical in nature.

The word's orthographic body is a structural characteristic of words that correlates with N and has led to the suggestion of a late locus for the N effect. In English, a great proportion of neighbours result from changing the first letter of the word. As a consequence, high-N words tend to share their orthographic body and in addition this orthographic body usually rhymes. This relationship between N, orthography and phonology introduces the possibility that N effects might be the consequence of phonological rather than orthographic computation. Adelman and Brown (2007) tested this hypothesis analysing the results from four existing mega-studies of word recognition in English (Balota, Cortese, Hutchison, Neely, et al., 2000; Balota & Speiler, 1998; Spieler & Balota, 1997; Seidenberg & Waters, 1989). They conducted a series of regression analyses in which they include phonographic neighbourhood, which refers to the number of words formed by changing one letter and phoneme from a given word, as a predictor variable. Other variables included in their analysis were word frequency, orthographic neighbourhood size, first phoneme, number of letters, word regularity, number of friends, number of enemies and rime consistency ratio. The results showed a significant facilitation of number of phonographic neighbours over and above the effects of regularity and rime consistency. Number of orthographic neighbours did not reliably predict reaction times in any of the four sets

analysed (apart from a small impact in the Seidenberg & Waters, 1989, data). Adelman and Brown (2007) concluded that neighbourhood effects cannot be accounted for by orthographic processing only; instead the conversion of print to sound is the more likely source of the effect.

N describes the overlap between orthographic forms represented in the mental lexicon. As the lexical decision task is particularly reliant on lexical access and lexical selection, N could be expected to be an important factor in recognition speed and accuracy. The literature concerning N effects in lexical decision indicates that, in general, words with many neighbours are recognised more quickly. A number of studies (Andrews, 1989; 1992; Forster and Shen, 1996; Sears, Hino & Lupker, 1995) reported that words with large N were recognised at shorter latencies than words with few neighbours. This finding is contrary to the predictions of the interactive activation model (McClelland & Rumelhart, 1981), which posits that competition between orthographically similar words in the lexicon should slow responses. However, N appears to interact with word frequency such that the recognition of low frequency words is facilitated by having many neighbours while high frequency high N words are slower than high frequency low N words (Andrews, 1989; Balota et al., 2004; Forster & Shen, 1996). This interaction allows the empirical findings concerning N effects in lexical decision to be reconciled with McClelland and Rumelhart's (1981) model. According to dual route models, high frequency words are more likely to be influenced by lexical processes than low frequency words. Hence the effect of having a large number of neighbours for high frequency words is that there is considerable competition among lexical representations, and lexical inhibition processes slow responses as predicted by interactive activation model. The recognition of low frequency words is assisted by sublexical processes. Following the interpretation that neighbourhood size supports sublexical spelling to sound mappings (Andrews, 1989), low frequency high N words receive additional input from the sublexical route and recognition responses are facilitated. The same is unlikely to be true for acronyms. It is rare for acronyms to share spelling to sound mappings with their orthographic neighbours (EEG versus LEG). Sublexical processes would not help in the recognition of acronyms.

1.5.5 Word Frequency and Word Familiarity

Word frequency refers to the number of times an individual encounters or uses a particular word. The intuition that frequency of occurrence could have an influence in word processing was first supported by Howes and Solomon's (1951) findings, and its importance in word processing has been extensively demonstrated ever since. High frequency words are recognised, produced, and recalled faster and with greater accuracy than low frequency words (Connine, Mullinex, Shernoff, & Yelen, 1990; Oldfield & Wingfield, 1965; Whaley, 1978; Yonelinas, 2002).

Two main procedures have been employed to measure word frequency: statistical and rated estimations. Statistical valuations of frequency derived from corpora of written language have been commonly considered as objective measures of frequency (Baayen, Feldman, & Schreuder, 2006). However frequency counts are subject to error. The error is dependent on the size of the corpus, the sample of text used and individual differences in the use of language. Three corpuses stand out as the most cited, and therefore most commonly used, in word recognition research. The Brown Corpus (Kučera & Francis, 1967) comprises over one million words extracted from 500 samples of text, published in 1961, and coming from a wide variety of American English texts. The Centre for Lexical Information (CELEX) database (Baayen, Piepenbrock, & van Rijn, 1993) provides information of present day Dutch, German and British English languages. The English part is based in the COBUILD corpus (University of Birmingham, 1980) sized 18 million words. Finally, the Educator's Word Frequency Guide (WFG, Zeno, Ivens, Millard, & Duvvuri, 1995), is based on 17 million words from 60,500 samples coming from printed texts encountered by American students at different levels of education. It has been observed that frequency norms generated from corpus of printed frequency might not be truly representative of the language in use (Brysbaert & New, 2009; Gernsbacher, 1984). This is because written language is edited, more diverse than spoken language, and fixed to the linguistic style of its time. Other sources of criticism come from the sample bias associated with statistical estimations. This bias is more pronounced in small corpuses where low frequency words in particular, lose discriminatory power (Burgess & Livesay, 1998; Zevin & Seidenberg, 2002). Brysbaert and New (2009) conducted a study looking at traditional and more contemporary frequency norms.

They found that the bias for low frequency words represents a concern only on corpuses sized below 16 million words. Brysbaert and New (2009) compared the predictive power of word frequency as obtained from six different frequency norms on word recognition times (as available from Balota et al., 2004). They showed that norms available from internet discussion groups (Hyperspace Analogue to Language, HAL, Lund & Burgess, 1996) and subtitles ($SUBTLEX_{us}$, Brysbaert & New, 2009) showed the highest correlations with word processing variables.

The biases found in word frequency counts have prompted some researchers to study word recognition processes using frequency ratings (often in addition to written frequency measures, Balota et al., 2004; Connine et al., 1990; Gernsbacher, 1984). In order to obtain frequency ratings participants are asked to estimate how many times they encounter and/or use a particular word. This measure of frequency is normally considered to be subjective and is often used interchangeably with the concept of word familiarity. Frequency corpuses tend to underrate the frequency of acronyms because either they avoid the inclusion of abbreviations (Zeno et al., 1995) or are based on language samples where acronyms are scarcely represented (e.g., from subtitles $SUBTLEX_{us}$).

The importance researchers have assigned to word frequency is reflected in the fact that most models of word processing and word learning have incorporated word frequency in their operating architectures (Coltheart, 2001; Harm & Seidenberg, 1999; Monaghan & Ellis, 2010). Frequency effects in word naming tend to interact with word regularity and/or consistency (Ellis & Monaghan, 2002; Jared & Seidenberg, 1990; Monaghan & Ellis, 2002; Weekes, Castles, & Davies, 2006). This means that, reading times are particularly slow and inaccurate for low frequency inconsistent and/or irregular words. Considering the orthographic inconsistency/ irregularity of acronyms and assuming that acronym-naming exploits the same reading system as that used when naming mainstream words, large frequency effects are predicted in acronym naming times and accuracy.

The frequency effect is also a common finding in the word recognition literature. High frequency words are recognised faster than low frequency words in the lexical decision paradigm (Connine, et al., 1990; Fredriksen & Kroll, 1976; Gerhand & Barry, 1999a; Hino & Lupker, 2000; Hudson & Bergman, 1985; Perea & Rosa, 2002; Richardson, 1976; Rubenstein, Garfield, & Millikan, 1970; Turner, Valentine & Ellis, 1998). Coltheart et al. (2001), following an earlier assertion by Grainger and Jacobs (1996), suggested that the effect of frequency arises because those words that occur commonly in print have higher levels of resting activation than those words infrequently encountered and thus reach a "recognition threshold" easier, that is faster. Other authors have proposed slightly different accounts for the frequency effect (e.g., serial search models, Forster, 1976; verification models, Becker, 1976; Paap, Newsome, McDonald & Schvaneveldt, 1982). However, the consensus is that words encountered often are somehow easier to retrieve.

1.5.6 Letter and syllable length

Word length measured in terms of its orthographic (number of letters) or its phonological (number of syllables or phonemes) aspects shows a positive correlation with word naming and recognition times (Balota et al., 2004; Hudson & Bergman, 1985; New, Ferrand, Pallier, & Brysbaert, 2006). Phonological and orthographic measures of word length are also strongly intercorrelated in standard words since increasing the number of syllables or phonemes inevitably increases the number of letters. Slower reaction times for words with many letters are a common finding in oral reading (Balota et al., 2004; Foster & Chambers, 1973; Frederiksen & Kroll, 1976; Spieler & Balota, 1997; Ziegler, Perry, Jacobs & Braun, 2001). In addition, Balota et al., (2004) also observed an interaction between letter length and word frequency with a greater influence of letter length over low frequency words. However, null effects of letter length when skilled readers name words have also been reported (Bijeljac-Babic, Millogo, Farioli, & Grainger, 2004; Weekes, 1997). Weekes (1997) carried out a study in which participants were asked to name two sets of words (100 high frequency words, 100 low frequency words) and one set of 100 non-words, in a mixed and randomly presented order. Words and non-words varied in letter length (3 to 6) and each letter length was represented the same number of times in each set (25). An ANOVA analysis showed a significant interaction between letter length and word frequency with larger length effects for low than for high frequency

words as in Balota et al., (2004). This effect, however, was not reliable in a subsequent regression analysis in which letter length did not account for a significant percentage of unique variance once other variables such as orthographic neighbourhood size, grapheme frequency and number of phonemes were taken into consideration. A possible cause for the discrepancies between Balota et al., (2004) and Weekes (1997) results is the different frequency indexes used. Balota et al., (2004) rely on the WFG (Zeno et al., 1995) database, based on 17 million words, while Weekes (1997) used Kucera and Francis (1967) norms, a small corpus whose discriminatory power (for low frequency words in particular) has been a matter for concern (Brysbaert & New, 2009). Bijeljac-Babic et al., (2004) also failed to find a letter length effect in adult readers. Their study involved young readers (between 8 and 11 years old) as well as adults, and for this reason they selected 75 French words 'expected to be known by 3rd grade readers' (p. 415). This means that their reading material was highly familiar. Considering the high familiarity of the stimuli the lack of letter length effect in adult readers is not surprising knowing that letter length has a greater influence on low frequency, less familiar items (Balota et al., 2004). A number of studies have also shown an influence of the number of syllables in oral reading times and accuracy. Number of syllables interacts with word frequency as number of letters does with more pronounced length effects reported for multisyllabic, low frequency words (Ferrand, 2000; Jared & Seidenberg, 1990).

Theoretically, length effects have been conceptualised as indicators of serial processing. Taking the dual route model as the theoretical framework the reported interaction between word length and frequency could be explained as the result of the rapid, parallel processing of high frequency words via the lexical pathway (irrespective of word length) but the slow processing of low frequency words by the same lexical route. The slowness in the lexical processing of low frequency words makes the activity of the sublexical route more apparent showing facilitation when processing short words (Balota et al., 2004; Coltheart et al., 2001).

1.6 Semantic dementia and surface dyslexia

1.6.1. Description of the disorder

Semantic dementia (Snowden, Goulding & Neary, 1989) is a progressive neurodegenerative disorder. Hodges, Patterson, Oxbury & Funnell (1992) provided a description of the characteristics of semantic dementia. It is associated with an impairment of semantic memory, which results in the inability to name items and deficits in single-word comprehension. Semantic dementia patients also have difficulty in generating examples of a given category. In general, though, the patients' grasp of sentence structure and phonology is relatively intact, as is their perceptual ability, autobiographical and episodic memory. They are also capable of solving nonverbal problems in the normal range. Semantic dementia is characterised by disordered reading, namely surface dyslexia.

Surface dyslexia is a reading deficit characterised by "impaired oral reading of words where the pronunciation cannot be inferred from general knowledge of the sound structure of the reader's written language" (Jefferies, Lambon-Ralph, Jones, Bateman, & Patterson, 2004, pp.290) while the ability to read aloud stimuli that have a predictable pronunciation is preserved. Simply put surface dyslexic patients are inaccurate when asked to read aloud irregular words (particularly low frequency irregular words), but perform well when reading words with regular spelling to sound correspondences (e.g. Behrmann & Bub, 1992; Bub, Cancelliere & Kertesz, 1985, McCarthy & Warrington, 1986; Patterson & Hodges, 1992; Shallice, Warrington, & McCarthy, 1983). Further, reading errors in these patients tend to be "regularisations" (Marshall & Newcombe, 1973), and they pronounce irregular words as if they followed the typical spelling to sound conversion (e.g. "pint" to rhyme with "mint").

1.6.2 Modelling semantic dementia and surface dyslexia

1.6.2.1 The DRC Account

As mentioned previously, the two routes of the DRC model use different methods to arrive at a pronunciation. Using the lexical route, the skilled reader can access a stored representation of the stimulus, and the pronunciation is retrieved. Using the non-lexical route, the pronunciation of the stimulus is computed by the application of a set of spelling to sound conversion rules. For irregular words the pronunciation suggested by these two methods will be different, and the resolution of the conflict takes time. In semantic dementia, the degradation of the semantic system leads to failure in lexical access, and an over-reliance on the non-lexical pathway. The use of the grapheme-phoneme correspondence principles results in regularisation errors and difficulty in reading irregular words correctly. As semantic memory declines and semantic dementia progresses, so reading performance becomes worse. It is argued that word frequency modulates the effect (Baluch & Besner, 1991; Marshall & Newcombe, 1973; Paap & Noel, 1991), such that low frequency items are lost sooner than high frequency items and are susceptible to incorrect reading earlier.

1.6.2.2 The Triangle Account

In this model, the orthography-phonology pathway deals with stimuli with varying efficiency based on their characteristics. Items that are high in frequency are processed more efficiently than their low frequency counterparts; items adhering to spelling to sound correspondences are processed more efficiently than items that flout the spelling to sound rules. Triangle models suggest that high frequency irregular words are encountered with sufficient frequency that the correct response is learned. The reading of low frequency words with regular spelling to sound correspondences is aided by the phonology of orthographic neighbours. For example, "lint" benefits from the model's encounters with other orthographically similar rhyming words such as "hint," "mint" and "tint." For a low frequency irregular word, however, no such support is offered by its orthographic neighbours, and the orthography-phonology pathway is not constrained enough to allow the correct pronunciation. It is here that

semantic input is required. In this conception of the reading deficits in surface dyslexia, it is argued that the damage to the semantic units leaves the orthography-phonology pathway unrestrained and prone to error in low frequency irregular items.

Previous researchers have presumed that acronyms require lexical reading, or input from the semantic system, to be read correctly (Laszlo & Federmeier, 2007a; b; 2008). This is due to the unusual combination of orthography and phonology inherent in acronyms. If this is the case, then acronym reading should pose a particular problem for an individual with semantic dementia and surface dyslexia.

1.7 EEG and ERP methods

The study of cognitive processes often uses neuroscience techniques to provide a window to the biological functioning of the brain. One such technique is electroencephalogram (EEG). When the neurons in the brain are activated, electrical current is generated. The current consists of Na+, K+, Ca++ and Cl- ions (Atwood & MacKay, 1989). Large groups of neurons create electrical activity which is sufficiently large that it can be measured by electrodes placed on the scalp. EEG records these potentials. According to Teplan (2002), the greatest advantage of using EEG for medical and research applications is that neural activity can be recorded within a fraction of a second. This allows the time course of neural processing to be charted in response to various types of stimuli.

Treatment of the raw EEG signal allows for the examination of evoked, or event-related potentials (ERP). The presentation of a stimulus causes a fluctuation in the voltage of the EEG signal. This fluctuation in activity is usually considerably smaller than spontaneous EEG noise. To highlight the ERP while reducing the background electrical activity, the recordings from a number of trials over a number of participants are averaged (Gevins & Remond, 1987). The technique defines epochs of interest which are time-locked to the presentation of a stimulus, and creates an average of the EEG voltages in the epoch. This is necessary because the brain is always performing some functions which are not relevant to the task. These functions

are represented in the EEG trace but the currents caused by these functions are randomly distributed throughout the test session. By averaging across trials and participants, the random activity is cancelled out. In contrast, the potentials evoked by the processing of the experimental stimulus always occur at roughly the same point on every trial. This remains prominent in the ERP wave while the background noise is suppressed by the averaging technique. Thus the ERP is a high temporal resolution reflection of the activity which is evoked consistently by the presentation of the stimulus.

1.8 Aims and outlines of the experimental chapters.

Thus far the introduction to this thesis has focussed on descriptions of the techniques which are commonly used in language research, and the variables which affect performance in these tasks. An attempt has been made to make a case for the potential for acronyms to add to research in this area. This thesis addresses three research questions. The following sections will detail the aims of the current experiments and discuss the specific research questions addressed.

1.8.1 Are acronyms processed like mainstream words?

Acronyms are created as a shorthand method of writing a particularly cumbersome phrase. The purpose of this shorthand is to make the text easier to process, and to allow it to be understood with greater speed. However, no research has explicitly examined this assumption. It has been demonstrated that switching from one task (e.g. colour naming) to another task which requires an alternative system (e.g. reading aloud) incurs a processing cost (Rogers & Monsell, 1995). The use of acronyms to facilitate the reading of a text therefore presupposes that they are processed using the same system as for mainstream words. At the time of writing this introduction, the previous research that has been conducted using acronyms predominantly assessed whether they are stored alongside words in the mental lexicon (Besner, Davelaar, Alcott and Parry, 1984; Brysbaert, Speybroeck and Vanderelst, 2009; Coltheart, 1978; Laszlo & Federmeier, 2007a; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984). Evidence suggests that acronyms are indeed lexicalised.

It could be assumed that as acronyms are stored alongside words they will also be processed in a similar way. Word characteristics such as frequency, age of acquisition, imagebility and orthographic neighbourhood are all suggested to exert their influence on processes linked to the lexicon. If the underlying processes are common to mainstream words and acronyms, then these characteristics should also be important in acronym reading and recognition. However, as acronyms are so peculiar in terms of orthography, phonology and even semantics, there may be circumstances in which acronyms require different or additional processes. Indeed, it may be that acronyms are so unusual that their recognition is a particularly effortful process, and that this alters the impact that psycholinguistic variables have on participant responses. This presents a new question to researchers, and one that is of interest in this thesis. The first aim of the current research is to assess how similar responses in acronym trials are to what is observed among mainstream words using a number of prominent paradigms in the word reading and recognition literature. If it is revealed that acronym and word responses are comparable then the conclusion that they are processed in the same system may reasonably be drawn.

This is an important question to answer. Firstly, it has been suggested that acronyms may provide a useful tool with which to assess models of word reading and to explore the nature and locus of common effects in word processing (e.g. Laszlo & Federmeier, 2007). Of course, this use of acronyms can only be justified if acronym processing is achieved by the word reading system. Secondly, if words and acronyms are shown to be processed in similar ways, then it is necessary for theories of word reading to be able to account for responses to both types of stimuli. As yet, no theoretical model has offered any account of acronym processing.

The focus of chapters 2, 3 and 4 is an assessment of the behavioural responses of participants to acronym stimuli, and a comparison with mainstream words. Chapter 7 returns to this research question and extends it to include the electrophysiological response that is elicited during the processing of acronyms and mainstream words.

Chapter 2 describes a series of experiments which aimed to examine frequency effects in lexical decision and naming tasks including acronyms alongside mainstream words.

As mentioned above, the common finding is that high frequency words are recognised and pronounced sooner than low frequency words. Frequency has been incorporated into a number of theories of the lexicon (Becker, 1976; Forster, 1976; Morton, 1969), and it is considered that the frequency of a word's occurence affects the level of resting activation for its lexical representation (Perea & Rosa, 2005). If acronyms are represented alongside words in the mental lexicon as argued by previous researchers (Besner et al., 1984; Brysbaert et al., 2009; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984), then they to should have levels of resting activation which are determined by their frequency. Thus it is expected that a speed and accuracy advantage for high frequency acronyms will be observed.

Chapter 3 describes the collection of a set of normative values for acronyms, taking into account the variables discussed in section 1.5 above. Following the gathering of the norms, acronym naming reaction time and accuracy data are analysed in relation to the characteristics of the acronyms. Significant influences of frequency, age of acquisition, imageability and letter length are expected in line with previous studies of mainstream words (Connine et al., 1990; Monaghan & Ellis, 2002; Strain, Patterson, and Seidenberg, 1995), under the assumption that the processes underlying word and acronym reading are shared. A second set of analyses, concerning the factors in lexical decision for acronyms are also reported. It is predicted that frequency, age of acquisition and imageability will be important in reaction times and accuracy in the lexical decision task, following the patterns exhibited in mainstream word recognition (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Connine, et al., 1990; Morrison & Ellis, 2000).

Chapter 4 describes a study of acronym comprehension using the discrete word association task. A number of measures of word association are discussed, namely associative strength, response category and word association RT. Previous literature has implicated frequency, age of acquisition and imageability in the generation of word association responses (Brysbaert, Van Wijnendaele, & De Deyne, 2000; de Groot, 1989). Effects of these factors are expected in relation to acronym association, assuming that they are processed similarly to other lexical items. Indeed, as the

representations of words and acronyms should be interlinked within the lexicon, the pattern of responses should be very similar to those reported in the literature. Participant are predicted to offer semantically associated responses to the majority of acronym cues, and to respond more quickly to imageable, early acquired or high frequency acronyms. These factors are examined using multiple regression techniques.

Chapter 7 includes a naming task and a lexical decision task wherein acronyms and mainstream words selected are repeated in each of four blocks. This aims to assess the effect of practice in acronym naming, and predicts that acronyms benefit greatly from repetition. The tasks present the same items in four blocks, as well as collecting EEG data with which to examine ERP components which have been shown to differentiate between words and non-words (Compton et al., 1991; McCandliss et al., 1997; Mari-Beffa et al., 2005; Martin-Loeches et al., 2001a; 2001b). It is predicted that behavioural responses for acronyms will show significant improvement with practice as is the case in mainstream words.

The use of the ERP data is particularly useful in the assessment of the potential similarity between words and acronyms. This is because the electrophysiological response is observably different in amplitude and location with different stimuli. For example, behavioural data shows that familiar faces are processed more quickly than unfamiliar faces (Dubois, Rossion, Schiltz, Bodart, Michel, Bruyer & Crommelinck, 1999) and familiar words are processed more quickly than unfamiliar words (Connine et al., 1990). However, a negative deflection in the ERP waves for face processing occurs about 170ms after the presentation of the stimulus located in right occipital areas; for words a negative deflection is observed at the same latency in left occipital areas (see Bentin, McCarthy, Perez, Puce & Allison, 1996 and McCandliss, Posner, & Givon, 1997 for examples). Therefore a comparable ERP response to acronyms and words is highly likely to be due to a similarity in their processing, and not due to equivalent effects of a factor in two separate tasks.

There are two ERP components of particular interest in this thesis, namely the left-lateralised N170, and the Recognition Potential (RP). Both show differences in amplitude between words and non-words. If the lexicality effect in the N170 component reflects early lexical access, as suggested by Dien (2009) acronyms are predicted to show ERP amplitudes similar to words. The importance of semantics in the RP (Mari-Beffa et al., 2005) leads to the prediction that amplitudes for acronyms and mainstream words will be similar in this window.

1.8.2 Do acronyms require processing similar to that required by irregular words?

Of course, the literature describes a number of factors which are shown to interact with the nature of the spelling to sound conversion in mainstream words. In regular words, the relationship between the letters in the written word and the phonology required for the spoken form is predictable. In irregular words there is no such consistency in pronunciation. A handful of previous studies have used the orthographic and phonological characteristics of acronyms to evaluate currently influential models of word reading (Laszlo & Federmeier, 2007b; 2008). Central to the experimental manipulations in these studies was the assumption that acronyms would be processed like irregular words by virtue of their unusual spelling to sound configuration. To date, this assumption has never been tested.

While acronyms are orthographically and phonologically unusual, in the majority of cases, acronyms are named one letter at a time. This means that a simple rule will allow a high degree of accuracy in reading acronym stimuli. This may confer acronyms with a kind of regularity of their own. Therefore a major aim of this thesis is to consider whether acronyms are irregular, or indeed, whether all acronyms can be treated in the same way. This question is particularly considered in chapters 5 and 6, and the answer is potentially important for theories of the word reading system. In particular, the dual route model as it currently stands would prescribe that acronyms must be read by the lexical route (i.e. as irregular words). The pronunciation of acronyms certainly does not follow the grapheme phoneme correspondences included in the dual route model. Therefore, if it transpires that acronyms are not read by the same processes as irregular words, and they cannot be read in the same way as regular words either, then an alternative route must be required for acronym reading. This

would require a revision to dual route theories. Similarly, the triangle model would need to be revised to account for acronym reading if no involvement of the semantic system was required.

Chapter 5 describes three experiments administered to a patient with semantic dementia and surface dyslexia, each of which is repeated three times. The tasks assess the patient's semantic categorisation, recognition and naming ability. These tasks vary in their reliance on the lexico-semantic system. It is expected that the patient will perform poorly on the tasks relative to age and education matched controls, and that her performance will degenerate as the condition progresses. This case study will allow for the regularity of acronyms to be assessed, as a defining feature of surface dyslexia is that irregular word reading is poor while regular word reading is preserved.

Chapter 6 discusses the influence of context on the processing of acronyms. Acronyms are presented in an experiment which contains only acronyms, and in a second experiment which contains only a small number of acronyms within a list of mainstream words. It is hypothesised that reading responses for the acronyms will be dependent on the surrounding items, following the pathway control hypothesis (Baluch & Besner, 1991). Specifically, acronyms named one letter at a time are expected to benefit from being presented in a list of other letter by letter acronyms. This will only be the case if there is a system for reading acronyms which does not require lexical look-up. If acronym reading necessitates lexical reading (i.e. if acronyms are like irregular words) then the same system can be used to pronounce all of the stimuli presented.

1.8.3 Can currently influential models of word reading accommodate acronym performance?

The entire thesis is united by a common and over-arching theme, specifically an assessment of the ability of currently influential word reading models to accommodate the acronym findings. While it is acknowledged that no model has yet

attempted to address acronym reading and recognition processes, it is possible to extend predictions from both connectionist and non-connectionist theories with regard to acronyms. It is important to assess the ability of the models to account for acronym processes for two reasons. First and foremost, acronyms are a part of everyday language and thus any discussion of reading processes should be able to account for all of the stimuli that human participants are able to decode. Secondly, experimental manipulations in several published studies have attempted to use acronyms to evaluate models. Laszlo and Federmeier (2007), for example, concluded that the N400 repetition effect that they observed for acronym stimuli could not be accommodated within the framework of the DRC (Coltheart et al., 2001), because they assumed acronym reading must be underpinned by lexical processing. However, this conclusion can only be drawn if acronym processing is achieved in the way that it has been assumed.

A summary of the results from all the experiments presented in this thesis is provided in Chapter 8. In each case, the findings are discussed in relation to current models, and an assessment of the success of the models is provided. Some ideas for further research are described thereafter.

CHAPTER 2

INVESTIGATING FREQUENCY IN ACRONYM RECOGNITION AND READING.

2.1 Introduction

As stated in Chapter 1, acronyms are a specific subset of words in the language that are used to abbreviate complex or cumbersome phrases and concepts. They are formed by extracting the initial letters of each word in the phrase and presenting the initials consecutively. This process generates, for example, the acronym BPS in place of the full term British Psychological Society. A characteristic of acronyms is that often have unusual, even illegal, orthographies yet they are meaningful and familiar. In the 20th century, acronym use has proliferated in both academic and non-academic writing. This proliferation has been reflected in the growing research interest in acronym processing. A large amount of this research interest has been devoted to address whether acronyms are stored alongside words in the mental lexicon (Besner, Davelaar, Alcott and Parry, 1984; Brysbaert, Speybroeck and Vanderelst, 2009; Coltheart, 1978; Laszlo & Federmeier, 2007a; 2007b; 2008; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984). Findings suggest that acronyms elicit similar behavioural and electrophysiological effects as mainstream words in a number of paradigms. A summary of three key findings is presented below.

The word/acronym superiority effect

The Reicher-Wheeler task was developed by Reicher (1969) to investigate whether initial analysis of visual information was performed serially, or in parallel. The procedure requires that participants identify a given letter within a stimulus string. Reicher (1969) briefly presented participants with four letter words or non-words. The participants were then offered a choice of 2 letters, and had to identify which letter had appeared in the stimulus. Participants were significantly better at identifying letters embedded in a word, than they were at identifying a letter in a non-word. The forced choice alternatives were such that the incorrect option would also

create a stimulus of the same type: word or nonword (i.e. either E or O could have the omitted letter in R-AD while still creating acceptable words). Thus it appeared that the benefit for the perception of letters embedded in real words was not attributable to guessing strategies. This is known as the word superiority effect. Reicher (1969) argued that this was evidence that the letters in words are processed in parallel.

McClelland and Rumelhart (1981) accounted for the word superiority effect in their discussion of the interactive activation model. This model proposes that existing word knowledge and new information from the presented stimulus work together to contribute to the perception of individual letters. Thus two vertical lines and a top left to bottom right diagonal are features which activate the letter level representation for N. At the same time, the presentation of a word automatically activates all the other words in the lexicon which have letters in common. That is to say, the presentation of HINT activates all words of the form –INT, H-NT, HI-T and HIN-. The word level activation also feeds back to the letter level. Therefore the identification of a letter within a word is being aided by feature and word level information. Letters presented in non-words do not receive as much activation from the word level, and hence are less readily perceived. By this account, a superiority effect should also be observed when the letter to be identified forms part of an acronym as opposed to a non-word, because letters in acronyms ought to receive both word and feature level activation. To assess this possibility, Besner et al. (1984) compared letter identification in acronyms to that in illegal letter strings. It was reported that letter identification was indeed improved when presented in an acronym. This finding was replicated by Noice and Hock (1987) and Laszlo and Federmeier (2007a). The evidence of an acronym superiority effect was taken as an indication that acronyms were stored in the mental lexicon.

However, letter identification is also improved when embedded in legal non-words as compared to illegal letter strings (Aderman & Smith, 1971; McClelland, 1976; Spoehr & Smith, 1975). McClelland and Rumelhart (1981) argued that this pseudoword advantage was due to the small amount of activation that resulted from the orthographic similarity between a pseudoword (such as MAVE) and real words

(CAVE, GAVE, HAVE, PAVE etc.). From this perspective it might be the case that visual familiarity is the important factor in the acronym superiority effect rather than their representation in the mental lexicon.

The N400 repetition effect

Further evidence of the lexical status of acronyms was provided by Laszlo and Federmeier (2007b; 2008) using the ERP technique. The N400 component is a negative going deflection which is observed around 400-600ms after the presentation of a stimulus. It is considered an index of semantic processing (Kutas & Federmeier, 2000; Kutas & Hillyard, 1980; Van Petten, Coulson, Rubin, Plante, & Parks, 1999). The amplitude of the N400 elicited by a word is larger when it is first presented than when the same word is presented again. This repetition effect is shown in response to pseudowords but not when the stimuli are illegal letter strings. Laszlo and Federmeier (2007b; 2008) showed that a significant reduction in N400 amplitude was observable for acronyms. Importantly, closer examination of their data revealed that the repetition effect for acronyms was restricted to those items that the participants knew. That is to say that known acronyms showed word-like N400 repetition effects, while unknown acronyms elicited activity similar to non-words. This is supportive of the position that acronyms may be lexicalised.

Unfortunately the findings detailed above to indicate that acronyms are stored in the lexicon have also been observed with pseudowords (Laszlo & Federmeier, 2007a; 2007b), and this leaves open the possibility that the effects are due to visual familiarity rather than lexical access per se. Laszlo and Federmeier (2007b) reported significant decreases in the amplitude of the N400 in pseudoword trials. Pseudowords look like words or sound like words but ultimately they are non-words and as such cannot have a lexical representation. Here too the overlap of a pseudoword and familiar real words is integral to the interpretation of the findings.

The results of the above experiments are suggestive of the integration of acronyms in the mental lexicon, but far from compelling. In the most recent study of the lexical status of acronyms, Brysbaert et al. (2009) emphasised the meaning of an acronym over the form. They used acronyms in an associative priming paradigm which specifically relies on semantic links between the target and the prime. The common finding in priming tasks is that a response to a target word is affected by the characteristics of an item that precedes it (the prime), even if the prime disappears so quickly that it is not consciously detected. Associative priming manipulates the relatedness of the meanings of prime and target. Meyer and Schvaneveldt (1971), for example, showed that lexical decision responses to the word DOCTOR were quicker when primed with NURSE than with BUTTER. Such findings are taken to reflect that semantically related words in the lexicon are automatically activated when a prime appears (i.e. DOCTOR is activated when NURSE is presented). The result of this automatic activation at the presentation of NURSE, is that DOCTOR has a head start, and is 'easier' to recognise as a word. A prime which is unknown to the participant cannot activate related words in the lexicon, and thus no facilitation is observed.

In Brysbaert et al.'s (2009) study, participants were presented with a lexical decision task in which word targets were preceded by briefly presented primes. In half of the 96 prime-target pairs the prime was an acronym, and in half the prime was a word. Each of the targets was presented twice, once preceded by a semantically related prime (BLT-SANDWICH; FIB-LIE), and once with an unrelated prime (SNT-SANDWICH; HIM-LIE). Associative priming effects followed acronym primes as well as word primes. The facilitation resulting from acronym primes was observed irrespective of letter case. Thus, BLT, blt and bLt increased the speed of the response to the target by the same amount. Brysbaert et al. (2009) concluded that this finding was "particularly convincing for the lexical processing of acronyms" (pp. 1838). A number of studies concerning the processing of mainstream words have determined that letter case is unimportant (e.g. Forster, 1998; Rayner, McConkie, & Zola, 1980).

This has been argued to be because lexical access is based on abstract letter identities, and that the actual written form of the stimulus is discarded early in the processing.

The available literature concerning acronyms is suggestive of their lexical status (Besner et al., 1984; Brysbaert et al., 2009; Coltheart, 1978; Laszlo & Federmeier, 2007a; 2007b; 2008; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984). In Brysbaert et al.'s (2009) study acronyms were included as part of a lexical decision task, but participants were not required to make an explicit response to any acronym stimuli. The effect that an acronym prime had on the lexical decision for a mainstream word was used to infer that acronyms were lexically stored. The present chapter is the first to explore the lexical status of acronyms by using them as *targets* for lexical decision and naming tasks. In both tasks significant effects of lexical variables such as frequency are commonly reported (Connine, Mullenix, Shernoff, & Yelen, 1990; Oldfield & Wingfield, 1965; Waley, 1975; Yonelinas, 2002). Under the assumption that acronyms are part of the lexicon, then common acronyms should be processed more quickly than less frequent acronyms[2].

The lexical decision task requires that participants decide whether a string of letters represent a real word or an invented non-word. When the non-words presented are illegal in English (RQP), lexical decision responses to non-words are given quickly (Richardson, 1976). In this circumstance, the decision to reject non-words can be made based on orthography alone. No words begin with RQ, nor do any words end in QP. Further processing is not required to determine the appropriate response to RQP. If all the non-words are illegal letter strings, then accepting words can also be achieved by an assessment of visual familiarity. As soon as the participant perceives a vowel in the string they can assume that what is presented is a real word. However, many lexical decision studies include non-words which resemble the orthography and phonology of English (e.g. RUP) and in this case participants are significantly slower

[2] It is noted that frequency effects are not limited to word reading and recognition tasks. Frequency is also commonly reported to affect responses in object naming studies (e.g. Barry, Morrison & Ellis, 1997). The presence of an advantage for high versus low frequency acronyms does not necessarily indicate that they are stored in the lexicon, but the interpretation that acronyms are stored in the lexicon predicts a frequency effect.

to reject the non-words. It is no longer possible to determine that RUP is not a word based on the letter patterns. Under these circumstances it has been assumed that lexical access is required in order to perform the task accurately (James, 1975; Richardson, 1976). All known words have a lexical representation, but non-words will not be represented in the lexicon. A 'yes' response can only be given if the stimulus has a stored representation, and this has been sufficiently activated. Once the level of activation has reached the criterion level, it is possible to make the decision that the stimulus has a representation in the lexicon, and that it can be accepted as a word. If a lexicon entry has not been accessed before a deadline, then it can be assumed that the presented letters do not form a word. This means that orthographically legal non-words are rejected at longer latencies in the lexical decision task.

The logical continuation of this view is that items which reach the threshold more easily are recognised with greater speed. This task may therefore be of particular interest in the assessment of the lexicality of acronyms (as long as the non-words are chosen such that acronyms cannot be identified on the basis of their orthography). Acronyms and any other word can only be successfully identified as meaningful if their lexicon entries exist and are accessed. One of the most commonly described factor to affect lexical decision times and accuracy is frequency (Monsell, 1991). Words which are encountered often in daily life are recognised quickly, and uncommon words are significantly slower to elicit response (Connine et al., 1990; Fredriksen & Kroll, 1976; Gerhand & Barry, 1999; Hino & Lupker, 2000; Hudson & Bergman, 1985; Perea & Rosa, 2002; Richardson, 1976; Rubenstein, Garfield, & Millikan, 1970; Turner, Valentine & Ellis, 1998). This has been attributed to higher levels of resting activation for commonly occurring stimuli (Perea, Rosa, & Gómez, 2005). Assuming that acronyms are indeed lexicalised items it can be predicted that frequency effects will be observed in lexical decision responses. Indeed, to accept an acronym as meaningful among orthographically similar non-words, a participant must look beyond an orthography which is not allowable in English. In experiment 2.1 the role of frequency in lexical decision for acronyms is assessed.

Dual route models of word recognition and naming (Coltheart et al., 1993; 2001) propose two pathways to process written stimuli. One route accesses a stored representation of the word, while the other applies a system of rules to achieve pronunciation based on sublexical information. Research has indicated that the importance of the two pathways can be altered by the demands of the task (Balota & Ferraro, 1996; Balota, Law & Zevin, 2000; Monsell, Patterson, Graham, Hughes & Milroy, 1992). The findings of these studies show that getting participants to rely on sublexical processes eradicates the effect of frequency.

Balota and Ferraro (1996), for example, presented participants with 160 high frequency and 160 low frequency words in a rhyme judgement task. Non-words were also included. The participants were asked to decide whether the two stimuli rhymed. This task was designed to encourage the use of the sublexical route relative to the lexical pathway. The phonology for non-words can only be assembled using sublexical processes, and hence sublexical processing was particularly important in the successful completion of the task. In the rhyme judgement task, no frequency effects were observed in response times. The same participants were also asked to complete a lexical decision task using the same stimuli. In the lexical decision task, use of the lexical pathway is necessary and as a result high frequency words elicited significantly faster responses than low frequency words. The unusual or illegal orthography of acronyms affords the opportunity to manipulate the route needed to make a lexical decision response. The instructions given to the participants are all that need to be altered. As mentioned previously, accepting an acronym as meaningful in a lexical decision requires lexical access. Training participants to consider acronyms as words cues the use of the lexical route and high frequency acronyms ought to have an advantage over those of lower frequency. However, it may be possible to train participants to class acronyms as non-words and hence to reject them in the lexical decision task. Under these circumstances the illegal orthography of acronyms means there is no need to access the lexicon as acronyms can be rejected on the basis of letter patterns alone. This would lead to the prediction that frequency would have no impact on response latencies. Experiments 2.1 and 2.2 tested this hypothesis.

In the standard lexical decision task (experiment 2.1) an advantage for high versus low frequency acronyms is expected. No frequency effects are expected in experiment 2.2 when participants are asked to classify acronyms as non-words. In both experiment 2.1 and 2.2, regular and irregular words are also included. These are introduced to offer comparisons with the acronym stimuli. Regular and irregular words differ in terms of the predictability of their orthography to phonology conversion. Regular words follow predictable spelling to sound rules. Irregular words are unusual in their pronunciation, and hence require lexical processing. In the few studies that have previously examined acronyms, it has been assumed that their unusual orthographic and phonological configurations necessitate processing which is similar to that in irregular words (Laszlo & Federmeier, 2007a; 2007b; 2008). If acronyms are processed like irregular words, it follows that responses in acronym trials should be more similar to irregular than to regular words. Frequency effects have been commonly reported in mainstream word recognition and as such, frequency effects are also expected here. Frequency effects are larger in irregular words than in regular words (Visser & Besner, 2001). Again, the assumption that acronyms must be processed like irregular words would predict a larger advantage for high versus low frequency acronyms than is observed for high versus low frequency regular words. Furthermore, the responses to words in experiment 2.2 will require the same processing as in experiment 2.1. Thus the frequency effects in mainstream word trials ought to remain constant across the two tasks, while acronym responses might differ. The inclusion of mainstream words will also allow the ease of lexical access for acronyms to be investigated. Specifically, it is expected that words and acronyms of a similar frequency should be recognised at similar latencies.

Experiment 2.1 Lexical decision for acronyms

2.2.Method

2.2.1 Participants

Thirty undergraduate students at Swansea University took part in the experiment. The sample was made up of 7 male and 23 female participants, whose mean age was 20 years (range 18 - 39). The participants were given course credit for their

participation. They all were native English speakers with normal or corrected normal vision, who reported no difficulties in reading.

2.2.2 Materials

A total of two hundred stimuli consisting of letter strings between three and five letters in length were used. The stimuli comprised fifty acronyms (25 high frequency and 25 low frequency), 100 common words (25 regular and high frequency, 25 regular and low frequency, 25 irregular and high frequency, 25 irregular and low frequency) and 50 non-words (25 orthographically legal, 25 orthographically illegal). Frequency ratings were previously obtained for the acronym sets by asking 30 undergraduate participants to estimate on a seven point scale how frequently they came across each acronym. Participants who rated acronym frequency did not perform the lexical decision task. A measure of written and spoken frequency from the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995) was used for the set of mainstream words. Words were regarded as regular when their pronunciation followed the grapheme to phoneme correspondence rules of the DRC model (Coltheart et al., 2001).

Mainstream words were matched on imageability (from The MRC psycholinguistic database, Coltheart, 1981), and age of acquisition (from Bird, Franklin, & Howard, 2001). A series of t-tests were conducted to ensure a correct matching for imageability and age of acquisition between sets. No significant differences were found ($p > .1$). The stimuli details can be found in appendix 2.1.

Legal non-words were created by changing one letter in a word and making sure the invented string remained orthographically and phonologically legal in English. The illegal non-words were generated by altering one character from acronyms other than those used as experimental stimuli, making sure they did not form a word and were 'unpronounceable.'

2.2.3 Procedure

Stimulus presentation and recording of reaction times was controlled via SuperLab Pro (version 2.0.4, Cedrus Corporation, 1999). Stimuli were presented on a 19"

monitor. Participants responded using a standard computer keyboard. Participants were asked to distinguish between real and invented words. When the stimulus was considered a word, participants pressed the "P" key. The "Q" key indicated that a non-word had been presented. Participants had thirty trials for practice at the beginning of the experiment (10 words, 10 acronyms and 10 non-words). Practice items were not repeated in the experimental trials.

Trials began with a fixation cross presented for 1000ms. This was followed by a letter string that appeared in black ink in the middle of the screen in lower case, Times New Roman font, size 12 point. The letter string remained on the screen until the participant made a response. Following the participant response, automatically generated feedback was presented in place of the initial stimulus to inform the participant whether their choice had been "correct" or "incorrect." If the response was correct the word 'correct' appeared in the middle of the screen if it was incorrect the word 'incorrect' appeared in the middle of the screen. A correct response to an acronym stimulus was to class it as a word. The feedback remained on screen for 1000ms. Participants were informed when the practice trials had been completed and the experiment was about to start.

Experimental trials were displayed in an identical manner to the practice trials excepting that the feedback was omitted. The computer automatically recorded the time between the presentation of the stimulus and the participant responding via the keyboard during the experimental trials. Each experimental session lasted 10 minutes, and comprised two hundred trials in total.

2.3 Results

Errors (11%) were excluded from the RT analysis. Any responses timed at less than 300ms or more than 1500ms were treated as outliers and removed prior to analysis. This resulted in the deletion of 0.83% of the trials. Mean response times for correct responses were calculated for each condition. Participants responded fastest to

identify high frequency regular words, and it took them longer to reject low frequency acronyms. A full list of the means and standard deviations of correct responses, plus the percentage errors in each condition are presented in Table 2.1 below. It should be noted that participants were performing at chance levels in low frequency acronym trials. Only one of the participants had correctly recognised more than 25% of the low frequency acronyms. Potential explanations for this poor accuracy rate are detailed in the discussion.

Table 2.1 –Mean response times (M), standard deviations (SD) and percentage of errors (Errors (%)) for Experiment 2.1

	Acronyms		**Regular Words**		**Irregular Words**	
	High	**Low**	**High**	**Low**	**High**	**Low**
M	675	768	535	554	535	558
SD	82	99	68	66	68	73
Errors (%)	11	51	1	5	1	2

Recognition times were examined using type of stimulus (3; acronym versus regular word versus irregular word) x frequency (2) analyses of variance. ANOVA were carried out by subjects (F_1) and by items (F_2). Frequency and type of word were treated as within subjects factors in the analysis by subjects and as between subjects variables in the analysis by items. Significant main effects of type of stimulus were found both by subjects and by items [F_1 (2, 58) = 244.361, MSe = 2536.001, $p < .001$, $\eta^2 = .894$; F_2 (2, 144) = 166.550, MSe = 3142.153, $p < .001$, $\eta^2 = .698$]. Post hoc t-tests with a Bonferroni correction applied ($\alpha/6 = .008$) indicated that responses for acronyms (721ms) were given at significantly longer latencies than either regular (544ms, $p < .001$) or irregular word trials (547ms, $p < .001$). Regular and irregular words were not significantly different ($p = 1$). The main effect of frequency was also

statistically significant in both analyses [F_1 (1, 29) = 78.687, MSe = 1163.468, $p < .001$, $\eta^2 = .731$; F_2 (1, 144) = 23.351, MSe = 3142.153, $p < .001$, $\eta^2 = .140$], such that high frequency items were recognised more quickly than their low frequency counterparts. The interaction between type of stimulus and frequency was significant [F_1 (2, 58) = 13.588, MSe = 1894.510, $p < .001$, $\eta^2 = .319$; F_2 (2, 144) = 5.554, MSe = 3142.153, $p < .01$, $\eta^2 = .072$]. As is illustrated in Figure 2.1, the advantage for high versus low frequency acronyms was greater than for regular or irregular words.

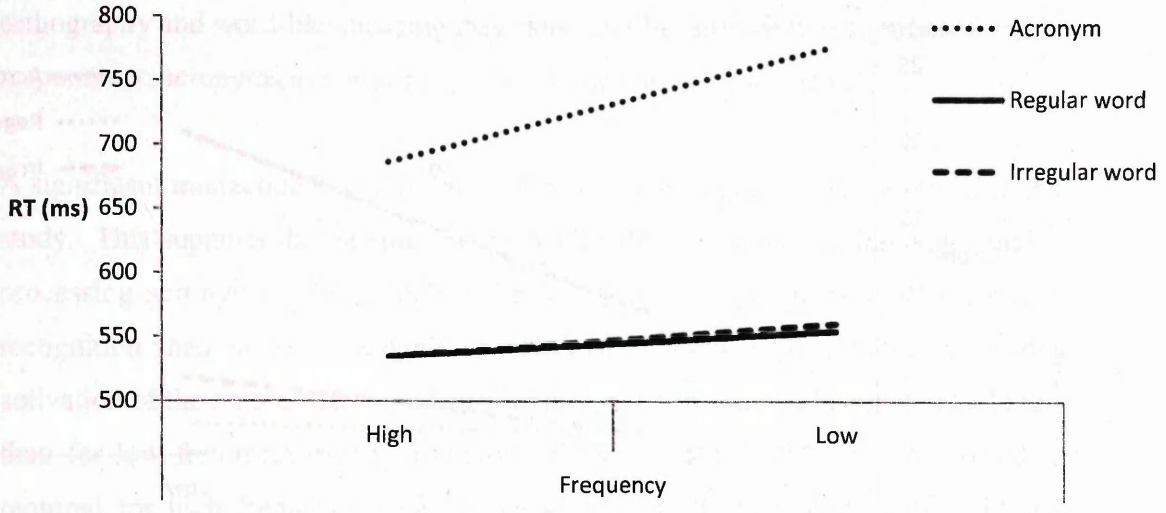


Figure 2.1 – Mean response times for correct lexical decision responses. High frequency items were recognised quicker than low frequency for each type of stimulus. For acronyms the advantage was 92ms. The effect of frequency was significantly smaller for mainstream words.

A second set of type of stimulus (3) x frequency (2) ANOVA analyses were computed concerning the error rates. The factors were entered as within subjects variables in the analysis by subjects and as between subjects variables in the analysis by items. Again the main effect of type of stimulus was significant in the analysis by subjects and by items [F_1 (2, 58) = 314.922, MSe = 9.390, $p < .001$, $\eta^2 = .916$; F_2 (2, 144) = 140.768, MSe = 21.916, $p < .001$, $\eta^2 = .662$]. Bonferroni corrected post hoc t-tests ($\alpha/6 = .008$) indicated that significantly fewer errors were made in irregular word trials than in regular word trials, and that the error rate for acronyms was higher than for either of the mainstream word stimuli. A main effect of frequency was also

observed [F_1 (1, 29) = 152.769, MSe = 9.501, $p < .001$, $\eta^2 = .840$; F_2 (1, 144) = 52.621, MSe = 21.916, $p < .001$, $\eta^2 = .268$]. Participants made significantly fewer errors when the word/ acronym was high in frequency. The interaction between type of stimulus and frequency was significant [F_1 (2, 58) = 56.315, MSe = 9.014, $p < .001$, $\eta^2 = .661$; F_2 (2, 144) = 26.930, MSe = 21.916, $p < .001$, $\eta^2 = .272$]. As in the reaction time analyses, the effect of frequency was greatest for acronyms. Error rates for irregular words were not affected by frequency. This interaction is shown in Figure 2.2.

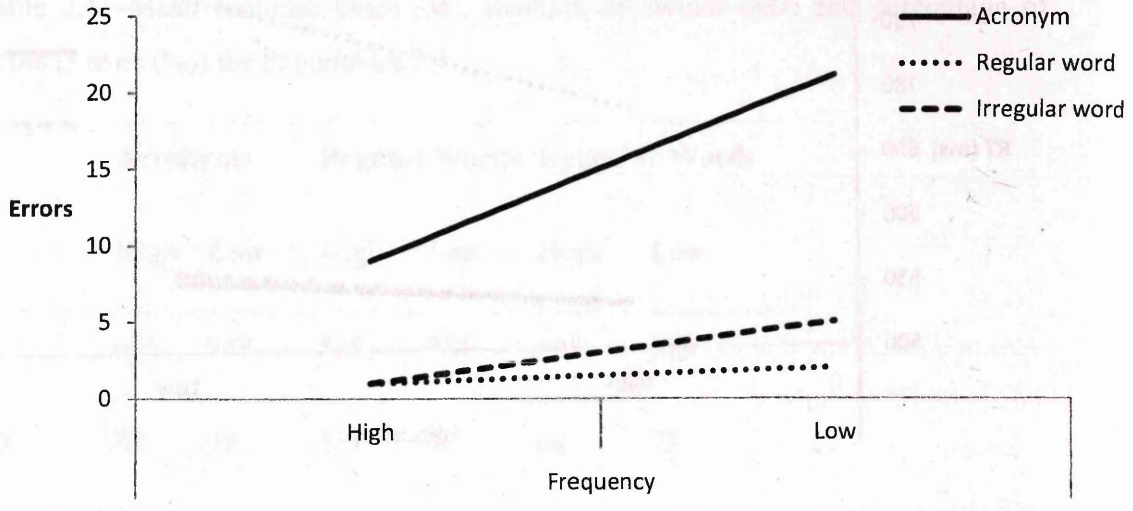


Figure 2.2 – Mean number of errors for each stimulus type. Frequency had no effect on the error rate in irregular word trials. On average participants made 12 fewer errors in high frequency acronym trials than in low frequency trials. The effect of frequency was smaller for regular words but still significant.

2.4 Discussion

Words which are encountered often in daily life are recognised more quickly and accurately than infrequent words (Connine et al., 1990; Fredriksen & Kroll, 1976; Gerhand & Barry, 1999; Hino & Lupker, 2000; Hudson & Bergman, 1985; Perea & Rosa, 2002; Richardson, 1976; Rubenstein et al., 1970; Turner et al., 1998). This frequency effect in lexical decision was replicated in this study. Frequency effects have been considered a consequence of differential ease of lexical access. Therefore

the existence of frequency effects in acronym processing indicates that acronyms, as well as words, are lexicalised. Recognition times and error rates in the present experiment were also significantly affected by stimulus type. Closer inspection revealed that this reflected slower responses in acronym trials than in either of the mainstream word types. Acronyms have unusual orthographies, often comprising several consonants or vowels together in combinations which do not occur in typical English words. They are nevertheless representations of a given meaning and hence have an inherent semantic component. The disparity between non-word-like orthography and word-like meaning may cause conflict sufficient to significantly slow responses to acronyms as compared to words, such as exhibited here.

A significant interaction between type of stimulus and frequency was observed in this study. This supports the interpretation of the conflict between spelling and sound in processing acronyms. Being high in frequency was of greater benefit in acronym recognition than in word recognition. Following Perea et al. (2005), the resting activation of the representations of high frequency acronyms/words ought to be higher than for low frequency acronyms/words. Thus less additional activation would be required for high frequency items to be recognised. For acronyms this additional resting activation was particularly beneficial given the difficulty in resolving the conflict between orthography and semantics. A strongly activated lexical representation meant that the illegal orthography had a relatively smaller interfering influence. Further evidence for this interpretation is provided by the interaction between frequency and stimulus type in accuracy rates. When participants are presented with non-words in lexical decision tasks, they must decide that what they are seeing is not meaningful. The common conception is that a processing deadline is imposed, and that if the recognition threshold has not been reached in time the stimulus is rejected as a non-word (Coltheart, Besner, Davelaar & Jonasson, 1977). It is possible to suggest that low frequency acronyms do not achieve a criterion level of activation quickly enough to overcome their illegal orthography. Thus the deadline is reached and the acronym is incorrectly rejected.

It should also be noted that for some of these acronyms the rated frequency was very low indeed. The scale used required that raters used a score of 1 to indicate that they used an acronym "rarely or never." It is conceivable that some of the low frequency

acronyms used in this lexical decision task were not known to all of the participants. This could have contributed to the remarkably high error rate in low frequency acronym trials.

In experiment 2.2 participants were trained to respond to acronyms as if they were non-words. This task was designed to decrease the need for lexical access to complete the task. As most acronyms have illegal orthographic representations it would be possible to successfully perform this task without access to the lexicon. As described in the introduction, the rejecting non-words with illegal orthographies seems to be a rapid process (Richardson, 1976). Only an analysis of the visual form is required. This same orthographic analysis could be used to reject acronyms. Using a rhyme judgement task which relied on the sublexical information, Balota & Ferraro (1996) were able to eradicate the effect of frequency for words that showed a frequency effect in lexical decision. By increasing the importance of the orthography of acronyms in completing the task, and de-emphasising lexical processing, it was predicted that the frequency effect would be attenuated in acronym trials.

Experiment 2.2 Classifying acronyms as non-words

2.5 Method

2.5.1 Participants

Thirty psychology students (7 male) with a mean age of 25 years (range 18 - 27) took part in the experiment. All were native English speakers that reported no visual or reading problems. Participants received course credit for their participation.

2.5.2 Procedure

Experiment 2.2 used the same apparatus and followed the same procedure as in Experiment 2.1. The only difference was that this time participants were trained to consider acronyms as non-words. In the practice trials "incorrect" feedback was

provided if the participant classed an acronym as a word. The same stimuli items as those in experiment 2.1 were used.

2.6 Results.

Incorrect responses were excluded from the reaction time analyses (3 %). Responses longer than 1500ms and shorter than 300ms were considered outliers and removed from further analyses (1%). Although the general accuracy of the participants was good, one participant had made errors in 32% of the high frequency acronym trials. This participant was excluded from the data set. The data from the remaining 29 participants were subjected to two different analyses, one with accuracy as the dependent variable and one with reaction times (RTs) as the dependent variable. Means and standard deviations for correct trials along with percentage of errors in each condition are shown in Table 2.2.

Table 2.2 – Mean response times (M), standard deviations (SD) and percentage of errors (Errors (%)) for Experiment 2.2.

	Acronyms		**Regular Words**		**Irregular Words**	
	High	**Low**	**High**	**Low**	**High**	**Low**
M	650	639	593	624	598	613
SD	137	130	96	108	95	104
Errors (%)	2	2	2	5	2	3

Type of stimulus (3) x frequency (2) ANOVA were calculated concerning reaction times for word and acronym trials. The by subjects analysis entered both factors as within subject variables. Type of stimulus and frequency were treated as between subject factors in the analysis by items. A significant main effect of type of stimulus

was revealed in both the analyses [F_1 (2, 56) = 9.742, MSe = 2876.828, $p < .001$, η^2 = .258; F_2 (2, 144) = 5.366, MSe = 4013.803, $p < .01$, η^2 = .69]. Post hoc analysis using Bonferroni corrected follow up tests ($\alpha/6 = .008$) indicated that responses in acronym trials (645ms) were significantly slower than those in regular word trials (608ms, $p < .05$) or irregular word trials (606ms, $p < .05$). Latencies in irregular and regular word trials were not significantly different ($p = 1$). The main effect of frequency was significant by subjects [F_1 (1, 29) = 7.007, MSe = 841.292, $p < .05$, η^2 = .200] and by items [F_2 (1, 144) = 4.563, MSe = 4013.803, $p < .05$, η^2 = .31]. A significant interaction between frequency and type of stimulus was observed in the by subjects analysis, and approached significance in the analysis by items [F_1 (2, 56) = 6.943, MSe = 920.932, $p < .01$, η^2 = .199; F_2 (2, 144) = 2.933, MSe = 4013.803, $p = .056$]. There was no significant frequency effect in acronym trials ($p > .1$). High frequency regular words were recognised significantly faster than low frequency regular words ($p < .001$). The 15 ms advantage for high versus low frequency irregular words approached significance ($p = .09$). This interaction is shown in Figure 2.3.

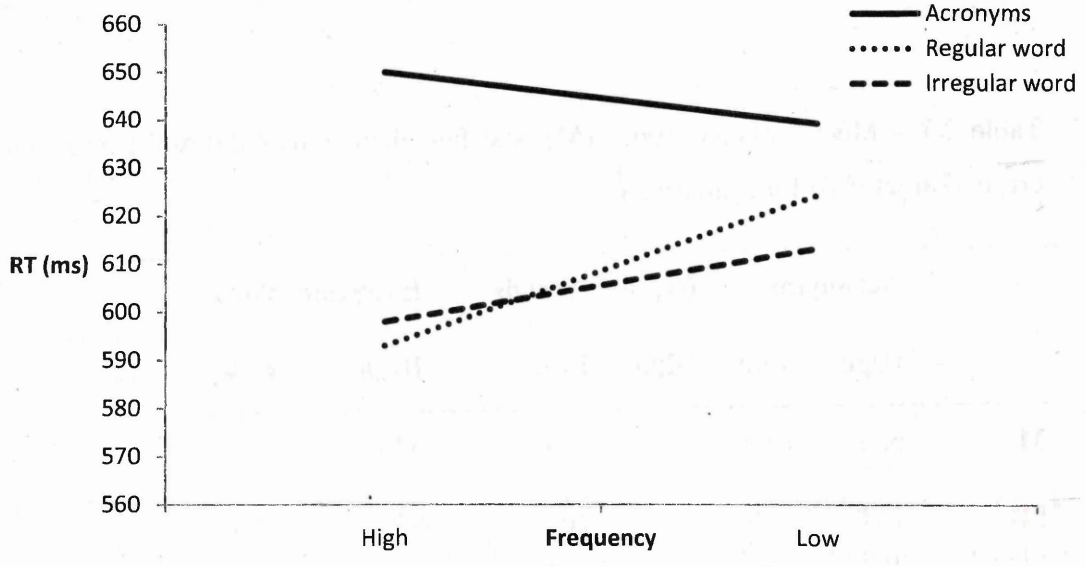


Figure 2.3 – Mean response times for correct lexical decision responses. High frequency words were recognised quicker than low frequency words. The effect of frequency was not significantfor acronyms.

Error scores were entered into a second set of type of stimulus (3) x frequency (2) ANOVA. No main effects of type of stimulus were observed [F_1 and $F_2 < 1$], and the

main effect of frequency only reached significance in the analysis by subjects [F_1 (1, 29) = 5.788, MSe = 11.810, $p < .05$, $\eta^2 = .166$; $F_2 < 1$]. No significant interactions were found.

2.7 Discussion

Experiment 2.2 asked participants to respond to acronyms as if they were non-words. This instruction was given so that the orthographic characteristics of acronyms were of greater importance than their lexical representations in the completion of the task. By emphasising sublexical processes it was expected that the effect of frequency on acronym responses would be eliminated. In fact, the analysis of experiment 2.2 showed main effects of frequency on both reaction times and accuracy. The "yes" decision for mainstream words was appropriate in experiments 2.1 and 2.2. Thus, it could be hypothesised that frequency effects would be observed in regular and irregular word trials irrespective of the instructions concerning acronyms. Indeed, the responses for high frequency regular words were significantly faster and more accurate than for low frequency regular words in experiment 2.2, mirroring the word recognition literature (Connine et al., 1990; Fredriksen & Kroll, 1976; Gerhand & Barry, 1999; Hino & Lupker, 2000; Hudson & Bergman, 1985; Perea & Rosa, 2002; Richardson, 1976; Rubenstein et al., 1970; Turner et al., 1998). Frequency effects in the recognition of irregular words also approached significance.

The lack of any advantage for high versus low frequency acronyms was as expected. The task was designed in such a way that accurate responses for acronyms could be given without necessitating lexical access. Thus frequency information was not integral to responses in acronym trials. The findings here are partially supportive of the extant literature concerning the strategic deployment of the sublexical route (Balota & Ferraro, 1996; Balota et al., 2000; Monsell et al., 1992; Zevin & Balota, 2000). It should be noted, though, that responses in acronym trials were significantly slower than in either of the mainstream word conditions, just as they were in experiment 2.1. Emphasising the sublexical route ought to allow acronyms to be rejected easily on the basis of their orthography, and responses would be expected to be recorded at similar latencies to those in illegal non-word trials. In fact, rejecting

illegal non-words took participants an average of 40ms less than rejecting acronyms. It seems likely that the lexical representations of acronyms were accessed and that participants had to inhibit the "word" response in order to perform accurately. The findings of experiment 2.1 suggest that the lexical representations for high frequency acronyms are accessed reasonably quickly. Low frequency acronyms, on the other hand, were slower to reach a recognition threshold in experiment 2.1.

This suggests that the activation of their lexical representations is accumulated more slowly. In experiment 2.2, the activation of the lexical representation made it harder to reject acronyms. The fact that participants recognised the acronyms was a hindrance to making an accurate response. It is plausible that the slow RTs in acronym trials reflect inhibition of recognition activation at the decision stage. If high frequency acronyms were strongly activated then inhibiting a "yes" lexical decision response would have been particularly effortful. Low frequency acronyms may have been less strongly activated (possibly not even recognised before the response deadline imposed by the participant) and would have required less effortful inhibition. Thus the long latencies for all acronyms may reflect a combination of recognition and subsequent response inhibition. The lack of frequency effects in acronyms could be interpreted as a result of the difference in the strength of lexical activation before the response was initiated.

Experiment 2.3 Reading acronyms aloud

2.8 Introduction

The first two experiments examined lexical decision responses for acronyms. Experiment 2.3 aimed to test the assumption that acronym reading is achieved by a similar process to that used in irregular word reading. This will be the first experiment to explicitly address the question as to whether acronyms necessitate lexical reading, and this is a central purpose of the thesis as a whole.

In the naming task used here, participants are asked to read aloud a visually presented stimulus. An important variable in naming is spelling to sound regularity. According to dual route accounts of word reading (e.g. Coltheart, Curtis, Atkins & Haller, 1993; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) there are two possible ways to reach a pronunciation for a written stimulus. One route ascribes the most commonly associated phonemes to the letters in the word and assembles the output from the constituent phonemes. This is the grapheme phoneme correspondence route, and it is useful for reading non-words and words for which the pronunciation follows the major correspondences. These are known as regular words.

However, a significant proportion of English words are not pronounced according to grapheme phoneme correspondences. To accommodate these (irregular) words, a second lexical route is available. This route achieves pronunciation by retrieving the stored representation from the lexicon. An interaction between frequency and regularity is commonly reported in naming performance (Coltheart & Rastle, 1994; Paap & Noel, 1991; Rastle & Coltheart, 1999; Seidenberg, 1985; Seidenberg, Waters, Barnes & Tanenhaus, 1984; Waters & Seidenberg, 1985). Thus reading aloud words with regular spelling to sound correspondences is not affected by word frequency, but low frequency irregular words take longer to name than their high frequency counterparts.

One of the explanations for this stems from the conflict between the outputs offered by the two routes proposed in the DRC (Coltheart et al., 2001). Regular words will be pronounced in the same way regardless of whether the pronunciation is achieved by grapheme phoneme correspondence or by lexical access. The pronunciation for irregular words will be different depending on the processing route. The lexical representation for a high frequency word is retrieved sufficiently quickly that there is no opportunity for the GPC route to interfere. On the other hand, low frequency words are not accessed as quickly in the lexicon, and hence the potential outputs from both routes are available at the same time. This results in a conflict which has to be resolved before a response can be given. The relationship between orthography and phonology in acronyms does not usually follow grapheme phoneme correspondences.

Therefore, from a dual route perspective, a frequency effect might be observable in acronym naming responses, as it is in irregular words. This will be the first empirical test of the assumption that acronyms are processed in a similar way to irregular words.

2.9 Method

2.9.1 Participants

Twenty participants with a mean age of 23 years (range 18 - 34) took part in the experiment. They were all students at Swansea University. Of these, 6 were male, 14 were female. All participants were monolingual English speakers without a diagnosis of dyslexia.

2.9.2 Materials

The same fifty acronyms and one hundred words from Experiments 2.1 and 2.2 were used as the stimuli in this study. However, none of the non-words were included in the naming task.

2.9.3 Procedure

Stimulus presentation and recording of reaction times was controlled via E-Prime (Schneider, Eschman & Zuccolotto, 2002). Stimuli were presented on a 19" screen monitor. Participants were instructed to read aloud the letter string presented onscreen as they would under normal circumstances. That is, as if they were reading aloud from a magazine, newspaper or book. Each trial began with a fixation cross being presented for 1500ms, serving as a buffer between one trial and the next so as to prevent losing trials if the microphone picked up the last syllable of the participants' previous response. Following this, the target stimulus was centrally presented in Times New Roman font, point 12. Participants responded via a microphone and serial response box. Targets remained onscreen until a response had been detected by the computer. Sessions were audio recorded to allow for error analysis. Reaction times were automatically recorded by E-Prime. The timer began when the target appeared

on the screen and stopped when the participant spoke into the microphone. Five practice trials were used to ensure that the participants were comfortable with the procedure and the equipment was working correctly before the 150 experimental trials began.

2.10 Results

Errors made by the participants (4%), and those trials lost through voice-key malfunction were removed from the data set before any further treatment of the data was undertaken (6%). Any responses under 300ms and greater than 1500ms (a further 2%) were also deleted. One participant was removed from the analyses completely as his/her reading responses were available for fewer than 70% of trials following treatment of the data. The mean response latencies, standard deviations of RTs and percentage of errors are presented in Table 2.3 below.

Table 2.3 – Response naming times (M), standard deviations (SD) and percentage of errors (Errors (%)) for Experiment 2.3

	Acronyms		**Regular Words**		**Irregular Words**	
	High	**Low**	**High**	**Low**	**High**	**Low**
Mean	690	736	598	605	591	625
SD	104	147	88	92	93	105
Errors (%)	1	7	5	4	5	3

Table 2.3 shows that high frequency irregular words were named fastest, with low frequency acronyms taking the longest before a response was offered. Error rates were highest when naming low frequency acronyms.

Type of stimulus (3) x frequency (2) ANOVA were calculated concerning reaction times for word and acronym trials. Type of stimulus and frequency were treated as within subject factors in the analysis by subjects. The by items analysis entered both factors as between subject variables. Significant main effects of type of stimulus were found in the analysis by subjects [F_1 (2, 36) = 33.017, MSe = 4547.771, $p < .001$, $\eta^2 = .647$] and by items [F_2 (2, 144) = 73.526, MSe = 2942.938, $p < .001$, $\eta^2 = .505$]. Post hoc t-tests using a Bonferroni correction ($\alpha/6 = .008$) revealed that responses were given at significantly greater latencies in acronym trials (713ms) than either regular (602ms) or irregular (608ms) words. The main effect of frequency was also significant [F_1 (1, 18) = 25.551, MSe = 928.205, $p < .001$, $\eta^2 = .587$; F_2 (1, 144) = 8.917, MSe = 2942.938, $p < .01$, $\eta^2 = .058$]. High frequency items elicited faster responses than low frequency items. The type of word by frequency interaction was significant by subjects but not by items [F_1 (2, 36) = 3.655, MSe = 1068.252, $p < .05$, $\eta^2 = .169$; F_2 (2, 144) = 2.010, MSe = 2942.938, $p > .1$]. This interaction is depicted in Figure 2.4. Frequency effects were exhibited by participants when reading irregular words and acronyms, but not when regular words were presented. No formal analysis of error responses was performed as the mean number of incorrect responses in five out of the six conditions was less than 1.

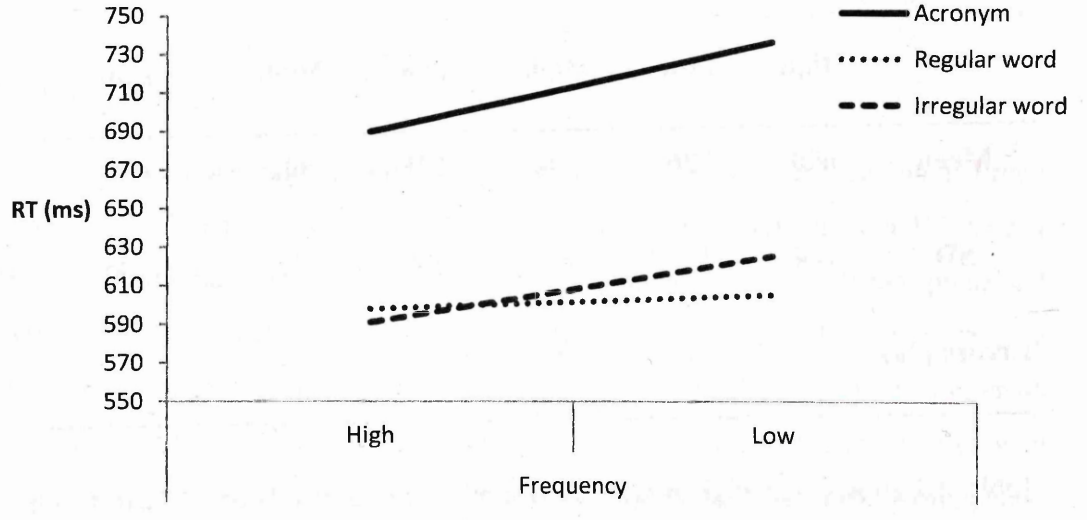


Figure 2.4 – Mean naming times for each stimulus type. Frequency had no effect on the response latency in regular word trials. A processing advantage was observed for

high versus low frequency acronyms and for high versus low frequency irregular words.

2.11 Discussion

In line with the findings of the lexical decision tasks, the naming data showed significant effects of type of word and frequency. Participant responses to acronyms were again significantly slower than responses to words. This may be attributable to the context of the experiment. Specifically, the correct pronunciation for the majority of the targets in experiment 2.3 was to produce a single word-like response. For acronyms, though, the correct pronunciation is usually to name each constituent letter in turn. Successfully reading of acronyms therefore required that the participants used an alternative strategy to the majority of items in the study. This mechanism of pronunciation is used less often, and the employment of a less efficient mechanism served to make acronym reading more effortful and hence slower.

Irregular words, which cannot be read correctly by sublexical processes, are susceptible to frequency effects while regular words are unaffected by frequency (Coltheart & Rastle, 1994; Paap & Noel, 1991; Rastle & Coltheart, 1999; Seidenberg, 1985; Seidenberg, Waters, Barnes & Tanenhaus, 1984; Waters & Seidenberg, 1985). This pattern of results was exhibited in Experiment 2.3. Acronyms also exhibited frequency effects, with high frequency items named significantly faster than low frequency items. This indicates that reading acronyms may also involve input from the lexical route. The finding of frequency effects in acronym reading further supports the idea of acronyms as items in the language which require lexical access.

2.12 General Discussion

Three experiments were designed to investigate whether acronyms were integrated into the mental lexicon alongside words. The role of frequency was assessed in lexical decision and naming tasks including regular words, irregular words and acronyms. The findings of the present research can be summarised as follows. First, high frequency acronyms were recognised and read aloud more quickly than their low frequency counterparts. Second, responses to acronyms were considerably slower than those in mainstream word trials.

Words which are encountered often in daily life are recognised quickly, and uncommon words are significantly slower to elicit responses. High frequency words therefore need to accumulate less additional activation before they are recognised than low frequency words. A frequency effect was observed in word trials in experiments 2.1, 2.2, and 2.3. An interaction between frequency and stimulus type was also observed in experiment 2.1, such that recognition responses for acronyms benefitted more from being high in frequency than responses for words. This can be taken as evidence that acronyms are integrated into the lexicon, and supports the findings of previous studies concerning acronyms (Besner et al., 1984; Brysbaert et al., 2009; Prinzmetal & Millis-Wright, 1984). It is speculated that the size of the frequency effect for acronyms is indicative of the range of frequencies in the experimental stimuli. Low frequency acronyms may be encountered only very rarely and therefore retrieving their lexical entries may be particularly difficult. High frequency acronyms such as BBC or DVD are such an integral part of daily language use that their representations in the lexicon are easily accessed. Further, the least frequently encountered acronyms received ratings of roughly 1 from the participants. A rating of 1 was given to an acronym which was encountered "rarely/never." Thus it is plausible that some of the low frequency acronyms had never been encountered by the lexical decision participants.

Further evidence for the lexical representation of acronyms comes from the naming task in experiment 2.3. From the dual route perspective, differences between regular and irregular words arise in word naming when there exists a conflict between the pronunciation offered by lexical and sublexical routes. The difference between regular and irregular words is smaller when the words are high frequency because the lexical route achieves pronunciation before the sublexical processes have been completed, and therefore there is no interference with responses to irregular words. The correct pronunciation for acronyms, in general, does not follow grapheme to phoneme correspondences. Thus, according to the dual route model, the reading must be achieved by the lexical route. The effect of frequency observed for acronyms indicates that the lexical route is influential in acronym reading.

In both experiments the responses to acronyms were recorded at significantly longer latencies than for words. This probably reflects the relatively low proportion of

acronyms in everyday English. The reading system is less practiced at processing acronyms and therefore less efficient. It is clear, however, that frequently occurring acronyms pose few problems for the reader nevertheless, as accuracy rates were generally high.

Experiments 2.1 and 2.2 aimed to add to the literature that suggests that the role of the two pathways for reading proposed in dual route models can be altered by the demands of the task. Balota and Ferraro (1996) presented a rhyme judgement task designed to encourage the use of the sublexical route. No frequency effects were observed in response times. Significant effects were, however, observed in a lexical decision task using the same items. In the present experiment 2.2, the unusual orthography of acronyms was emphasised in a lexical decision paradigm. The participants were instructed to classify acronyms as non-words. This could successfully be accomplished without lexical access and hence no frequency effects were predicted. Frequency effects in acronyms were eradicated in this task while an advantage for high versus low frequency words was preserved. However, the latencies in acronym trials were significantly longer than for regular or irregular words. It is suggested that the lexical representations for acronyms were automatically accessed and that the subsequent recognition needed to be inhibited before the appropriate response could be given. The higher resting activation for high frequency acronyms leads to rapid recognition for this type of stimulus (as evidenced by experiment 2.1) and a greater effort is required to inhibit the recognition response. Thus high frequency acronyms take a long time to respond to due to the conflict between the recognition and the demands of the task. Low frequency acronyms accumulate the activation necessary for recognition more slowly (see experiment 2.1) and hence there is less activation to inhibit in order to reject them.

A degree of caution should be exercised when interpreting the results of the studies described here. In experiment 2.1 the participants were able to recognise low frequency acronyms only at chance levels. This has implications for experiment 2.2. Rejecting an acronym that the participant had never encountered, and hence did not know was an acronym, increased the errors in low frequency acronyms in experiment 2.1. The instructions in experiment 2.2 required that acronyms were considered non-words and therefore rejected. In this task any acronym that the participant had no

knowledge of would elicit the correct response. However, this would mean that potentially two types of response are represented in the reaction time data. It could be expected that acronyms that were rejected because they were unfamiliar to the participant would have similar response latencies to illegal non-words. Previous studies have shown that rejecting illegal letter strings is particularly quick. Thus if the participants in experiment 2.2 had a similar level of knowledge of the low frequency acronyms as the participants in experiment 2.1, around half of the acronyms could essentially have been perceived as non-words. These responses would considerably decrease the mean RT for low frequency acronyms. Thus it is possible that the non-significant difference between high and low frequency acronym trials in experiment 2.2 is a not a reflection of the emphasis on sublexical processes but the influence of rapid responses to unknown low frequency items on mean RT.

The high error rate for low frequency acronyms in experiment 2.1 also has implications for the naming task. In the naming task a significant frequency effect was observed in acronym reading times. This was taken as evidence of the role of lexical processing in acronym trials. However, if a large proportion of the low frequency acronyms were not known to the participants in experiment 2.3 then no lexical representations would have been created for them. This would make lexical reading impossible for those acronyms. Nevertheless the reading responses were generally accurate. Inspection of the acronym stimuli reveals that all 25 of the high frequency acronyms require that each constituent letter in turn. In the low frequency acronyms, 4 items are pronounced in a word-like manner (AWOL, BAFTA, NASA, and SIDS). It is plausible that these four items had an impact on the mean RT for the low frequency acronym condition. The impact of print to pronunciation characteristics warrants further investigation before the naming data can be fully explained.

As a final point, studies in mainstream word reading examine the role of one factor while controlling for a number of variables. Indeed the words used here varied in terms of their frequency but age of acquisition and imageability values were matched. No such control was possible for acronyms because normative values do not exist as yet. Therefore a number of other characteristics of acronyms may be exerting an influence on the reading and recognition responses collected in this study. Without

appropriate norms, though, properly controlled studies cannot be designed, and interpretation of results will always be open to criticism. This should be a priority for future research with acronym stimuli.

CHAPTER 3

A NORMATIVE STUDY OF ACRONYMS

3.1 Introduction

As seen in Chapter 2, acronyms appear to be integrated into the mental lexicon. The frequency with which an acronym is encountered was shown to influence participant responses, with high frequency acronyms being recognised and named more quickly than low frequency acronyms. However, a number of factors which are known to be influential in word reading and recognition were not controlled for (age of acquisition, imageability, orthographic neighbourhood etc.). This is because no normative values are available for acronyms. Chapter 2 concluded that the collection of norms and the assessment of the important variables should be a priority for research using acronyms. Chapter 3, therefore, gathers information concerning seven variables which are either manipulated or carefully controlled in reading research.

Acronyms have been an integral part of experimental manipulations in a number of studies of word recognition and reading (Gibson et al., 1964; Henderson, 1974). The main reason for the use of acronyms has been their unusual combination of meaning and pronunciation, especially because the latter does not obey the standard spelling to sound correspondences of the language in use. The orthographic irregularity of acronyms, thus, has been paired with that of illegal letter strings while their meaning and familiarity has been considered as equivalent to that of other words in the language. Although their meaning and peculiar pronounceability are indeed acronym characteristics, these might have been over emphasised to the detriment of other factors also known to be relevant in oral reading and word recognition processes. First, for example, not all acronyms comprise only consonants or all vowels and those that do can be read by the application of a particular rule (i.e., letter naming). This rule might make acronyms somehow 'regular' and different from other illegal letter strings. Second, acronyms tend to be items that are acquired during adulthood and there is abundant evidence showing that late learned words are processed slower than

early acquired words (see Johnston & Barry, 2006; Juhasz, 2005 for a review). Third, acronyms are related to a more restricted number of familiar meanings than conventional words and words with few meanings tend to be processed slower than words with many meanings (Azuma & Van Orden, 1997; Ferraro & Hansen, 2002; Hino & Lupker, 1996; Klepousniotou & Baum, 2007). Another important difference is that orthographic and phonological length is often uncorrelated in acronyms. In contrast to conventional words, an acronym can often be orthographically short but phonologically long (e.g., '*HIV*' has only three letters but seven sounds *'aicheyevee'*). Finally, the number of orthographic neighbours associated to acronyms is generally much lower than those found in standard words. Orthographic neighbourhood refers to all the words that can be formed by changing one letter from a target word while keeping constant the rest. The predominance of evidence suggests that words with few orthographic neighbours take longer to be recognised (Alameda & Cuetos, 2000; Andrews, 1992; Perea, Acha & Fraga, 2008; Whitney & Lavidor, 2005; though see caveat in section 3.2.2). All these properties (e.g., a late age of acquisition, short letter length, low number of meanings, etc.) make acronyms a very idiosyncratic material, possibly more than ever thought. More importantly, sets of acronyms and familiar words merely matched in letter length might not be easily comparable and results from previous studies (Lazlo and Federmeier, 2007a, b; 2008) could have been confounded with a number of uncontrolled variables. Acronyms have been generally viewed as some kind of irregular word or even as a sort of 'non-word with meaning'. However, the question of whether acronyms are processed as irregular words has never been tested. In order to address this question acronym naming and lexical decision times were contrasted against a number of lexical and semantic factors known to be relevant in reading standard words and manifestly overlooked in previous studies involving acronyms.

This chapter describes an investigation of 146 acronyms in relation to their orthographic illegality, peculiar pronunciation and six other lexico-semantic characteristics. The study is important since acronyms appear to be an effective material in the investigation of word recognition and reading aloud. Interestingly, in most word recognition and naming studies in which no acronyms but conventional words are used, a careful selection of the material is carried out to ensure that only the factor under investigation varies while intercorrelated variables are controlled for.

Normative data has proven useful in these studies of word recognition and production, yet there is a complete absence of norms for acronyms. This is in spite of the fact that acronyms are not only useful material to facilitate the experimental manipulations in word processing research but also a topic of scientific enquiry as explored in Chapter 2. A number of studies (Besner, Davelaar, Alcott, & Parry, 1984; Coltheart, 1978) have been concerned with the lexicality of acronyms and attempts have been made to clarify whether acronyms enjoy the cognitive status of a word or a non-word. In Chapter 2 it was found that high frequency acronyms were named and recognised more quickly than low frequency counterparts. Frequency is an important property which has been included in the architecture and function of a number of models of the lexicon (Becker, 1976; Forster, 1976; Morton, 1969). The observed effect of frequency in acronym processing led to the conclusion made in Chapter 2 that acronyms are lexicalised. Brysbaert, Speybroeck, and Vanderelst (2009) reached the same conclusion. They found that acronyms produced an associative priming effect equivalent to that generated by conventional words and importantly this effect was independent of case presentation.

In recognition of the growing interest in acronyms in psycholinguistic research and the imperative need of normative data for this type of stimuli, an investigation of the lexico-semantic properties of 146 acronyms and their relationship with acronym naming and lexical decision speed was undertaken. This chapter has two major objectives. One is to determine the regularity status of acronyms. The fact that acronyms are orthographically illegal does not necessarily mean that they are processed as irregular words. A major proportion of acronyms are pronounced by naming each constituent letter aloud which might endow acronyms with some kind of regularity. The potential regularity of acronyms will be tested by contrasting the impact that a series of factors has on acronym naming and lexical decision speed and accuracy. Reduced or null effects of AoA have been found when naming regular words. Robust AoA effects in acronym reading will indicate similarities between those processes governing acronym naming and irregular word naming. A subsidiary aim is to provide further support for acronyms as lexicalised written stimuli by collecting lexical decision responses and assessing the factors important in acronym recognition. The factors under investigation along with their specific predictions are described below.

The second aim of this chapter was to generate an inclusive database to enable appropriate experimental control in future research. The factors considered were age of acquisition, rated and printed frequencies, bigram frequency, trigram frequency, imageability, number of letters, number of phonemes, number of syllables, number of orthographic neighbours, acronyms print-to-pronunciation pattern and voicing. These norms will benefit research in acronyms and word reading in healthy and clinical populations. The acronym characteristics considered in the present chapter are described below. Then the data collection for the norms, the acronym naming study and an examination of lexical decision for acronyms are presented.

3.2 Acronym characteristics

The selection of acronym properties included in the norms was guided by those factors that have been shown to affect single word processing (e.g., reading words aloud, distinguishing real words from invented words or naming objects). A detailed discussion of each factor has been provided in Chapter 1. Here the discussion has been limited to the explicit hypotheses regarding their influence in acronym naming times and accuracy. On the whole, the interpretation that acronyms are lexically represented would predict similar effects as are observed in mainstream words. Frequency, age of acquisition and imageability are expected to exert particularly strong influences on the response times and accuracy of the participants.

3.2.1 Age of acquisition

Age of acquisition (AoA) refers to the moment in time in which words, objects and faces are first learned. The arbitrary mappings hypothesis (Ellis & Lambon Ralph, 2000) for AoA effects allows the investigation of the assumed irregularity of acronyms. According to this account, the AoA effect is the result of cumulative learning in a network which gradually loses plasticity. Ellis and Lambon Ralph's simulations demonstrated that early-acquired words affect the structure of the system to a greater extent than words presented later. This means that the network becomes increasingly inefficient at learning new words. However, this loss of plasticity is less problematic in instances where the newly-learned item shares features with items that have already been acquired. For example, the pronunciation of regular words follows

a set of rules. The late acquired regular word can therefore exploit the structure of the network generated in learning earlier words. Irregular words, however, do not follow the same rules, and thus late acquired words cannot be assisted by existing word knowledge. This leads to a processing deficit for late acquired irregular words. If acronym processing is similar to that of irregular words AoA effects will be observed in acronym naming times. However, if letter naming can be taken as a rule that confers acronyms with some kind of regularity then no AoA effects will be observable.

AoA effects are also prominent in studies using the lexical decision tasks (e.g. Butler & Hains, 1979; Morrison & Ellis, 1995; Morrison & Ellis, 2000; Whaley, 1978). Words which were learned early in life are recognised more quickly than late acquired words. Brysbaert, Van Wijnendaele, and De Deyne (2000) discussed the proposition that AoA effects have a semantic root rather than a phonological one. They presented participants with a word association task and with a semantic categorization task, both of which are specifically tailored to access the semantic system, and reported significant AoA effects. Brysbaert et al. (2000) suggested that the AoA effect could be a result of the interconnection between words and concepts. Specifically, it was proposed that late acquired words are learned by relating the new concept to a previously existing word representation. As a result of this learning process the representations for early acquired words are accessed more often, and therefore are recognised more quickly and accurately. Semantic hypotheses of the AoA effect would predict a greater influence of AoA in the lexical decision task than in naming. A similar prediction can be derived from the arbitrary mappings hypothesis. Spelling to meaning mappings are less predictable than those between spelling and sound. Thus late acquired words (or acronyms) are unable to draw on previously acquired information and significant effects of age of acquisition should be exhibited in lexical decision performance. Therefore an effect of AoA in lexical decision for acronyms is predicted. The unusual or illegal orthography of the majority of acronyms might make them particularly difficult to differentiate from non-words, and hence the influence of the semantic system may be especially important in lexical decision response times and accuracy.

3.2.2 Number of orthographic neighbours or neighbourhood size (N).

One way in which the lexical similarity of a word has been operationalised is counting the number of words formed by changing one letter from the given word while keeping constant the position and identity of the rest of the letters (Coltheart, Davelaar, Jonasson, & Besner, 1977). For example, replacing the vowels from the word *peace* produces four neighbours: *'peach', 'pence,' 'pease'* and *'place'*. It is often referred to as N and it is the more commonly used measure in studies of lexical similarity. A common finding in word naming is that words with high-N are named faster than words with low-N (Andrews, 1989; 1992; Mathey, 2001; Sears, Hino, & Lupker, 1995).

In relation to acronym naming, N effects are predicted only if they emerge from the early processing of their constituent letters as suggested by Andrews (1989). In contrast, if the N effects derive from phonological similarity or from the interaction between orthography and phonology (Adelman & Brown, 2007), the impact of N in acronym naming would be reduced or absent since for most acronyms the translation from letters into sounds will not correspond to that of its neighbouring words in terms of single phonemes or rhyme units (e.g., as in EEG, LEG, PEG, BEG, EGG).

The literature concerning N effects in lexical decision indicates that, in general, words with many neighbours are recognised more quickly. A number of studies (Andrews, 1989; 1992; Forster and Shen, 1996; Sears, Hino & Lupker, 1995) reported that words with large N were recognised at shorter latencies than words with few neighbours. Andrews (1989) suggested that neighbourhood size supports sublexical spelling to sound mappings. Thus low frequency high N words receive additional input from the sublexical route and recognition responses are facilitated. The same is unlikely to be true for acronyms. It is rare for acronyms to share spelling to sound mappings with their orthographic neighbours (EEG versus LEG). Sublexical processes would not help in the recognition of acronyms. Thus it could be expected that N effects in lexical decision for acronyms may be inhibitory (i.e. large neighbourhoods result in slower responses) in line with the interactive activation model.

It should be noted that the supposed existence of N effects is a somewhat contentious issue. Stadthagen-Gonzalez and Davis (2006) highlighted that N correlates highly

with age of acquisition and imageability, and that although both of these variables are important factors in word processing, studies have not explicitly controlled for their effects. In Davis' (2010) spatial coding model, words with a small N are not predicted to elicit significantly different responses from words with a large N. This was supported by unpublished empirical research in which AoA and imageability were controlled. However, the spatial coding model *does* predict an advantage for words that do not have neighbours relative to words that do. This is an important point in that the orthography of many acronyms prevents them from having neighbours, while others have a large number of neighbours. In this way, acronyms may prove to be a particularly useful tool in the examination of neighbourhood effects, and evaluating models of word reading.

There are also a number of phenomena in the recent literature that suggest that N is too restrictive a definition of lexical similarity. It has been demonstrated that targets for lexical decision can be influenced by primes which involve the transposition of letters in adjacent (e.g. TRIAL and TRAIL, Perea & Lupker, 2003) or non-adjacent positions (e.g. CASINO and CANISO, Perea & Lupker, 2004). Further, Davis (2006) discussed the spread of activation from WIDOW to WINDOW (adding a letter) and PLANET to PLANE (deleting a letter). An alternative metric of orthographic similarity that has recently been described is orthographic Levenshtein distance 20 (OLD20; Yarkoni, Balota & Yap, 2008). This measure is based on the number of operations required to make 20 new words from a base word by way of addition, substitution and deletion of letters. For example, changing the base word STRANGE to WRANGLE requires three operations, deleting the initial S, substituting T with W and inserting an L before the final E. The OLD20 score is the mean number of operations required to make the 20 closest words. While this metric is not explicitly assessed in the remainder of this thesis, it is recognised that there may be circumstances in which its addition may provide important information about acronym processing, particularly as acronyms generally do not have many neighbours by Coltheart's definition.

3.2.3 Bigram and Trigram frequency

Bigram and trigram frequencies refer to the frequency at which pair of letters or sets of three letters appear together in written words of any given length. Thus, from a

word formed from *n* letters, *n*-1 bigrams and *n*-2 trigrams can be formed. Bigram and trigram frequencies are sub-lexical measures of what is known as orthographic redundancy or orthographic familiarity (Andrews, 1992; Graves, Desai, Humphries, Seidenberg, & Binder, 2010). Bigram frequency has been reported to affect tasks involving word recognition for low frequency words (Biedermann, 1966; Broadbent & Gregory, 1968; Conrad, Carreiras, Tamm, & Jacobs, 2009; Massaro & Cohen, 1994; Owsowitz, 1963; Rice & Robinson, 1975; Rumelhart & Siple, 1974; Westbury & Buchanan, 2002), although the reported evidence suggests that bigram and trigram frequencies generally have little impact on behavioural measures of word naming and word recognition. There is, however, some evidence that the brain is sensitive to variations in experience with particular letter patterns. Recent EEG studies (Hauk, Davis, Ford, Pulvermuller, & Marslen-Wilson, 2006; Hauk, Patterson, Woollams, Watling, Pulvermuller, & Rogers, 2006) have offered evidence of "letter n-gram frequency" (a combination of bigram and trigram frequencies) effects appearing in event-related potential data at around 100 milliseconds after stimulus onset. Available evidence indicates a general absence of bigram and/or trigram frequency effects in standard word naming and recognition. If acronym processing is similar to the processing of any other word in the language no bigram or trigram frequency effects are predicted in acronym naming or lexical decision speed or accuracy.

3.2.4 Imageability

Imageability refers to the ease with which a word evokes a mental image (Paivio, Yuille, & Madigan, 1968). Research has shown that highly imageable words are better recognised and memorised than less imageable words in tasks of lexical decision, cued and free recall (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Kennet, McGuire, Willis, & Schaie, 2000; Paivio 1965). The dual-code hypothesis (Paivio, 1971; 1991), accounts for the imageability effect arguing that abstract words activate verbal codes while concrete words activate verbal and imagery codes. The hypothesis states that the assistance of the imagery system facilitates the processing of concrete words. The influence of imageability in unimpaired oral reading, however, is uncertain. Strain, Patterson, and Seidenberg (1995) found an advantage for high versus low imageability words in naming inconsistent words. Other studies have failed to observe imageability effects in naming (Gerhand, 1999;

Monaghan & Ellis, 2002). It has been argued that this discrepancy could be a result of the different methods used to define inconsistency (Ellis & Monaghan, 2002; Strain, Patterson and Seidenberg, 2002). According to either of the classification criteria for consistency most acronyms can be considered inconsistent and often they are also low frequency. Thus, particularly strong imageability effects should be observable when reading acronyms if as suggested by Strain et al (1995) imageability influences are detectable when reading inconsistent low frequency words. Imageability effects have been more consistently reported when using the lexical decision task. Greater accuracy and faster responses are normally found for highly imageable words (Cortese, Simpson, & Woolsey, 1997; de Groot, 1989; James, 1975; Strain & Herdman, 1999; Strain et al., 1995; Zevin & Balota, 2000), especially when the words are of low frequency. It is argued that high frequency words have a higher level of resting activation than low frequency words (Perea & Rosa, 2005) and that they therefore require less additional activation before recognition. High frequency words are recognized so fast that imageability does not have the opportunity to show its influence. However, low frequency words take longer to be recognized and therefore they are able to benefit recognition from semantic activation. Plaut and Shallice (1993) argued that high imageable words have richer semantic representations than abstract words. Thus low frequency concrete words receive more semantic input than abstract words, and recognition times are faster as a result. Acronyms are also likely to benefit from being imageable, particularly as their orthography is so uncommon in English. Highly imageable acronyms are predicted to elicit faster recognition times than their less imageable counterparts.

3.2.5 Word Frequency and Word Familiarity

Word frequency refers to the number of times an individual encounters or uses a particular word. This study presents a rated estimation of the subjective frequency/ familiarity of a list of acronyms along with a printed frequency measure for each acronym. Frequency corpuses tend to underrate the frequency of acronyms because either they avoid the inclusion of abbreviations (Zeno et al., 1995) or are based on language samples where acronyms are scarcely represented (e.g., from subtitles $SUBTLEX_{us}$). For this reason acronyms' printed frequency was calculated using three internet search engines (www.altavista.com; www.google.co.uk; www.bing.com) as

suggested by Blair, Urland and Ma's (2002) method. That is, each acronym was entered into the search function and the number of hits returned was recorded as the measure of the acronym frequency. Three different search engines were used in order to provide an indication of reliability. In addition, a rated estimation of each acronym subjective frequency/ familiarity was also collected.

The importance researchers have assigned to word frequency is reflected in the fact that most models of word processing and word learning have incorporated word frequency in their operating architectures (Coltheart, 2001; Harm & Seidenberg, 1999; Monaghan & Ellis, 2010). Frequency effects in word naming tend to interact with word regularity and/or consistency (Ellis & Monaghan, 2002; Jared & Seidenberg, 1990; Monaghan & Ellis, 2002; Weekes, Castles, & Davies, 2006). This means that, reading times are particularly slow and inaccurate for low frequency inconsistent and/or irregular words. Considering the orthographic inconsistency/ irregularity of acronyms and assuming that acronym-naming exploits the same reading system as that used when naming mainstream words, large frequency effects are predicted in acronym naming times and accuracy.

The frequency effect is also a common finding in the word recognition literature. High frequency words are recognised faster than low frequency words in the lexical decision task (Connine, et al., 1990; Fredriksen & Kroll, 1976; Gerhand & Barry, 1999a; Hino & Lupker, 2000; Hudson & Bergman, 1985; Perea & Rosa, 2002; Richardson, 1976; Rubenstein, Garfield, & Millikan, 1970; Turner, Valentine & Ellis, 1998). The consensus is that words encountered often are somehow easier to retrieve. If acronyms have lexical representations (Brysbaert et al., 2009) frequency effects should be observed in lexical decision responses.

3.2.6 Letter and syllable length

Word length measured in terms of its orthographic (number of letters) or its phonological (number of syllables or phonemes) aspects shows a positive correlation with word naming and recognition times (Balota et al., 2004; Hudson & Bergman, 1985; New, Ferrand, Pallier and Brysbaert, 2006).

Number of letters and syllables were calculated for the acronyms included in the present study. The correlation between these variables was predicted to be low since often acronyms are short in number of letters but long in number of syllables (e.g., BBC, DVD, etc). The disparity between letter and syllable length would help to reveal the relative contribution of orthographic and phonological length in acronym reading. In addition since many acronyms are pronounced naming each of the constituent letters aloud a linear length effect was intuitively predicted in acronym naming times.

In relation to acronym recognition times, increasing word length generally results in increased response latency (Balota et al., 2004; New et al., 2006). However, a particularly relevant finding is reported in New et al.'s (2006) analysis of lexical decision responses drawn from the English Lexicon Project (Balota et al., 2000). In analysis 3, New et al (2006) ran multiple regressions on successive pairs of word lengths (3-4 letters up to 12-13 letters) and found that between 3 and 5 letters increasing word length was facilitatory. Length effects were not significant from 5 to 8 letters, and each additional letter then had an inhibitory effect. The majority of the acronyms considered here are between 3 and 5 letters in length (there is one 6 letter acronym, NASCAR), and hence it is possible that a facilitatory word length effect will be observed in the lexical decision task. Specifically, the finding reported by New et al. (2006) would lead to the prediction that acronyms containing more letters may be recognised more quickly.

3.2.7 Print-to-Pronunciation patterns: Typicality and Ambiguity

The spelling system of modern English is the result of a complex and rich language history that has produced a distinctive way of translating letters into sounds. The classification of the spelling regularities and therefore also inconsistencies along with the examination of their influence on reading has been profusely studied (Coltheart et al., 2001; Rastle & Coltheart, 1999; P. Monaghan, & Ellis, 2010; Strain, Patterson, & Seidenberg, 2002; Zorzi, Houghton, & Butterworth, 1998). The difficulty of this enterprise is reflected in the fact that establishing the best classification method still is a bone of contention.

Venezky (1970) was one of the first to study the letter-to-sound patterns in English. He grouped the written representation of sounds into 'graphemes' (a letter or combination of letters equivalent to one sound) and established two types of grapheme-to-phoneme correspondences; 'major' for those occurring with higher frequency and 'minor' for those occurring with lower frequency. As an illustrative example of Venezky's taxonomy, the pronunciation of *'ea'* as in *'seal'* was described as a major correspondence, while the pronunciations for *'ea'* in *'steak'* or *'bread'* were minor correspondences. Adhering to Venezky's (1970) classification, Coltheart (1978) proposed a ruled-based-mechanism for coding phonological information, known as the grapheme to phoneme correspondence (GPC) system. The application of the rules governing 'major correspondences' or the GPC system, allows the correct pronunciation of all the English *regular* words. However, a different but parallel lexical mechanism is required to allow for correct pronunciation of *irregular* words (those whose graphemes are converted to phonemic correspondences not embedded in the GPC system). Both the lexical mechanism and the GPC mechanism (also referred to as 'routes') will produce the correct pronunciation for all regular words and non-words. However, these two routes generate conflicting pronunciations for irregular words. The resolution of the conflict takes time and this slows down responses. A common finding supporting the existence of these two routes for reading is that regular words are processed faster and more accurately than irregular words (Baron & Strawson, 1976; Gough & Cosky, 1977; Parkin, 1982; Stanovich & Bauer, 1978; Waters & Seidenberg, 1985).

An alternative word reading account is based in the amount of features shared by the words in the vocabulary. Glushko (1979) showed that the pronunciation of a non-word could be achieved through a mechanism based on features shared with known words. According to Glushko, the most important characteristic when translating letters into sounds is the consistency of the pronunciation of words with similar spelling. For example, the word body *'ade'*, as in *'wade'*, is pronounced in the same way in all similarly spelled words (e.g., *'bade'* and *'fade'*), and is hence described as *consistent.* In contrast, *'save'* is pronounced differently to *'have'*, and is therefore an example of an *inconsistent* word. In Experiments 1 and 2, Glushko (1979) demonstrated that pseudowords created from words with irregular pronunciations

(such as '*heaf*' from the irregular word '*deaf*') were named slower than pseudowords based on words with regular spelling to sound correspondences (e.g. *'hean'*, from *'dean'*). Glushko (1979) argued that the longer production latency for *'heaf'* over *'hean'* was the result of the *'eaf'* ending stemming from a group of exception words (e.g., *'deaf' 'leaf'*). This data led to the suggestion that "words are not regular or exceptional in themselves, but only in the context of the other words that are activated in the course of reading them" (p.684). Glushko's (1979) Experiment 3 indicated that words with regular grapheme-phoneme correspondences but inconsistent word bodies were named slower than regular words with consistent word bodies. Glushko argued that consistent words are named faster because the activation of neighbouring nodes facilitates their processing. Results from a number of studies have highlighted the idea that some words with unusual spelling-to-sound correspondences are, perhaps, more unusual than others. Kay and Bishop (1987), for example, found that consistency effects were confined to low frequency words with few "friends" (words with the same word body pronounced the same as the target) and Jared, McRae and Seidenberg (1990) showed large inconsistency effects in word naming when the frequency of word-friends is low and/or when the frequency of enemies (words whose body is spelled the same but pronounced differently) is high. Cortese and Simpson (2000) and Jared (2002) also varied GPC regularity and word body consistency orthogonally in tests of word naming. Both studies indicated that consistency had an impact on production latency over and above any effects of regularity, as well as on the numbers of errors made by participants. These findings support the position that a hard and fast rule system might be insufficient for the conversion of words from print to sound. A rule system such as the grapheme-phoneme correspondences can only split words into two halves – those that follow the rules and those that violate them.

The problem of how the cognitive system deals with the translation of letters into sounds in English is complex and open to debate. Pronunciation of acronyms, however, might be less limited by the idiosyncrasies of the English language than mainstream words. Neither of the two classification systems reviewed can be employed satisfactorily with acronyms. This is because the majority of the acronyms would be classified as inconsistent (e.g., in EEG, for example, the word body *'-eg'* is common to LEG, BEG and KEG, but the pronunciation is very different) and

irregular (the application of GPC rules to acronym reading would produce either incorrect or impossible responses e.g. HIV and BBC, respectively). However, most acronyms would be pronounced correctly by applying a simple rule: naming its letters. Two features have been taken into account at the time of classifying the pronunciation of acronyms: pronunciation-typicality and ambiguity. Acronyms named spelling aloud each of their letters (e.g., DVD) have been classified as *typically pronounced acronyms* while acronyms named following the spelling to sound correspondences of the language (e.g., DOS) have been classified as *atypically pronounced acronyms*. When faced with acronyms formed entirely by consonants or vowels (e.g., CNN, AOA) the application of the spelling to sound correspondences used in mainstream words is not possible. Such an item could only be pronounced by naming each of its letters aloud in turn, and has hence been considered as *unambiguous*. Acronyms containing a mixture of consonant and vowels have the potential of a 'word-like' pronunciation (e.g., SARS, ROM). However, this pronunciation potential is not always fulfilled (e.g., HIV, ISP) and that is why these acronyms have been classified as *ambiguous*. The combination of these features, *pronunciation typicality* and *pronunciation ambiguity* provides three different types of acronym pronunciations: 1) Ambiguous and typical (e.g., HIV), 2) ambiguous and atypical (e.g., ROM), and 3) typical and unambiguous (DVD). The definition of unambiguous pronunciation prevents the existence of atypical and unambiguous acronyms.

While regularity and consistency effects are commonly found in the naming literature, lexical decision responses are not typically affected by regularity or consistency (Hino & Lupker, 1996; 2000; Seidenberg, Waters, Barnes & Tanenhaus, 1984; Waters & Seidenberg, 1985) unless the demands of the task particularly emphasise phonological processing. The lexical decision task requires words to be distinguished from non-words, and this process can be achieved via a process of lexical selection (Coltheart, 1978; Coltheart et al., 1993). Lexical selection processes do not require phonological information, and hence, all other things being equal, the lexical decision responses for regular and irregular words are achieved with equivalent speed and accuracy. Thus, it is expected that the print to pronunciation characteristics of acronyms will impact the

speed with which they are read aloud, but not how quickly they are recognised as meaningful.

3.2.8 Word's initial sound

A number of studies have shown that the acoustic characteristics of the word's first phoneme influence the accuracy of voice-key measurements. This is because voiceless consonants trigger voice-key devices later than voiced consonants and vowels (Kessler, Treiman, & Mullenix, 2002; Pechman, Reetz, & Zerbst, 1989). In the present study this factor was taken into account when analysing acronym naming times and therefore the sonority associated to the first phoneme of the acronyms (voiced or voiceless) is provided.

The presence or absence of effects in the naming and lexical decision task will reveal important information about the way in which acronyms are processed. As a general rule, the lexical representation of acronyms would lead to the prediction that acronym responses would be affected by the same variables as mainstream words. That is to say, large frequency, age of acquisition and imageability effects would be expected if acronyms are processed like mainstream words. Under this assumption there should be only a small impact of sub-lexical variables (e.g. length) on acronym processing. However, if the variation in the predictability of the pronunciation of acronyms is an analogue for regularity in word reading, then there may be interactions between print to pronunciation characteristics and the psycholinguistic variables. If, on the other hand, acronyms are irregular as has previously been assumed, then all acronyms should be equally affected.

3.3 Method for the collection of the norms

3.3.1 Participants

One hundred and twenty English native speakers, 34 males and 86 females, participated in the compilation of these norms. Each of the factors to be estimated;

rated frequency, imageability and age of acquisition, was rated by a set of 40 participants. Participants were volunteers from Swansea University with a mean age of 24 (range 18 to 37). They all had normal or corrected-to-normal vision. None participated in the estimation of more than one factor, and all received course credit for their participation.

3.3.2 Materials

A total of 269 acronyms were initially selected from the Oxford English Dictionary (Oxford University Press, 2009), and from the Acronyms Initialisms and Abbreviations Dictionary (Mossman, 1994). Acronyms were gathered if they were intuitively thought to be relatively familiar and an effort was made to select acronyms from a diversity of domains such as science, technology, business, industry, jargon, medicine, etc. The set of 269 acronyms originally chosen was randomised. The randomised list was subsequently split into two questionnaires of approximately equal lengths (131 and 138) for administration to participants. A randomised set of 20 acronyms were present in both lists to allow an assessment of reliability. This procedure increased the sizes of the lists to be rated to 141 and 148 acronyms each. Twenty acronyms were printed per page, in the same randomised order for the estimation of rated frequency or word familiartity, age of acquisition and imageability.

Care was taken to make sure that the selected acronym definitions (from Oxford English Dictionary and the Acronyms, Initialisms and Abbreviations Dictionary) corresponded to the more dominant meaning available to the participants tested in the present study. In order to accomplish this, a word association task was devised. Twenty participants (3 male, 17 female), none of whom had participated in any other acronym related task and with a mean age of 21 years old (SD = 1.997), were presented with each of the 269 acronyms using E-Prime (Schneider, Eschman, & Zuccolotto, 2002). They were instructed to say aloud the first thing that came to their mind in response to the acronym presented onscreen. A microphone placed approximately 10 cm away from the participant detected his/ her vocal response.

Then, the participant could type the word they had just said. Participant responses were then placed into five broad categories; semantic, orthographic, phonological, compound and erratic. Semantic responses included those referring to the full term for the acronym, as well as semantically related information (e.g., BBC – television). In order to establish the dominance of the acronym definition only the semantic associations were taken into account. The full term listed in appendix 3.1 is the sense of the acronym which elicited the majority of semantic association responses.

The present database comprises 146 out of the original 269 acronyms. One hundred and sixteen acronyms were excluded because they were reported to be unknown by more than 50% of the participants that completed the age of acquisition questionnaire. A further 7 acronyms were deleted because they were unknown to more than 50% of the participants that completed the association task.

Acronyms were not included if they consisted of fewer than three letters (BA), contained lower case letters (kJ), used numerical characters (4WD) or formed a mainstream word (AIDS).

3.3.3 Database variables

The list of 146 acronyms is presented in appendix 3.1 along with their definitions, the percentage of participants who give an associated response semantically related to the definition provided, and their values for voicing, print-to-pronunciation patterns, number of letters, number of syllables, number of phonemes, number of orthographic neighbours, imageability, rated frequency, printed frequencies, age of acquisition, bigram and trigram frequencies.

3.3.3.1 Procedure

3.3.3.1.1 Rated Frequency/ Word familiarity

The two randomised lists of acronyms (141 items and 148 items long respectively) were each presented to a group of 20 participants for frequency rating (10 male, 30 female, mean age 25 years, SD = 2.04). Each page consisted of 20 acronyms to be rated on how frequently they were used or encountered. Ratings were made using a seven-point Likert scale ranging from 1 (*Rarely/Never*) through to 7 (*More than twice daily*). Each page was headed with the same instructions detailing that responses were to be made by circling the appropriate number and that the full range of the scale could be used if it was felt appropriate. One page of acronyms was presented as part of both versions of the questionnaire. Inter-rater reliability was assessed by correlating the ratings given by the two groups of participants for these 20 acronyms (r = .91).

3.3.3.1.2 Printed Frequency

Printed frequency estimates were generated following the procedure used by Blair, Urland, and Ma (2002). The number of hits returned by the internet search engines: Google, Bing and AltaVista were computed as indexes of word frequency. All were advanced searches restricted to the English language. The value presented here is the log transformation of the number of hits returned for each acronym.

3.3.3.1.3.Imageability

Two groups of 20 participants (14 male, 26 female, mean age = 23, SD = 1.52) were presented with one of two lists of acronyms and asked to estimate the imageability of each acronym on a 7 point scale. One list comprised 141 acronyms, the other listed 148, and each was presented in a randomised order. The instructions and scale, adapted from Paivio, Yuille and Madigan (1968), required participants to indicate the ease at which each of the acronyms evoked a mental image. Numbers in the scale were labelled to inform participants of the different degrees of image-evoking difficulty. These ranged from 1 (*image aroused after long delay/not at all)* to 7 (*image aroused immediately*). Twenty acronyms were presented per page. Twenty acronyms were included for rating by both of the groups of participants, and these

ratings were correlated to assess inter-rater reliability. The correlation was high (r = 0.91).

3.3.3.1.4 Age of Acquisition

The 141 and 148 acronym lists were presented to two groups of 20 participants (8 male, 32 female, mean age = 25, SD = 1.86), who were asked to estimate when they first learned each of the acronyms in the lists by writing down the estimated age in a box located besides each acronym. This method has been used successfully in the past (Ghyselinck, De Moor, & Brysbaert, 2000; Izura, Hernandez-Muñoz, & Ellis, 2005). The method has greater flexibility to provide late age ranges and this was thought particularly useful to generate AoA values of a material that might be learned relatively late. One hundred acronyms were presented per page in five equal columns. The inter-rater reliability for the twenty acronyms rated as part of both lists was r = 0.85.

3.3.3.1.5 Number of orthographic neighbours

Number of orthographic neighbours was calculated counting the number of words that differ in one letter with the target acronym while preserving the identity and position of the rest of the letters in the acronym. The calculation was based on the words listed in the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Where a word generated in this way was listed in the database more than once (as a verb and a noun, for example) this was only counted as one neighbour.

3.3.3.1.6 Acronym length

The length of each acronym was considered in terms of number of letters, number of syllables and number of phonemes.

3.3.3.1.7 Bigram and Trigram frequency

Bigram and trigram frequency values were obtained from the MCWord, an Orthographic Wordform Database (Medler & Binder, 2005). The unrestricted bigram and frequency values were used here. This measure simply counts the number of times that any bigram or trigram appears in the Celex database (Baayen et al., 1995)

3.4 Results and discussion

The ratings collected were collapsed across lists for age of acquisition, frequency and imageability estimations. Descriptive statistics for each of the continuous variables considered in this study are shown in Table 3.1. The variable related to the voicing of the acronym's initial sound was dichotomized into voiced (n = 116) or voiceless (n = 30) and considered therefore as a categorical variable. Similarly, three additional categorical variables were created to account for the acronym print-to-pronunciation pattern. These were: Unambiguous pronunciation (n = 85), ambiguous but typically pronounced acronyms (n = 48) and, ambiguous and atypically pronounced acronym (n = 13).

Acronyms and all the normative values are presented alphabetically in appendix 3.1. The correlation matrix for all variables considered in this study (continuous and categorical) is shown in Table 3.2. Pearson correlation coefficients were calculated for the continuous variables while point-biserial correlation coefficients were applied to the categorical variables. To ensure that the significance of the correlations reported was meaningful and valid, data was appropriately transformed to deal with skewed distributions. Thus, a logarithm transformation was applied to the printed frequency values obtained from the Google, Bing and AltaVista search engines, and also to rated frequency, number of syllables, number of phonemes, number of letters and imageability. One unit was added before the logarithm transformation was applied to number of orthographic neighbours, bigram frequency and trigram frequency. Age-of-acquisition ratings were normally distributed.

Some of the correlations in Table 3.2 are of particular interest. First, unambiguous acronyms (e.g., BBC) significantly correlated with number of syllables and phonemes indicating their tendency to need more syllables and phonemes to be pronounced. They also showed negative correlations with number of orthographic neighbours, bigram and trigram frequencies. Naturally, the unusual letter arrangement of unambiguous acronyms generates very few neighbours and low bigram and trigram

SWANSEA LIBRARY UNIVERSITY

frequencies. In contrast, ambiguous and typical acronyms (e.g., HIV) showed significant positive correlations with number of letters, bigram frequency and trigram

Table 3.1 – Descriptive statistics for each continuous variable

	Mean	SD	Minimum	Maximum
Age of acquisition	14.82	3.40	6.10	23.14
Imageability	5.09	1.06	1.85	6.90
Number of letters	3.32	0.57	3	6
Number of phonemes	5.84	1.52	3	14
Number of Syllables	3.14	0.56	2	5
Number of orthographic neighbors	2.25	3.43	0	23
Rated Frequency	2.79	0.86	1.4	5.85
Google printed frequency	7.26	0.81	5.18	9.11
Bing printed frequency	6.48	0.76	5.09	8.84
AltaVista printed frequency	7.74	0.71	6.12	9.67
Bigram frequency	3.33	0.93	0	4.57
Trigram frequency	0.91	1.06	0	4.17

Note: Google printed frequency, Bing printed frequency, AltaVista printed frequency, Bigram and Trigram frequency have been logarithm transformed.

frequency and a significant negative correlation with number of phonemes. Thus, these acronyms are likely to be formed by more letters with higher bigram and trigram frequencies. They also tend to be pronounced with fewer phonemes. This is possibly

the result of the presence of vowels in these acronyms. The vowel increases letter length but decreases phoneme length because fewer phonemes are needed when naming vowels than consonants. In addition, the presence of vowels increases the likelihood of finding high frequency bigrams and trigrams in acronyms. Interestingly, number of letters shows a negative correlation with number of syllables and number of phonemes. Thus, shorter acronyms require more syllables and phonemes when pronounced (e.g., naming each letter aloud). It is also worth noting that the three acronym printed-frequencies (from Google, Bing and AltaVista) correlate significantly with rated frequency and are also highly intercorrelated, indicating a high level of reliability. However, they do not show the same pattern of correlations with number of syllables, number of orthographic neighbors and imageability. All three printed frequencies correlate positively with number of letters and negatively with number of phonemes, meaning that high frequency acronyms tend to have more letters but fewer phonemes. In addition, and in contrast to what is normally found with mainstream words, none of the printed frequencies showed a significant correlation with age of acquisition. This means that the order in which acronyms are learned is not related to how frequently they are used in print. This lack of correlation is unusual in studies using common words (see Zevin & Seidenberg 2002; 2004). Age of acquisition ratings, however, showed significant and negative correlations with imageability and rated frequency, meaning that the later acquired the acronym the lower its imageability and perceived frequency. These inverse relations of age of acquisition with imageability and rated frequency have been typically found in studies using mainstream words (Morrison et al., 1997; Stadthagen-Gonzalez & Davis, 2006). It is also interesting to note that number of orthographic neighbours correlates positively with number of letters but negatively with number of phonemes. That is, the more letters and fewer phonemes in the acronym the greater the number of neighbours. This correlation departs from the correlations reported with mainstream words (see Adelman & Brown, 2007; Balota et al., 2004) and indicates that acronyms pronounced following grapheme to phoneme correspondences (e.g., those that have few phonemes) tend to have higher number of orthographic neighbours. 3.5 Method for the word naming experiment.

3.5.1 Participants

Twenty students from Swansea University with a mean age of 20 years (range 18 to 24 years old) participated in this experiment. None of them had collaborated in the collection of acronym associative responses, age of acquisition, imageability or frequency ratings and they had not been involved in the completion of the acronym association task. The 15 female and 5 male participants were all native speakers of English, non-dyslexic, and with normal or corrected-to-normal vision. Course credit was offered as a reward for participation.

3.5.2 Procedure

Participants named the 146 acronyms with complete database entries for frequency, age of acquisition, imageability, number of orthographic neighbors, orthographic and phonological acronym length. Acronyms were presented one at a time in black capital letters on a white screen (19-inch monitor) in size 12, Times New Roman font. Each trial started with a fixation cross which appeared in the middle of the screen for 1500ms. Then, an acronym appeared in the middle of the screen and remained there until the participant made a response. Participant responses were detected by a highly sensitive microphone (approximately 10cm away from the participant's mouth) attached to the computer. Activation of the microphone triggered the presentation of the next fixation cross. Trials were randomised for each participant. This was controlled by E-Prime (Schneider et al., 2002) using a Dell computer with an Intel Pentium 4 1.5 GHz processor. The experimenter noted all equipment errors. In addition, the experimental sessions were audio recorded for further inspection of accuracy in the data. Following the completion of the naming task, participants were given a list with all the acronyms they had been asked to read, and were required to indicate next to each acronym whether they knew it or not.

Table 3.2 – Correlation Matrix for fourteen variables and 146 acronyms.

Variable	2	3	4	5	6	7	8	9	10	11	12	13	14	
1. Unambiguous	-0.83**	-0.37**	n.s.	0.29**	0.60**	-0.21*	n.s.	n.s.	n.s	n.s.	n.s	n.s.	-0.47**	-
2. Ambiguous Typical	-	-0.22*	0.18*	n.s.	-0.38**	0.35**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.33**	(
3. Ambiguous Atypical		-	-0.50**	-0.54**	-0.42**	-0.21*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.27**	(
4. Number of Letters			-	-0.24**	-0.24**	0.44**	n.s.	n.s.	0.34**	0.38**	0.34**	n.s.	-0.30**	-(
5. Number of Syllables				-	0.57**	n.s.	n.s.	n.s.	-0.23*	-0.26**	n.s.	n.s.	n.s.	n
6. Number of Phonemes					-	-0.28*	n.s.	n.s.	-0.23**	-0.23*	-0.23**	n.s.	-0.42**	-(
7. Number of orthographic neighbours						-	n.s.	n.s.	n.s.	0.18*	n.s.	n.s.	0.18*	n.
8. Imageability							-	0.63**	n.s.	0.17*	n.s.	-0.57**	n.s.	n.
9. Rated Frequency								-	0.36**	0.30**	0.32**	-0.18*	n.s.	n.

10. Printed Frequency (Google)	-	0.89**	0.92**	n.s.	n.s.	n.s
11. Printed Frequency (Bing)		-	0.86**	n.s.	n.s.	n.s
12. Printed Frequency (AltaVista)			-	n.s.	n.s.	n.s
13. Age of acquisition				-	n.s.	n.s
14. Bigram Frequency					-	0.(
15. Trigram Frequency						-

Note. Unambiguous, Ambiguous Typical and Ambiguous Atypical were categorical variables. A logarithm transformation was applied to Number of Letters Number of Syllables, Number of Phonemes, Rated Frequency, all the Printed Fequency measures (Google, Bing and AltaVista) and Imageability. Number of Orthographic Neighbours, Bigram Frequency and Trigram Frequency were the logarithm transformation of the original value plus one.

* $p < .05$. ** $p < .01$.

3.6 Results

Although the major purpose of this study was not to investigate the influence of acronym knowledge on acronym naming, it was thought interesting to examine participants accuracy when naming known and unknown acronyms. Once the acronym naming task was finished, participants noted the acronyms they knew and those they did not know. These were used to classify correct and incorrect responses in a two (known, unknown) by three (unambiguous, ambiguous typical and ambiguous atypical) contingency table. Table 3.3 shows the mean rank of correct and incorrect responses in each of the categories created.

Table 3.3 – Percentage of correct and incorrect naming responses to known and unknown acronyms.

	Known		Unknown	
Acronym Pronunciation	Correct	Incorrect	Correct	Incorrect
Unambiguous	81.4	0.5	18.1	0
Ambiguous Typical	78.2	1.6	19.8	0.4
Ambiguous Atypical	84.2	9.2	2.7	3.8

Four Friedman's ANOVAs were carried out as a result of an orthogonal manipulation of response accuracy (correct, incorrect) and acronym knowledge (known, unknown). Potential differences between the three types acronyms (unambiguous, ambiguous typical and ambiguous atypical) were examined in each of these four Friedman tests. Correct responses to unambiguous, ambiguous typical and ambiguous atypical acronyms were not significantly different when the acronyms were known to the participants, χ^2 (2) = 0.86, $p > .1$, nor when the acronyms were unknown, χ^2 (2) = 0.86, $p > .1$. However, significant differences amongst the three types of acronyms were detected for incorrect responses to known acronyms, χ^2 (2) = 12.88, $p < .001$. This difference was further inspected using Wilcoxon tests. Bonferroni correction was applied and therefore effects are reported at $\alpha/3$ (i.e., 0.0167) level of significance. A significant difference was found between the errors produced when naming

ambiguous typical and ambiguous atypical acronyms, $T = 0$, $p < .01$, $r = -.36$. The difference between erroneous responses to unambiguous and ambiguous atypical acronyms known to the participant approached significance, $T = 6$, $p = .025$, $r = -.23$. No significant differences were found between incorrect responses to unambiguous and ambiguous typical acronyms known to the participants. Finally, a main effect of acronym's type was found for incorrect responses to unknown acronyms, χ^2 (2) = 11.47, $p < .01$. Further inspection of this effect using Wilcoxon tests (Bonferroni correction applied at $\alpha/3$ level of significance) showed a significant difference between ambiguous typical and ambiguous atypical acronyms, $T = 0$, $p \leq .016$, $r = -.29$, and between unambiguous and ambiguous atypical acronyms, $T = 0$, $p \leq .016$, $r = -.23$.

3.6.1 Reaction Times analyses

Participant errors (2.12%) and voice key malfunctions (3.94%) were removed from the analyses of reaction times and response times that were more than 2.5 standard deviations above or below the mean (1.13%) were removed from the analyses of reaction times. Correlations between harmonic means of response times, percentage accuracy and each of the numerical variables considered in this study are presented in Table 3.4.

Acronym naming times show a negative correlation with number of orthographic neighbours, imageability and also with all the frequency measures considered here (rated and printed) indicating that highly imageable and high frequency acronyms with high number of orthographic neighbours were named faster than low imageability and low frequency acronyms with low number of orthographic neighbours. Reaction time correlations with N, imageability and frequency are also characteristically found in word naming studies (Barca, Burani, & Arduino, 2002; Morrison & Ellis, 2000). Similarly, and in line with other word naming studies (Balota et al., 2004), number of letters shows a correlation with acronym naming times and accuracy, meaning that long acronyms were named slower and with more errors. In contrast to what is found in other word naming studies (Balota et al., 2004; Morrsion & Ellis, 2000) the number of syllables and the number of phonemes, showed negative correlations with accuracy indicating that phonologically long acronyms produced fewer errors.

Table 3.4 – Correlations between predictor variables, reaction times and accuracy.

	Reaction Times	Errors (%)
Number of Letters	.387**	.257**
Number of Syllables	n.s.	-.336**
Number of Phonemes	n.s.	-.305**
Number of orthographic neighbours	-.230**	n.s.
Imageability	-.249**	n.s.
Rated Frequency	-.255**	n.s.
Printed Frequency (Google)	-.281**	n.s.
Printed Frequency (Bing)	-.308**	n.s.
Printed Frequency (AltaVista)	-.289**	n.s.
Age of acquisition	.249**	n.s.
Bigram Frequency	n.s.	n.s.
Trigram Frequency	n.s.	n.s

Note: n.s. indicates that the correlations was not significant

**p<.001.

Having looked at the relationships between the dependent (naming times and accuracy) and independent variables (acronym print-to-pronunciation pattern, number of letters, number of syllables, number of phonemes, number of orthographic neighbours, imageability, rated frequency, printed frequencies, age of acquisition, bigram frequency, and trigram frequency) the predictive power of each independent factor was examined. The particular technique used here to analyse the data is known as the multilevel or hierarchical model (Miles & Shevlin, 2001). Multilevel models are linear regressions in which variation of groups can be modelled at different levels (Gelman & Hill, 2007). For the purpose of this study the data was structured hierarchically with a three-level hierarchy: one corresponding to the participants, and the other two to the predictor variables. One of the advantages of this model over classical regression is that it allows an examination of the predictive power of independent variables while accounting for systematic unexplained variation amongst the group of participants. Another advantage is that a higher number of predictors can be entered into the

multilevel regression analysis without the risk of producing unreliable estimates. For the purpose of all analyses reported here, acronym naming times were log transformed to reduce skew.

The three measures of acronym printed frequency were examined first in order to select the measure with greatest predictive power for the final analyses. Thus, the logarithm transformation of the printed frequencies as derived from Google, AltaVista and Bing search engines were compared. The three measures provided a significant change in the proportion of variance (R^2) explained when included in the last step of the multilevel model. The log transformation of the printed frequencies derived from the AltaVista search engine accounted for the greater proportion of variance (see Table 3.5) and therefore this was the measure selected for subsequent analyses.

Table 3.5 – Acronym printed frequencies comparisons

	Log AltaVista Frequency	Log Google Frequency	Log Bing Frequency
B	.030	.019	.027
SE B	.012	.009	.012
β	.059*	.048*	.063*
R^2	.244	.243	.243
ΔR^2	.004	.002	.003

Note † $p < .05$

Acronym's print-to-pronunciation pattern, number of letters, number of phonemes, number of orthographic neighbours, imageability, rated frequency and age of acquisition were entered as predictors in all the analyses. Although intercorrelations between rated and printed frequencies were significant, they were not high enough to cause multicolinearity concerns and therefore rated and printed frequencies were present in all analyses. Four potential interactions were also assessed. These were acronym's print-to-pronunciation characteristics

with word frequency (printed and rated), with age of acquisition and also with imageability. An interaction term was created by centering the continuous variables (printed and rated frequency, AoA and imageability), and multiplying the result by each of the dummy variables representing acronym print-to-pronunciation characteristics.

In order to introduce the three types of acronym print-to-pronunciation patterns (unambiguous, ambiguous typical, ambiguous atypical) into the analyses, two of the dummy variables, ambiguous typical and ambiguous atypical, were included in the analyses while unambiguous acronyms worked as the reference category. Both dummy variables were entered in step 2 of each analysis so the results could be meaningfully compared to the reference category.

Four regression analyses were performed on naming RTs. The phonological length of the word was entered into the analysis either in terms of number of syllables or number of phonemes, but not both at the same time. Similarly, the predictive power of either bigram or trigram frequency was assessed, but both measures of letter frequency were not entered into the same analysis. Analysis 1 contained syllable length and bigram frequency, analysis 2 assessed syllable length and trigram frequency, analysis 3 describes the model including phoneme length and bigram frequency, and phoneme length and trigram frequency were entered into the fourth analysis. Regression coefficients are presented below in Table 3.6.

The analysis explaining the greatest percentage of the variance associated to acronym naming times included bigram frequency and the number of syllables as predictor variables. Consistent main effects were found across the analyses for voicing, number of letters, printed and letter frequency, Age of Acquisition, and letter frequency (bigram or trigram). The main effect of number of orthographic neighbours was signifincant only when the bigram frequency was in the analyses (Analyses 3 and 4). The number of phonemes emerged as significant predictor in the analysis with trigram frequency and approached significance in the analysis with bigram frequency. Imageability did not emerge as significant predictor in any of the analysis. In terms of interactions, the printed frequency showed significant interaction in all the analyses with both types of ambiguous acronyms (typical and atypical). Age of Acquisition and Imageability also showed an interaction in all the analyses with

ambiguous typical acronyms. Finally, the interaction between rated frequency and ambiguous typical acronyms approached significance in all but one analysis. In order to inspect the nature of these interactions a bit further, a regression line was fitted for each type of acronym in terms of their reaction times and printed frequency (see Figure 3.1), Age of Acquisition (see Figure 3.2) and Imageability (see Figure 3.3). Thus, in relation to acronym's frequency, high frequency typical acronyms (ambiguous or unambiguous) were named faster than low frequency typical acronyms. However, high frequency atypical acronyms were named slower than low frequency atypical acronyms. The same interaction pattern was revealed when rated instead of printed frequency was used.

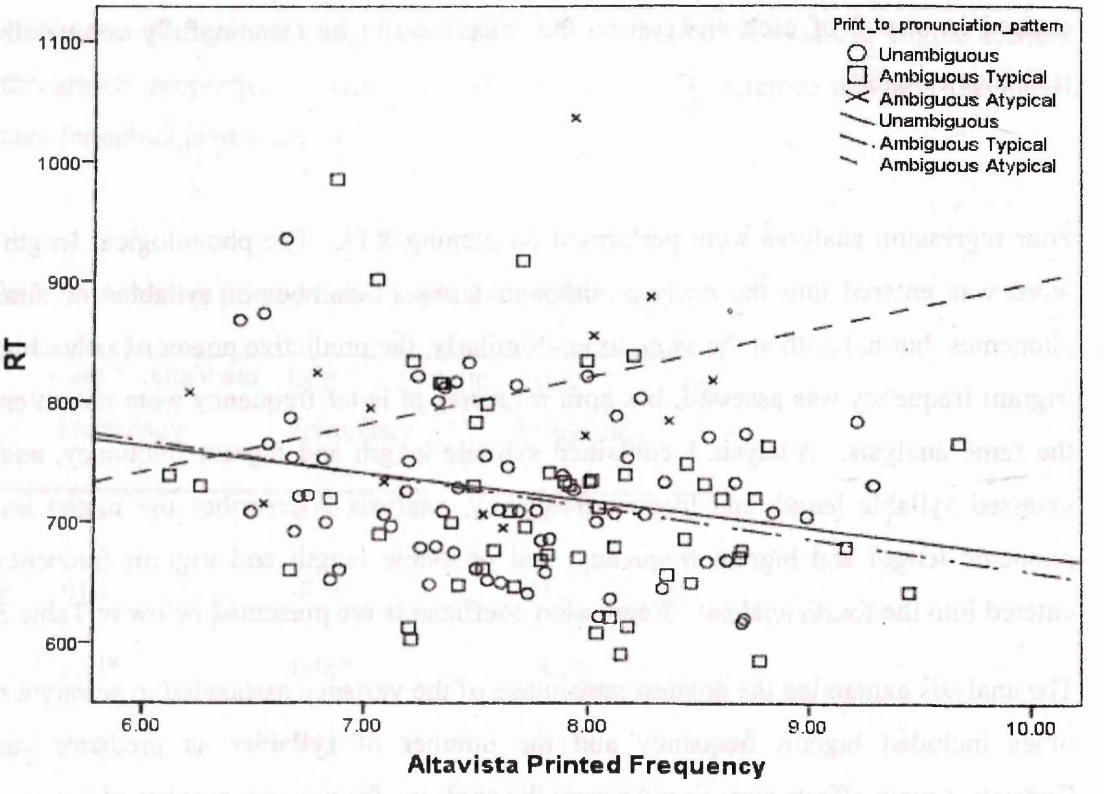


Figure 3.1 – Regression lines between Reaction Times and Printed Frequencies for the different types of acronyms.

Table 3.6 – Standardized regression coefficients (β) for the four multilevel analyses carried out on acronym naming times.

	Analysis 1	Analysis 2	Analysis 3	Analysis 4
Step 2				
Ambiguous Typical			-0.023	
Ambiguous Atypical			0.096**	
Step 3				
Voicing	0.110*	0.113*	0.102*	0.100*
Number of Letters	1.091*	1.148*	1.431*	1.423*
Number of Letters^2	-0.909*	-0.986*	-1.219*	-1.192*
Number of orthographic neighbours	0.016	0.027	0.057*	0.053†
Imageability	-0.234	-0.217	-0.259	-0.272
Imageability^2	0.052	0.037	0.092	0.105
Rated Frequency	0.077†	0.075†	0.078†	0.079†
Printed Frequency	-0.097*	-0.093*	-0.090*	-0.093*
Age of Acquisition (AoA)	-0.076†	-0.066†	-0.056†	-0.061†
Trigram Frequency	-0.070*	-0.065*		
Bigram Frequency			-0.108*	-0.117*
Number of Syllables	0.018			0.011
Number of Phonemes		0.085†	0.056	
AoA by Ambiguous Typical	0.101*	0.097*	0.098*	0.100*
AoA by Ambiguous Atypical	0.025	0.020	0.020	0.023
Rated Frequency by Ambiguous Typical	-0.049	-0.054	-0.058	-0.055
Rated Frequency by Ambiguous Atypical	0.036	0.034	0.041	0.042
Printed Frequency by Ambiguous Typical	0.057†	0.065*	0.074*	0.070*
Printed Frequency by Ambiguous Atypical	0.060†	0.058†	0.054†	0.056†
Imageability by Ambiguous Typical	0.119*	0.126*	0.124*	0.120*
Imageability by Ambiguous Atypical	-0.021	-0.014	-0.028	-0.032
R^2	.243	.244	.247	.248

Note: * $p < .01$, † $p < .05$,

Another interaction observed in all analyses was between age of acquisition and ambiguous typical acronyms. Again, a regression line for each acronym type was plotted against their naming times and age of acquisition values (Figure 3.2). Early acquired typical acronyms (ambiguous and unambiguous) were named faster than late acquired typical acronyms. However, the slope for atypical acronyms shows an inverse relation between reaction times and AoA with slower RTs for early acquired acronyms.

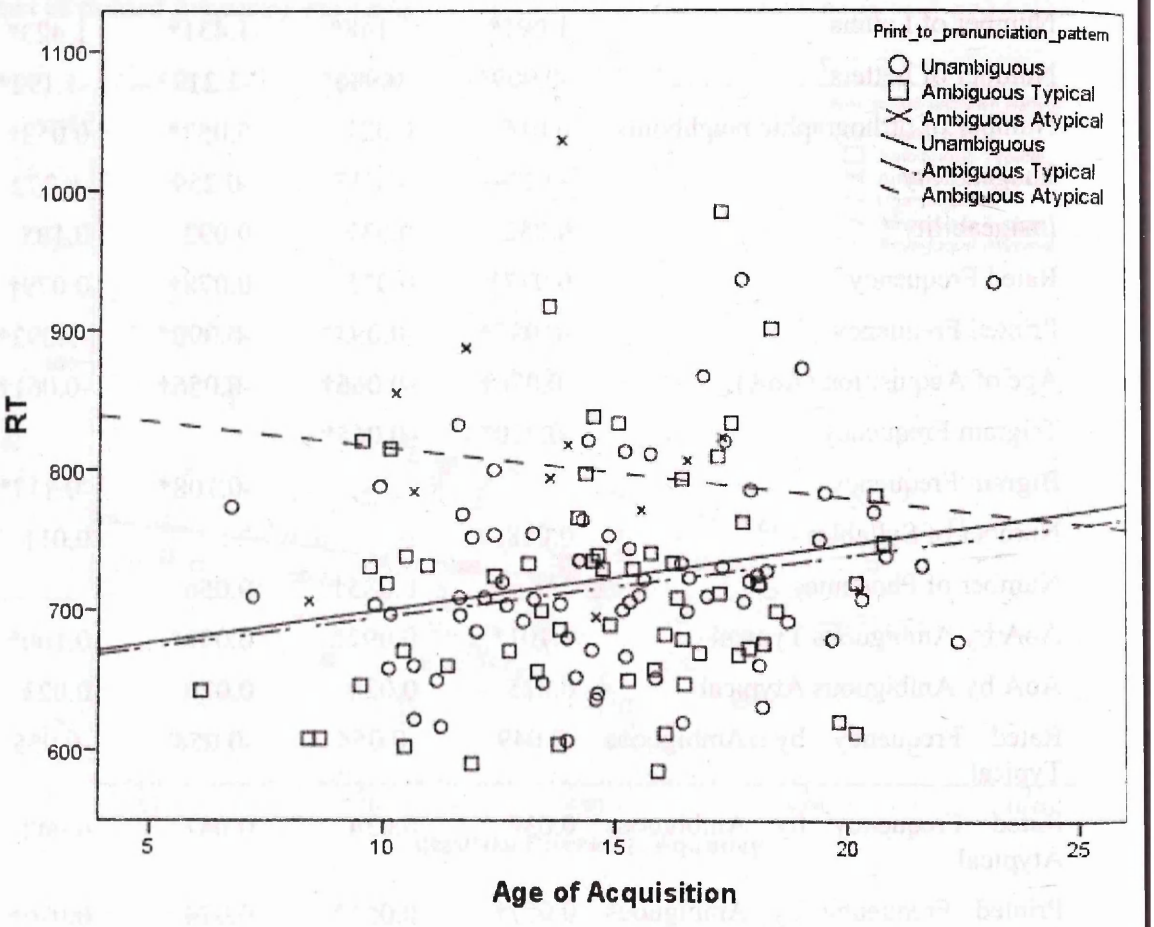


Figure 3.2 – Regression lines between Reaction Times and Age of Acquisition for the different types of acronyms.

Finally, the interaction between imageability and ambiguous but typically pronounced acronyms is depicted in Figure 3.3. High imageability acronyms were named faster than low

imageability acronyms. The imageability effect was stronger for typically pronounced acronyms (ambiguous or unambiguous) than atypically pronounced acronyms.

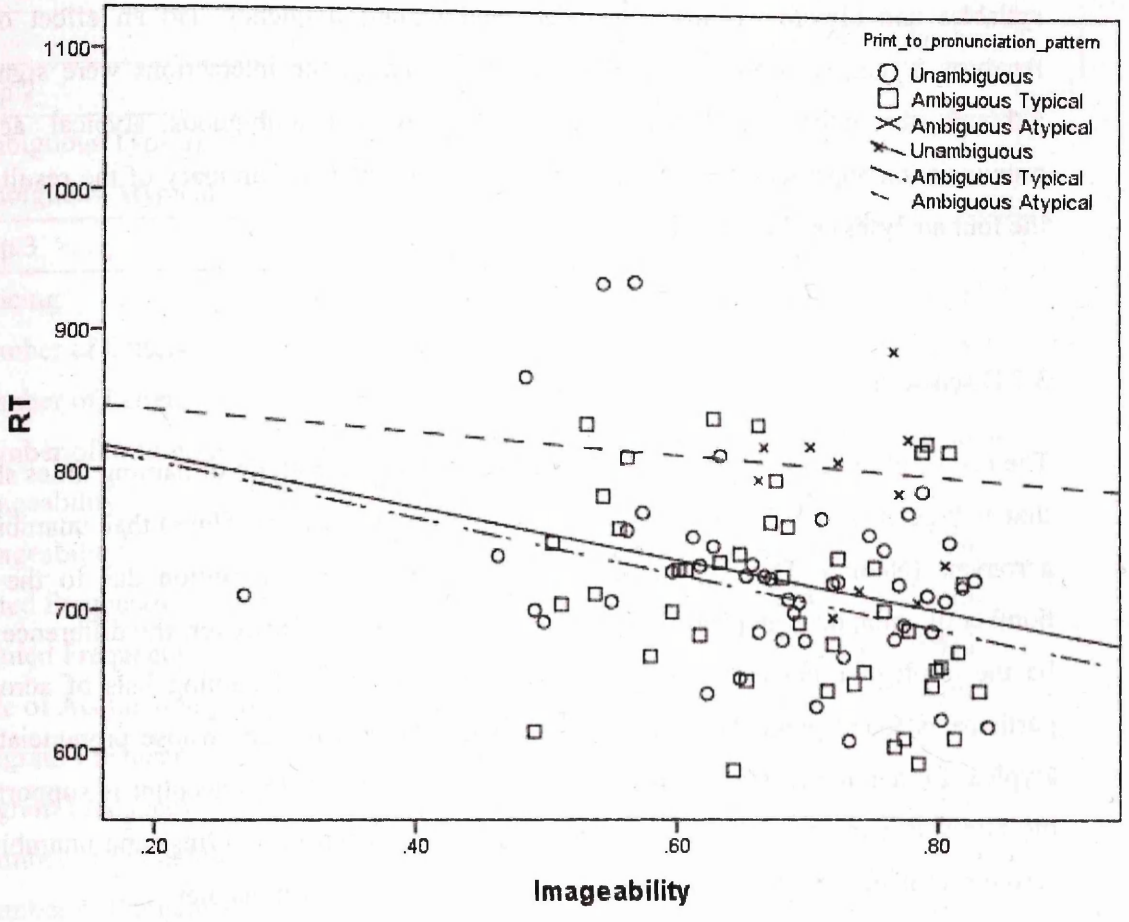


Figure 3.3 – Regression lines between Reaction Times and Imageability for the different types of acronyms.

3.6.2 Errors analyses

Four logistic multilevel hierarchical analyses were conducted with accuracy as the dependent variable. The multilevel technique allowed the accuracy of each participant for each acronym to be taken into account and therefore accuracy was registered as a dummy variable (correct responses coded as 0, incorrect responses as 1). As in the analyses of reaction times data was structured hierarchically with a three-level hierarchy: one corresponding to the participants,

and the other two to the predictor variables. Main effects of voicing and number of orthographic neighbours were found to be significant across the four analyses. The main effects of imageability and rated frequency approached significance across all the analyses. The main effect of printed acronym frequency was found in Analysis 4 (i.e. with number of syllables and bigram frequency included) and bigram frequency had an effect only in Analysis 3 (i.e., with number of phonemes in). None of the interactions were significant although the interaction between rated frequency and ambiguous atypical acronym pronunciation approached significance in Analyses 1 and 3. A summary of the results from the four analyses can be seen in Table 3.7.

3.7 Discussion

The results of the second step of the hierarchical multilevel analysis of naming times showed that ambiguous atypical acronyms were read significantly slower (760ms) than unambiguous acronyms (689ms). This difference should be interpreted with caution due to the small number of ambiguous atypical acronyms present in the study. However, the difference could be the result of a contextual effect. That is, in the context of naming lists of acronyms, participants found particularly difficult to produce those acronyms whose pronunciation is atypical for acronyms, albeit common for mainstream words. This account is supported by the fact that naming times did not differ for ambiguous typical (679ms) and unambiguous acronyms (689ms) by definition pronounced in a typical acronym manner.

The contribution of the selected set of predictor variables and interactions on acronym naming times were examined in the third step of the analyses. Acronyms' initial sound, number of letters, printed and rated word frequency, age of acquisition and letter frequencies (bigram and trigram) successfully predicted naming times in all the analyses carried out. Number of orthographic neighbours emerged as a significant predictor only when bigram frequency was in the analyses. Imageability interacted with typically pronounced acronyms indicating that its influence was stronger in this type of acronyms than in atypically pronounced acronyms.

As predicted, number of letters affected acronym naming times reflecting the general serial nature of acronym naming. From the phonological measures of word length only number of

Table 3.7 – Wald statistic the four multilevel analyses carried out on acronym accuracy.

	Analysis 1	Analysis 2	Analysis 3	Analysis 4
Step 2				
Ambiguous Typical			0.001	
Ambiguous Atypical			57.57*	
Step 3				
Voicing	10.60*	10.79*	8.570*	8.655*
Number of Letters	0.037	0.003	0.269	0.378
Number of Letters^2	0.032	0.001	0.149	0.307
Number of orthographic neighbors	8.661*	6.334*	9.325*	11.695*
Imageability	3.434	3.305	3.515	3.669
Imageability^2	3.680	3.631	3.806	3.856†
Rated Frequency	2.722	2.850	3.194	2.919
Printed Frequency	0.480	0.454	0.390	0.424†
Age of Acquisition (AoA)	0.309	0.525	0.452	0.200
Trigram Frequency	1.304	1.765		
Bigram Frequency			3.881†	3.183
Number of Syllables	0.327			0.577
Number of Phonemes		0.852	1.294	
AoA by Ambiguous Typical	0.708	0.675	0.776	0.797
AoA by Ambiguous Atypical	0.138	0.057	0.074	0.188
Rated Frequency by Ambiguous Typical	1.743	1.670	1.821	1.890
Rated Frequency by Ambiguous Atypical	0.013	0.064	0.095	0.016
Printed Frequency by Ambiguous Typical	0.006	0.052	0.003	0.037
Printed Frequency by Ambiguous Atypical	0.283	0.292	0.177	0.185
Imageability by Ambiguous Typical	2.197	2.336	2.301	2.195
Imageability by Ambiguous Atypical	0.044	0.001	0.002	0.065

Note. Note * $p < .01$, † $p \leq .05$

phonemes had an influence on reaction times. Bigram frequency affected reaction times andaccuracy while trigram frequency made a significant contribution to naming times only. Studies of standard word naming have struggled to find bigram frequency effects once other variables such as N, onsets and rimes are controlled for (Andrews, 1992; Bowey, 1990; Strain & Herdman, 1999). The fact that a particular variable does not show an effect on a particular behaviour (e.g., reaction time or accuracy) does not mean that the processes associated to that behaviour are free from its influence. Although bigram frequency effects are not commonly found in measures of word naming performance, its influence has been detected when measuring brain activity (Binder et al., 2006; Hauk et al., 2006a). The number of orthographic neighbours (N) exerted an influence in acronym naming times (analyses with bigram frequency) and accuracy. This result can only support Andrews' (1989) proposal of an early origin for the N-effect as a product of the interaction between letter and lexical units. This is because the translation from letters to sounds in acronyms does not correspond in the great majority of the cases, to that of the neighbouring words in relation to single phonemes or rhyme units (e.g. EEG and LEG, PEG, BEG, EGG). The clear influence of orthography (i.e. number of letters, N, bigram and trigram frequency) in acronym naming might indicate that the most compelling difference between acronyms and standard words lies in their orthographic assembly, highly arbitrary in acronyms and somehow more predictable or frequent in mainstream words.

In this study, printed and rated word frequency showed significant main effects in acronym naming times along with significant interactions with ambiguous typical acronyms and with ambiguous atypical acronyms, indicating different frequency effects for the three types of acronyms. The regression lines plotted in Figure 3.1 showed that high frequency unambiguous acronyms and high frequency ambiguous typical acronyms were named faster than their low frequency counterparts. However, high frequency ambiguous and atypical acronyms were named slower than low frequency ambiguous and atypical acronyms. This reversed frequency effect is interpreted as a result of the reading context. In the context of naming acronyms (pronouncing most of them by naming each letter aloud) reading aloud acronyms following grapheme to phoneme correspondences is slowed down because this pronunciation mechanism conflicts with a 'letter-by-letter naming' mechanism more frequently used in this particular task context. The higher the frequency of the acronym pronounced following grapheme-to-phoneme correspondences the greatest the conflict and

the time needed to resolve it. The same kind of argument can be applied to the significant interaction found between age of acquisition and ambiguous typical acronyms. Figure 3.2 shows the usual difference between naming early and late acquired typical-acronyms with faster naming for early learned acronyms than later learned acronyms. However, early learned ambiguous-atypical-acronyms are named much slower than late acquired ambiguous-atypical-acronyms. As with printed frequency the 'reversed' age of acquisition effect might be due to a conflict between pronunciation mechanisms. This conflict is not normally encountered since naming acronyms is infrequent in comparison with naming mainstream words[3]. The arbitrary mapping hypothesis (Ellis & Lambon Ralph, 2000) argues that AoA effects emerge only when the knowledge of the material learned first cannot be applied to material learned some time later. Word reading is a good example of this differential effect. AoA effects are particularly large when participants read aloud irregular words but tiny or null effects have been reported when naming regular words. The difference here is that while the pronunciation of late acquired regular words (e.g., *groin*) can be inferred from the pronunciation of other early acquired words (e.g., *coin*) the pronunciation of irregular late acquired words (e.g., *suave*) cannot be derived from the pronunciation of any other word learned earlier (regular or irregular). Most acronyms adhere to typical acronym naming rules (letter naming). According to the arbitrary mapping hypothesis, AoA should not affect acronym reading because late acquired acronyms should be able to exploit the rule learned earlier to facilitate processing of late acronyms, just as it happens when reading regular words. However, it could be the case that the main effect of age of acquisition observed here was due to the semantic intervention in acronym reading. The interaction found between imageability and acronym print-to-pronunciation supports this argument showing a greater effect of imageability on those typically pronounced acronyms. In addition, the acquisition of meaning and form occurs simultaneously for acronyms while the concepts of many irregular and late acquired words are known and familiar to the individual well before they find it in print for the first time.

In a naming task containing a large number of items which require a letter by letter pronunciation, ambiguous atypical acronyms (NATO) pose a particular problem. Their

[3] Similar analyses as those reported were carried out excluding ambiguous and atypical acronyms. Results were very similar to those reported indicating that the impact of this group of items was not large overall.

pronunciation is unlike the majority of the other targets which may account for the tendency for longer latencies in ambiguous atypical acronym trials, and the reversed frequency effects revealed in the regression analyses. In a lexical decision task, however, the processes underpinning the recognition of all acronyms are presumably similar irrespective of their print to pronunciation pattern. Furthermore by emphasising lexical access the importance of sublexical variables such as length might be attenuated. The collection of lexical decision latencies and accuracy data may clarify the role of AoA or frequency in acronym processing.

3.8 Method for the lexical decision experiment

3.8.1 Participants

Twenty students from Swansea University (5 male, 15 female) participated in this experiment. Participants ranged in age from 18 to 24 years (mean 20 years), and all were native English speakers. None of them had previously completed the acronym association task, nor had they contributed to the imageability, age of acquisition or frequency ratings. Participants had no impairments in reading or vision. Course credit was offered as a reward for participation.

3.8.2 Materials

All 146 acronyms were used as targets in the lexical decision task. One hundred and forty six non-words were also created. Non-words were generated by changing one letter of an acronym or a mainstream word. Non-words were between 3 and 5 letters in length (mean = 3.15). The same proportion of non-words and acronyms were pronounceable as a word-like unit. Specifically, 85 non-words contained only consonants (as there were 85 unambiguous acronyms), and the remaining 61 non-words comprised vowels and consonants in a plausible combination in English.

3.8.2 Procedure

Stimuli were presented one at a time in black capital letters on a white screen (19-inch monitor) in size 12, Times New Roman font. Trials were separated by a fixation cross which

appeared in the middle of the screen for 1500ms. An item appeared in the middle of the screen and remained there until the participant made a response. Participant responses were indicated via 5 button serial response box. Participants were asked to press the rightmost button with the right index finger if the item on the screen was an acronym and the leftmost button using the left index finger if the item was a non-word or a non acronym. Trials were randomised for each participant. This was controlled by E-Prime (Schneider et al., 2002) using a Dell computer with an Intel Pentium 4 1.5 GHz processor. The computer programme automatically logged reaction times and response accuracy.

3.9 Results

3.9.1 Reaction Times analyses

Three participants gave correct lexical decision responses to fewer than 75% of the acronyms included in the task, and were, therefore, excluded from further analyses. Errors (15.5%) and responses detected more than 2.5 standard deviations above or below the mean (2.4%) were removed from the analyses of the reaction times of the remaining 17 participants. Correlations between harmonic means of response times, percentage accuracy and each of the numerical variables considered in this study are presented in Table 3.8.

The negative correlation between imageability and reaction times indicates that highly imageable acronyms are recognised with greater speed. Similarly, highly imageable acronyms are recognised more accurately than acronyms which were low imageability. This imageability effect in lexical decision has been commonly reported in mainstream word recognition studies (e.g. Balota et al. 2004). Another characteristic of words shown to correlate with lexical decision latency and accuracy is frequency, such that responses to frequently occuring words were given quickly and accurately (Connine et al, 1990; Fredriksen & Kroll, 1976; Gerhand & Barry, 1999a; Hino & Lupker, 2000; Hudson & Bergman, 1985; Perea & Rosa, 2002; Richardson, 1976; Rubenstein et al, 1970; Turner et al, 1998). This finding is mirrored in the recognition of acronyms. Accuracy correlated positiviely with rated and printed frequency measures meaning that high frequency acronyms were recognised with greater accuracy than low frequency acronyms. In addition, significant negative correlations with frequency were also observed in the reaction time data, indicating that participants took longer to recognise low frequency than high frequency acronyms.

Table 3.8 – Correlations between predictor variables, reaction times and accuracy.

	Reaction Times	Accuracy (%)
Number of Letters	n.s.	.047†
Number of Syllables	n.s.	n.s.
Number of Phonemes	n.s.	n.s.
Number of orthographic neighbours	n.s.	n.s.
Imageability	-.224**	.339**
Rated Frequency	-.170**	.210**
Printed Frequency (Google)	-0.73*	.129**
Printed Frequency (Bing)	-.086**	.108**
Printed Frequency (AltaVista)	-.069*	.117**
Age of acquisition	.097**	-.178**
Bigram Frequency	n.s.	.062*
Trigram Frequency	n.s.	n.s.

Note: n.s. indicates that the correlations was not significant, **p< .001, *p< .01, †p< .05

Reaction times and accuracy also correlated with age of acquisition such that acronyms acquired early were recognised with greater accuracy and shorter latencies than late acquired acronyms. These age of acquisition effects parallel the advantage for early acquired words reported in the literature (Butler & Hains, 1979; Morrison & Ellis, 1995; Morrison and Ellis, 2000; Whaley, 1978). Acronyms with high bigram frequency and those which had more letters were more likely to be correctly recognised than shorter or lower bigram frequency acronyms.

The print-to-pronunciation classification of acronyms (i.e., unambiguous, ambiguous typical or ambiguous atypical) correlated with reaction times and accuracy. Ambiguous atypical acronyms (NATO) were recognised fast and accurately while unambiguous acronyms were recognised more slowly. Ambiguous typical acronyms correlated negatively with accuracy, indicating that this type of acronym elicited more of errors. The three printed frequency

measures were assessed to determine which provided the greatest change in the proportion of the variance in recognition times which was explained by the multilevel model. The log transformation of the printed frequencies derived from the Bing search engine accounted for the greater proportion of variance (see Table 3.9) and therefore this was the measure selected for subsequent analyses[4].

Table 3.9 – Acronym printed frequencies comparisons

	Log AltaVista Frequency	Log Google Frequency	Log Bing Frequency
B	-.013	-.012	-.015
SE B	.003	.003	.003
β	-.076†	-.078†	-.094†
R^2	.203	.204	.206
ΔR^2	.006	.006	.009

Note † $p < .05$

As in the naming experiment a series of four multi-level regression analyses were carried out as the result of alternating the submission of only one of the measures of phonological word length (number of syllables or number of phonemes) and one of the letter frequencies (bigram or trigram frequencies). A summary of the results from the four analyses can be seen in Table 3.10. The procedures for creating the interaction terms, and for entering the pronunciation pattern of the acronyms were the same as for the naming data previously described.

[4] As in the naming experiment, the same analyses were performed using each of the printed frequency measures. In each case the pattern of results was similar to those described using the Bing frequencies.

Table 3.10 – Standardized regression coefficients (β) for the four multilevel analyses carried out on acronym recognition times.

	Analysis 1	Analysis 2	Analysis 3	Analysis 4
Step 2				
Ambiguous Typical		-.032		
Ambiguous Atypical		-.046†		
Step 3				
Number of Letters	-.019	-.021	-.039	-.037
Number of orthographic neighbours	-.018	-.023	-.017	-.021
Imageability	-.250**	-.258**	-.255**	-.263**
Rated Frequency	-.023	-.018	-.019	-.015
Printed Frequency	-.056	-.058	-.059	-.061
Age of Acquisition (AoA)	-.069†	.073†	-.064	-.067†
Trigram Frequency		-.030		-.024
Bigram Frequency	-.020		-.008	
Number of Syllables	.009	.009		
Number of Phonemes			.042	.040
AoA by Ambiguous Typical	.121**	.121*	.120**	.120**
AoA by Ambiguous Atypical	.001	.006	-.001	-.004
Rated Frequency by Ambiguous Typical	-.051	-.057	-.056	-.061
Rated Frequency by Ambiguous Atypical	.020	.015	.015	.011
Printed Frequency by Ambiguous Typical	-.017	-.014	-.014	-.011
Printed Frequency by Ambiguous Atypical	.028	.034	.027	.034
Imageability by Ambiguous Typical	.127*	.133*	.131*	.137*
Imageability by Ambiguous Atypical	-.039	-.034	-.008	-.030
R^2	.283	.283	.283	.283

Note: ** $p < .001$, * $p < .01$, † $p < .05$

Regression lines were plotted to further examine the interactions. Figure 3.4 shows that acronyms with high imageability ratings were recognised more quickly than low imageability acronyms. This imageability effect was greater for ambiguous atypical acronyms than for either of the typically pronounced acronym types.

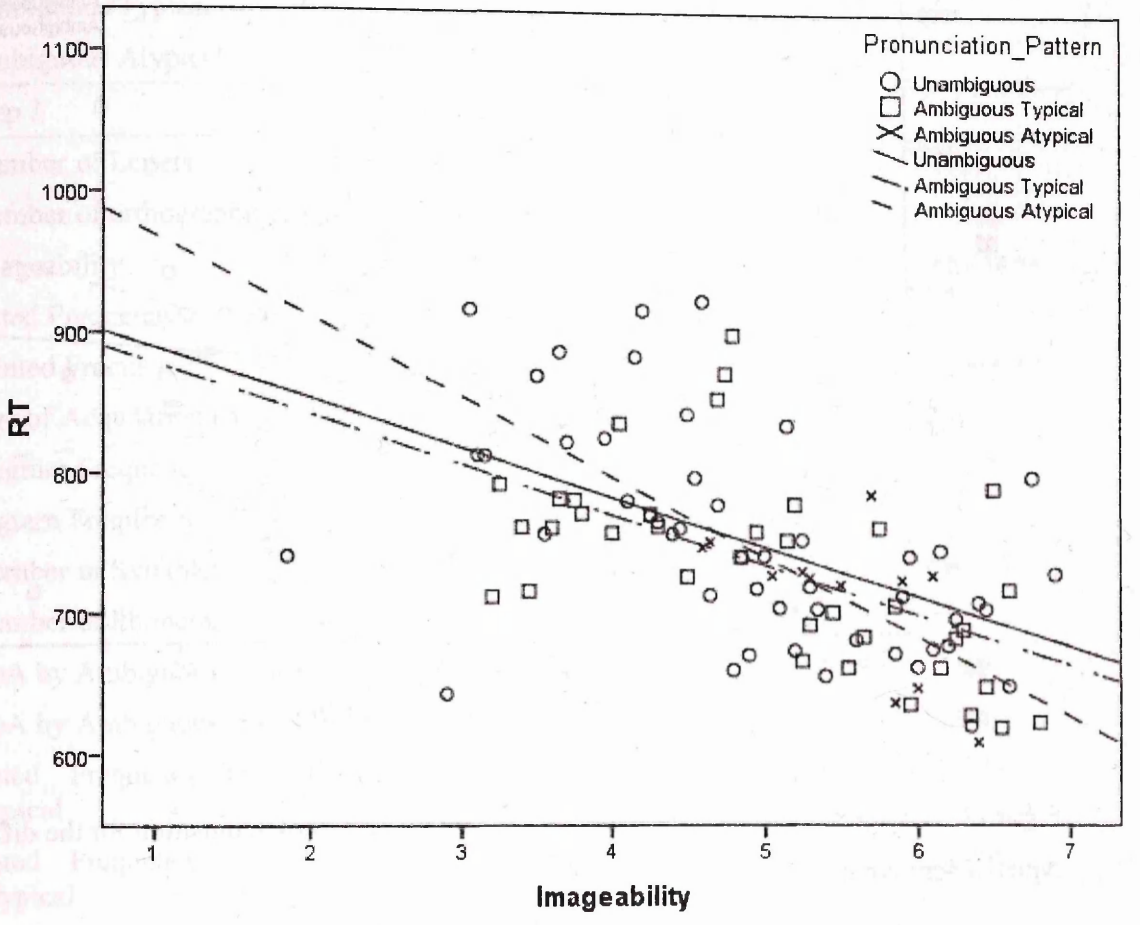


Figure 3.4 – Regression lines between Reaction Times and imageability for the different types of acronyms.

The pattern of responses in plotting recognition latencies against age of acquisition (Figure 3.5) indicated that ambiguous typical acronyms were recognised more quickly if they had been acquired early in life. The recognition times for unambiguous acronyms showed a slight trend towards an advantage for those which were acquired earlier. For ambiguous atypical acronyms, however, the effect of age of acquisition was reversed such that responses were slightly slower for early acquired acronyms than for late acquired acronyms.

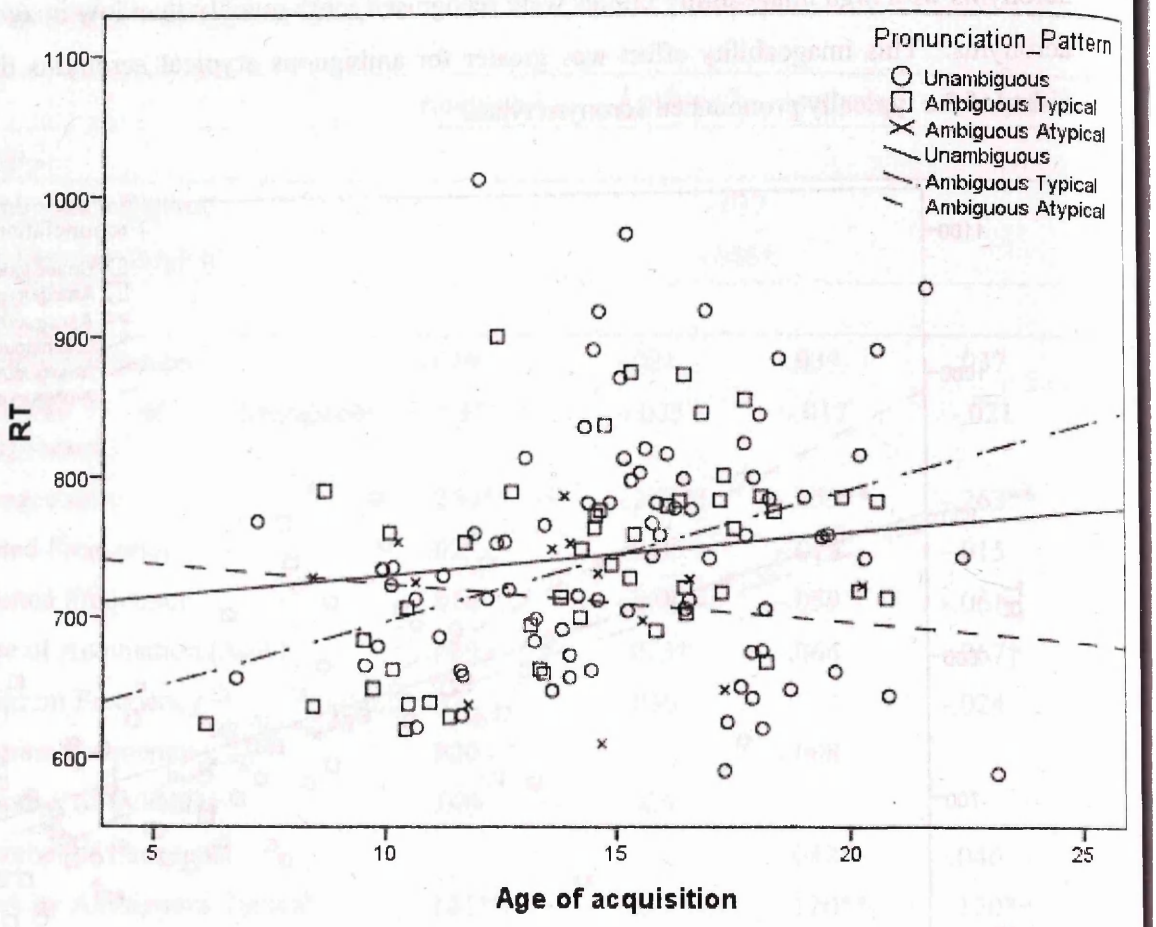


Figure 3.5 - Regression lines between Reaction Times and age of acquisition for the different types of acronyms.

3.9.2 Error analyses

To analyse the error data, four logistic regressions were performed, alternating the measure of phonological length and letter frequency entered into the final step of the multilevel model. Analysis 1 contained syllable length and bigram frequency, analysis 2 assessed syllable length and trigram frequency, analysis 3 describes the model including phoneme length and bigram frequency, and phoneme length and trigram frequency were entered into the fourth analysis. Accuracy was entered as dummy variable (1 indicating a correct response, 0 indicating an error). Log transformed frequency from the Bing search engine was entered as the printed frequency measure. Wald statistics are presented below in Table 3.11.

Table 3.11 – Wald statistics for the four multilevel analyses carried out on acronym lexical decision accuracy.

	Analysis 1	Analysis 2	Analysis 3	Analysis 4
Step 2				
Ambiguous Typical			6.193†	
Ambiguous Atypical			9.085*	
Step 3				
Number of Letters	.475	.849	.004	.921
Number of orthographic neighbours	4.342†	2.206	4.552†	2.513
Imageability	50.577**	51.121**	49.777**	49.836**
Rated Frequency	.402	.426	.327	.431
Printed Frequency	8.273*	12.225*	9.261*	12.899**
Age of Acquisition (AoA)	1.294	.393	1.234	.612
Trigram Frequency		6.312†		5.563†
Bigram Frequency	10.608*		9.995*	
Number of Syllables	.733	.357		
Number of Phonemes			.036	.226
AoA by Ambiguous Typical	.068	.154	.160	.160
AoA by Ambiguous Atypical	.170	.073	.085	.044
Rated Frequency by Ambiguous Typical	.038	.156	.140	.233
Rated Frequency by Ambiguous Atypical	2.354	2.296	2.613	2.506
Printed Frequency by Ambiguous Typical	.901	1.710	1.022	1.718
Printed Frequency by Ambiguous Atypical	4.159†	4.936†	5.014†	5.824†
Imageability by Ambiguous Typical	1.009	.969	1.196	1.055
Imageability by Ambiguous Atypical	2.963	2.937	3.136	3.188

Note: ** $p < .001$, * $p < .01$, † $p < .05$

Imageability, printed frequency, bigram frequency and trigram frequency significantly predicted accuracy across all four analyses. When the analyses included bigram frequency

(i.e. analysis 1 and analysis 3), main effects of number of orthographic neighbours were revealed. The interaction between printed frequency and ambiguous atypical acronym status was significant in all four analyses. Figure 3.6 shows the mean printed frequency of acronyms grouped by the accuracy of the responses. The mean frequency of ambiguous atypical acronyms which were incorrectly rejected in the lexical decision task was higher than the frequency of acronyms successfully recognised. For typical acronyms, mean printed frequency for correct answers were higher than for incorrect responses.

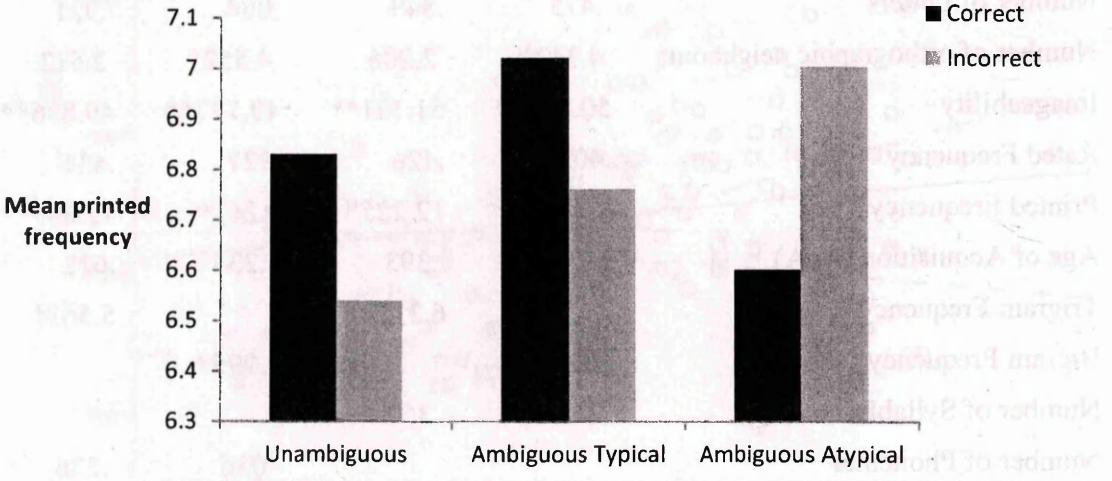


Figure 3.6 – Mean printed frequency of correct and incorrect responses to each type of acronym.

3.10 Discussion

Recognition latencies for ambiguous atypical acronyms were significantly faster (723ms) than for unambiguous acronyms (770ms) as revealed in the second step of the regression analysis. Responses to ambiguous typical acronyms were not significantly different in RT from those in unambiguous acronym trials. This difference in recognition latency between typical and atypical acronyms was not expected. In studies of mainstream word recognition, effects of spelling to sound characteristics are seldom significant (Hino & Lupker, 1996; 2000; Seidenberg et al., 1984; Waters & Seidenberg, 1985). This is because lexical access does not normally require phonological information. However, regularity effects have been observed in lexical decision tasks in which particularly emphasise phonological processing (Parkin & Underwood, 1983; Waters & Seidenberg, 1985). It may be that lexical decision for

acronyms is one such task. Orthography alone does not allow acronyms to be differentiated from the non-words used in the present lexical decision. Thus, an influence of phonology is exhibited. For ambiguous atypical acronyms (NASA, NATO) the phonology is similar to that of mainstream words. As such the phonology is readily available and can therefore help in the activation of the lexical representation, and hence the recognition of this type of acronym is fast. It might be the case that the phonological retrieval for ambiguous but typically pronounced acronyms (HIV, IBS) is more difficult to assemble because the system is not so used to naming individual letters, and because typically pronounced acronyms are phonologically longer. There is therefore less opportunity for phonological information to influence or help in the activation of the lexical representation of the target and responses are made more slowly.

The importance of the predictor variables and interactions on acronym recognition times were examined in the third step of the analyses. In all the analyses performed, RT was predicted by imageability and age of acquisition as was expected based on previously reported findings illustrating the role of these variables in word recognition tasks. The contribution of imageability and age of acquisition supports the conclusions of Brysbaert et al. (2009) that acronyms are lexicalised items. The emergence of significant interactions between ambiguous typical acronyms and both age of acquisition and imageability are of particular interest. The regression lines plotted in Figure 3.4 showed that highly imageable ambiguous typical acronyms were recognised more quickly than their less imageable counterparts. Imageability had an even greater effect on the latency of lexical decision responses to ambiguous and atypical acronyms. A potential explanation for this differential effect relies in the different way of computing the phonology of typical and atypical acronyms. It might be the case that due to the difficulties of the task, the orthographic forms of acronyms are insufficient to distinguishing them from the nonwords. Phonology might be then used to assist in this lexical decision process. The phonology for an ambiguous atypical acronym can be assembled using grapheme phoneme correspondences. This process is relatively quick, due to its frequent use, compared to naming each letter in turn. Thus when ambiguous atypical acronyms are presented their orthography and phonology rapidly activate their meaning and recognition is assisted by the three factors; phonology, orthography and imageability. The influence of imageability when recognising typically pronounced

acronyms is reduced since the activation of meaning is not so readily assisted by a quick phonological assembly. .

Similarly, Figure 3.5 shows a differential effect of age of acquisition on typical and atypical acronyms. Among ambiguous typical acronyms (HIV), early acquired items were recognised more quickly than those learned later in life. The effect of age of acquisition on recognition latencies for ambiguous atypical and unambiguous acronyms was very small, with the regression lines being almost horizontal. The arbitrary mappings hypothesis (Ellis & Lambon Ralph, 2000) states that age of acquisition effects are observed whenever the mappings required are unpredictable. Here, AoA had an impact on the responses to ambiguous but typically pronounced acronyms (HIV). This type of acronym could be pronounced following GPC rules, but the correct pronunciation requires that each letter is named in turn. Thus the mapping between spelling and sound is particularly arbitrary and therefore an AoA effect was observed. The pronunciations for ambiguous and atypical acronyms such as NATO follow grapheme phoneme correspondence rules as regular words do. Therefore it could be argued that ambiguous atypical acronyms are relatively consistent in their spelling to sound mappings in the English language and therefore there was little contribution of age of acquisition. Age of acquisition also had little impact on the recognition times for unambiguous typical acronyms (BBC). For this type of acronym the conversion of print to pronunciation is unusual. Few words in the English language are named one letter at a time. However, the fact that unambiguous acronyms comprise only consonants determines that only one pronunciation strategy is possible. Therefore the mapping between spelling and sound is predictable and insensitive to age of acquisition effects.

Some of the predicted effects were not obtained. A facilitatory effect of increasing letter length was expected based on the findings of New et al. (2006). This effect was not observed in the data. One plausible explanation for this is that the vast majority of the acronyms included were three letters long, and all were presented centrally. The result of this is that a single fixation would allow for all the letters in an acronym to be perceived at once, and that visual acuity would be at its highest. O'Regan and Jacobs (1992) reported no effect of letter length when participants viewed four or five letter words with a central fixation. The same may be the case in the current experiment. Contrary to expectations, N effects were also

absent in the lexical decision task. Again, the literature provides a potential explanation for this finding. An interaction between frequency and N is commonly reported such that a large orthographic neighbourhood is beneficial to the recognition of low frequency words, but inhibitory for frequently occurring words (Andrews, 1989; Balota et al., 2004; Forster & Shen, 1996). In the acronyms used for this study, N and frequency were not significantly correlated. It is possible that the inhibitory N effects for high frequency acronyms and facilitatory effects for low frequency acronyms cancelled out, resulting in an overall null effect of orthographic neighbourhood. It is also possible that Coltheart's N is a measure of orthographic similarity which is too restrictive a definition to be useful in acronym research. The OLD20 score is the mean number of operations required to make the 20 closest words. This goes beyond the more common N measure in two important ways. First it does not restrict the orthographic similarity to include only words of the same length, and second it allows for more than one letter to be changed. When considering acronyms the OLD20 measure may be more appropriate than N because of the unusual orthographic structure of acronyms (particularly in unambiguous acronyms) severely reduces the number of neighbours that are possible.

In sum the findings of the regression analyses on lexical decision latency can be accounted for by suggesting that acronyms are stored in the mental lexicon, and arguing that differentiating non-words from meaningful acronyms in a lexical decision task is a complex process which draws on phonological information.

3.11 General discussion

The present study set out to investigate whether the irregular print-to-pronunciation patterns found in acronyms have similar processing features to those commonly found with irregular words. A further and related aim was to conduct a detailed examination of acronyms characteristics and an evaluation of the manner in which they intercorrelate.

The study started collecting values for acronyms in a series of selected variables. Thus, questionnaires were created to rate acronyms in terms of their frequency of occurrence, age

of acquisition and imageability. Acronyms voicing, phonological, and orthographic length were computed by hand while number of orthographic neighbours were extracted from a program based on the Celex database (Baayen et al., 1993). Bigram and trigram frequencies were also considered and derived from the MCWord, an Orthographic Wordform Database (Medler & Binder, 2005). Print-to-pronunciation patterns in acronyms were divided into three categories; unambiguous pronunciation pattern (e.g., BBC), ambiguous but typical pronunciation pattern (e.g., HIV) and ambiguous atypical pronunciation pattern (e.g., SCUBA). Acronym's print-to-pronunciation patterns were considered as a further variable of interest in the study. The way in which acronym characteristics correlated resembled the correlations reported amongst standard words to a certain extent. For example, age of acquisition (AoA) correlated negatively with imageability and rated frequency, meaning that early acquired acronyms were more imageable and familiar (Morrison, Chappell, & Ellis, 1997; Stadthagen-Gonzalez & Davis, 2006). However, some correlations conflicted with what is normally found with mainstream words. For example, the negative correlation found between letter length and syllable length, and that found between letter length and number of phonemes shows an inverse relationship between orthographic and phonological length not present in mainstream words. For the acronyms studied here, as orthographic length increased phonological length decreased. This is possibly the result of the variety of print-to-pronunciation patterns observed in acronyms. Short acronyms tend to be pronounced naming each of their constituent letters (e.g., DVD) but long acronyms are more likely to include vowels and be pronounced following grapheme to phoneme correspondences (e.g., SCUBA). Other peculiar relationships are the positive correlations of orthographic length with printed frequencies and with number of orthographic neighbours but the negative correlations of phonological length in terms of number of phonemes with printed frequencies and with number of orthographic neighbours. This means, the more letters and fewer phonemes in the acronym the higher its frequency and N. Longer acronyms are more likely to be formed by a mixture of consonants and vowels. These structures are more likely to be akin to other words and therefore produce high number of orthographic neighbours. In addition, vowels require less phonemes to be named aloud than consonants (e.g., /ae/ for 'a' versus /eich/ for 'h'). Finally, the list of acronyms selected showed no correlations between their AoA and printed frequencies suggesting, contrary to what is found with non-acronym-words, that the order at which acronyms are learned is not reflected by their use in printed material. This study set out to provide data regarding the characteristics of acronyms, such that the use of acronyms as experimental stimuli could be subject to the same degree of control as stimuli for word

reading tasks. The normative values collected here will allow for the design of strictly controlled studies using acronyms.

Naming and lexical decision responses were collected for all 146 acronyms. Regression analyses were performed to examine which factors affected the accuracy and latency of participant responses. A significant main effect of age of acquisition was observed both in lexical decision and naming. Age of acquisition was also shown to interact with ambiguous typical acronyms in both studies. This is interpreted as evidence that print to pronunciation characteristics for some acronyms are more predictable than others in line with the arbitrary mappings hypothesis (Ellis & Lambon Ralph, 2000). In the naming task, the majority of acronyms presented could be pronounced correctly by naming each constituent letter in turn. Ambiguous acronyms, however, may have caused a conflict between conventional (word-like) pronunciation mechanisms and letter naming mechanisms because either process could result in a plausible reading. Thus age of acquisition was influential in acronym reading because of the inconsistent mapping between spelling and sound. The presentation of ambiguous atypical acronyms caused a further conflict between contending pronunciation mechanisms as they required a reading which was only needed for a minority of trials. For early acquired ambiguous atypical acronyms this conflict was greater than for late acquired items, and hence participant responses were recorded at longer latencies. In lexical decision for acronyms, orthography is not particularly informative in differentiating acronyms from non-words. It is argued that the phonological system is used to assist in the decision making process. The assembly of phonology for ambiguous and atypical acronyms using grapheme to phoneme conversion rules is similar to regular English words, and relatively predictable. The pronunciation of unambiguous acronyms such as BBC is also predictable because the letter patterns only allow one sensible pronunciation. For these types of acronym activation of the lexical representation stemming from the phonological system was available quickly and aided recognition for all acronyms irrespective of when they were acquired. The less predictable spelling to sound mapping for late acquired ambiguous yet typically pronounced acronyms (HIV) meant that the phonological system had less opportunity to influence the recognition process than it did when the acronyms were acquired early. As a result participants were faster to recognise early acquired ambiguous typical acronyms than their late acquired counterparts.

Significant interactions were observed between imageability and ambiguous typical acronyms in both naming and lexical decision responses. In naming, imageability effects were greater for ambiguous typical acronyms than for ambiguous atypical acronyms. It is argued that this too could be a reflection of the importance of print to pronunciation patterns in acronym processing. The advantage for high over low imageability acronyms in naming could reflect a semantic contribution to acronym reading. Thus the greater influence of imageability on ambiguous typical acronym naming times could be a result of the importance of lexical access in reading acronyms with two plausible pronunciations (word-like or letter by letter). Ambiguous atypical acronyms benefitted from being highly imageable in the lexical decision task more than typically pronounced acronyms. It is argued that this is again a reflection of a phonological contribution to the activation of the lexical representations and, hence, the recognition of acronyms. The phonology for ambiguous atypical acronyms may be assembled quickly because it follows rules which are applied more frequently in English, whereas typically pronounced acronyms take longer to decode. Thus imageability and phonology both facilitate the recognition of ambiguous atypical acronyms while ambiguous typical acronyms exhibit less phonological influence. Acronym naming performance was also significantly affected by length in number of letters, rated frequency, printed frequency and letter (bigram or trigram) frequencies. These factors did not exert a significant influence on lexical decision responses.

Two types of studies can be found in the literature concerning acronyms. One line of research has been concentrated in disentangling the potential lexicality of acronyms (Besner et al., 1984; Brysbaert et al., 2009; Coltheart, 1978). These studies have concluded that acronyms are lexical items. The findings of the lexical decision regression analyses support this position. Balota et al (2004) reported that highly imageable words were recognised faster than less imageable words. An advantage for words learned early in life is also commonly reported in the word recognition literature (Butler & Hains, 1979; Morrison & Ellis, 1995; Morrison and Ellis, 2000; Whaley, 1978). The emergence of significant effects of imageability and age of acquisition in the final step of the lexical decision multilevel model mirrors the findings reported in studies using mainstream words and suggests that acronyms are indeed lexicalised items.

The other type of study has used acronyms as a tool to examine aspects of different word reading models (Laszlo & Federmeier, 2007a; 2007b; 2008) or the word superiority effect, WSE (Gibson et al., 1964; Henderson, 1974). The findings of the naming study have implications for any research involving acronyms, but in particular those studies whose predictions are supported by assumptions made regarding acronym characteristics. Acronyms have, thus far, been considered to be similar to irregular words. However, those factors that commonly affect irregular word naming (e.g., age of acquisition, frequency or imageability) exerted differential influences on naming times and accuracy for different types of acronyms. This is interpreted as an indication that some acronyms might be somehow regular in the way print is translated into sound. Lazslo & Federmeier (2007b) examined the dual route model (Coltheart et al., 1993; 2001) and the triangle model (Seidenberg & McClelland, 1989; Harm & Seidenberg, 2004) in the context of N400 repetition effects, which had been previously reported in words and pseudowords, but not illegal non-words. According to Laszlo & Federmeier (2007b) these repetition effects reflected activity in the non-lexical pathway of the dual route model, and ought not to be observed in acronyms that cannot be read via this route. Conceptualizing acronyms as "irregular" stimuli was integral to their design and their conclusion that the N400 repetition effects which they observed for words, pseudowords *and* acronyms could only be explained by a triangle model account with a single process underpinning pronunciation for all word types. However, in the naming task reported here, the data suggests that acronyms might not always be irregular. The analyses indicated that an important factor in acronym naming time was the length of the acronym in number of letters. The proposal has been made that letter length effects in word reading reflect serial (sub-lexical) processes. If this is the case, then it would appear possible to read some acronyms without needing to access the lexical pathway as it is with regular words and pseudowords.

The evidence gathered here clearly shows that not all acronyms can be treated in the same way. In the lexical decision task, responses to ambiguous atypical acronyms (NATO) were given with greater speed and accuracy than ambiguous typical acronyms (HIV). In the naming task, atypically pronounced items were at a disadvantage relative to ambiguous typical items. Further, the fact that lexical decision and naming latencies are not predicted by the same set of variables indicates that the demands of the task play their part. It seems that the print to pronunciation characteristics of acronyms are particularly important in their

reading and recognition. The findings of this study can be taken to indicate that lexical decision tasks involving acronyms are particularly difficult.

Currently influential models of word reading do not accommodate acronym reading very well. The connectionist triangle model (Seidenberg & McClelland, 1989; Harm & Seidenberg, 2004) posits that pronunciation for all written stimuli is generated in the orthography-phonology pathway based on the knowledge of the sound required to pronounce the majority of similarly-spelled items correctly. Items which have pronunciations consistent with word-body neighbours are named quickly and efficiently, but inconsistent items require input from semantic system to constrain the O-P pathway sufficiently to generate the correct response and are named more slowly. Most acronyms, and certainly those with typical pronunciations, are inconsistent (EEG versus LEG, KEG, PEG etc) and therefore participant response times should have shown an increase. However, it is the typically pronounced (and inconsistent) acronyms which are named with greater speed and accuracy. According to the dual-route model (Coltheart et al., 1993; 2001) acronyms would necessarily be read via the lexical route as their pronunciations generally do not conform to grapheme-phoneme correspondence rules. If this was the case though, participant reaction times and accuracy should have been less affected by orthographic characteristics (N, number of letters, bigram and trigram frequencies) and more influenced by frequency, age of acquisition or imageability. The data indicate that the acronyms are being read by non-lexical processes, and that participants are applying a system of rules. Clearly these rules are not the same as grapheme-phoneme correspondences. Perhaps a third route is available to readers in which letters are processed individually.

There is precedent for this claim in the literature concerning letter-by-letter (LBL) dyslexics. As Howard (1991) noted, patients with acquired dyslexia will often name each letter of a written word in turn before producing a whole-word pronunciation. It has been argued that this strategy is used because there is an obstacle to processing the letters of a word in parallel. In cases where letter naming is preserved while whole word recognition is impaired it is possible to argue that there are disparate routes for the two processes. Rather than this capability developing to overcome a specific deficit, it is argued that this system is available to all readers. In normal readers the letter naming rule system is only applied when it is

necessary or efficient to do so, such as in acronym reading. Letter by letter readers may be forced to rely on this system in all instances.

A description of acronyms as a tool for further investigating word reading processes has been presented here and it has been possible to highlight where current word reading models fail to accommodate acronym reading performance. It is concluded that acronyms might be best described as regular and lexical items. Further evidence for this claim could be provided by using acronyms as stimuli in examinations of impaired reading performance, particularly in cases where the lexico-semantic system is specifically affected or in designs tailored to precluding lexical reading. It is proposed that models need to be adapted to allow for correct acronym reading, as although acronyms only constitute a relatively small proportion of language usage, they are becoming more predominant in scientific and popular literature and seem to pose few problems for the skilled reader.

CHAPTER 4

THE ROLE OF IMAGEABILITY, AGE OF ACQUISITION AND FREQUENCY IN ACRONYM COMPREHENSION

4.1 Introduction

Individuals skilled in using a particular language are able to recognise, understand and produce words with remarkable ease. The capability to select an appropriate word from the tens of thousands available to the speaker implies that word knowledge is stored in an organised manner (Aitchison, 2003). The common metaphor for this store is that of the mental lexicon (Oldfield, 1966), an internal dictionary which represents orthographic and phonological word forms as well as semantic information. However, the dictionary analogy is too simplistic. Traditional written dictionary entries are organised based on a simple alphabetical order, but evidence from skilled readers and patients with language disorders indicates that words and concepts in the mental lexicon appear to be stored as nodes in networks of inter-related items (e.g. Drieghe & Brysbaert, 2002; Kay & Ellis, 1987; Lukatela & Turvey, 1994; Meyer & Schvaneveldt, 1975). Anomia is a word finding deficit which is particularly apparent when patients are asked to name objects and pictures. Kay and Ellis (1987) described the case of patient EST. Two findings from this study suggest that words in the lexicon are stored in clusters of related items. First, although EST was unable to spontaneously name 78% of the pictures on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) and the names for 63% of the Snodgrass and Vanderwart (1980) pictures also eluded him, for some of the pictures EST gave an incorrect response that was related to the correct picture name (e.g. "jacket" instead of sweater or "hen" instead of cockerel). Second, in cases where EST was unable to immediately name the picture presented to him, he was nevertheless able to recall details about its use. In the appendix to their study Kay and Ellis (1987) detail EST's response to AXE. He was able to identify that it was an item used to chop wood. He was also able to retrieve the related words "saw," "hammer" and "chopper." This use of circumlocution indicates that the representation for AXE in the lexicon may have been difficult to retrieve but that other words stored in the same semantic network were available and automatically activated. In reading, a common finding is that

words are recognised or read aloud more quickly when a related word is presented immediately before it (Drieghe & Brysbaert, 2002; Lukatela & Turvey, 1994; Meyer, Schvaneveldt, & Ruddy, 1975). Priming effects such as these are explained by arguing that the presentation of a written word leads to the automatic activation of all the related words in the lexicon. Thus the word to be named is partially activated before it is actually presented, and less additional activation needs to be accumulated before the response can be generated. Following the assertion that words in the lexicon are stored in networks of related items (nodes), a body of research has been generated in the linguistic and psychological literature aiming to assess which words are linked, and how.

One technique used to illuminate the way in which words are organised in the lexicon is the word association task. There are several forms of word association task, but this review is limited to the findings of studies using the discrete association paradigm. In discrete association, the participant is presented with a single word and required to produce the first word that comes to their minds. In order to achieve this, the participant is forced to activate a second lexical representation which is connected to the target word. By asking a large number of participants to provide associations to the same cues, the way in which words are linked together is inferred. Several lists of the associations generated for a given cue word have been published (e.g. Kent & Rosanoff, 1910; Kiss, Armstrong, Milroy, & Piper, 1973; Moss & Older, 1996; Nelson, McEvoy, & Schreiber, 1998; Palermo & Jenkins, 1964; Postman & Keppel, 1970) and these are widely used in the psycholinguistic literature. Word association data also provides a measure of the strength of the link between cue and associate. Associative strength refers to the proportion of participants who produce the same response. For example, the Edinburgh Associative Thesaurus (Kiss et al., 1973) lists word association responses for 8,400 stimulus words, each one presented to 100 participants. For the cue word BLACK, 57 participants said WHITE from a total of 99 participants . Thus the associative strength between BLACK and WHITE is 57 divided by 99, that is 0.58. Research suggests that associative strength is a reliable indication of the predominance of a particular response in the population (Cramer, 1968; Fox, 1970; Jenkins & Russell, 1960; Nelson & Schreiber, 1992; Osipow & Grooms, 1965). Thus it is likely that around 58% of another group of 100 participants will say WHITE in response to BLACK. Furthermore, it has been illustrated that associative strength is a good predictor of performance in cued recall tasks (Nelson, Schreiber, & McEvoy, 1992) and of priming effects (Canas, 1990).

Word association is a test of lexico-semantic processes. Semantic network models posit that words in the lexicon are stored as interconnected nodes (e.g. Collins & Quillian, 1969; Collins & Loftus, 1975). Each node has a number of other nodes linked to it. Connections gain in strength every time that they are used. Thus an association between words which an individual retrieves often becomes stronger. For example, an owner of a tabby cat is likely to have a strong link between the concepts of *tabby* and *cat* which other individuals may not have. Research suggests that there are certain characteristics of a cue word which affect the strength of the links that stem from it, and hence influence the patterns of responses that it elicits in a word association task. Frequency, imageability and age of acquisition are among the factors which seem to influence word association behaviour. The findings related to these variables are discussed in turn below.

Word frequency refers to the number of times an individual encounters or uses a particular word. The intuition that frequency of occurrence could have an influence in word processing was first supported by Howes and Solomon's (1951) findings, and its importance in word processing has been extensively demonstrated ever since. High frequency words are recognised, produced, and recalled faster and with greater accuracy than low frequency words (Connine, Mullinex, Shernoff, & Yelen, 1990; Oldfield & Wingfield, 1965; Whaley, 1978; Yonelinas, 2002). As word association necessarily requires initial word recognition it could be expected that word association behaviour would show an influence of word frequency. The literature seems to indicate that the frequency of the cue does have some impact on the strength and number of associations generated, but it is far from clear what this influence is. Early investigations of the effect of frequency indicated that high frequency cues elicited a stronger dominant response than low frequency items, and fewer different responses overall (Hall & Ugelow, 1957; Postman, 1964; 1970). These findings can be explained using an interpretation of the relative strength of the links between high frequency words and their neighbours. The strong connections between high frequency words and concepts are likely to be shared by more individuals, leading many participants to offer the same associative response. The greater agreement between participants in their associations to high frequency words results in fewer different responses. If the effect of frequency on word association is a result of the strength of the links between one word and another in a semantic network, it would be possible to predict significant frequency effects on the latency of word association responses. Participants should therefore be quick to generate responses to high frequency

words with strong connections to associated concepts. However, de Groot (1989) demonstrated that the frequency of the cue word did not have a significant impact on the speed with which an associate was recorded, contradicting the predictions of semantic network models. Furthermore, de Groot (1989) reported that high frequency cues elicited more different responses than low frequency cues. This was the inverse of the frequency effects reported by Hall and Ugelow (1957) and Postman (1964; 1970). One major tenet of semantic network models is that the link between two concepts should be strengthened by its retrieval. Priming studies indicate that the activation of related words can be an automatic consequence of the previous presentation of a written word (e.g. Dreighe & Brysbaert, 2002; Lukatela & Turvey, 1994; Meyer et al., 1975). Thus the connections stemming from high frequency words should be particularly well-travelled as they are activated with every presentation. The evidence reported by de Groot (1989) indicated that frequently accessing a link was not sufficient to strengthen the association and speed subsequent retrieval. Instead de Groot argued that the link to the concept had to reach consciousness before the connection could be strengthened. She noted that the pattern of the frequency effects that had been reported in previous studies of word association were remarkably similar to the effects of imageability in her own experiments. De Groot examined the stimulus materials used by Postman (1970). She derived imageability ratings for each of the cues used in Postman's (1970) study from the Colorado Concreteness and Imageability norms (Posnansky et al., 1973). De Groot showed that the words in the four frequency bands in Postman's (1970) study were significantly different in imageability (lower frequency words were also lower in imageability). She concluded that previous frequency effects had been at least partly confounded with imageability effects,

Imageability refers to the ease with which a word evokes a mental image (Paivio, Yuille, & Madigan, 1968). Highly imageable words are better recognised and memorised than less imageable words in tasks of lexical decision, cued and free recall (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Kennet, McGuire, Willis, & Schaie, 2000; Paivio 1965). In discrete association tasks, a smaller number of different responses are elicited by words which are highly imageable. Further, the dominant response to a high imageability cue word has a greater associative strength than that for a less imageable cue (Altarriba, Bauer, & Benvenuto, 1999; de Groot, 1989). Imageability has also been shown to affect the speed with which association responses are offered. De Groot (1989) reported that associative responses

for high imageability words were offered more than 400ms sooner than for their low imageability counterparts. These findings were interpreted as evidence that the links between highly imageable/concrete word nodes and related concepts were stronger than the links stemming from low imageable/abstract word nodes. Stronger links between the cue word and "nearby" words in the lexicon allowed an association to be generated rapidly. The strength of the link can also be used as an explanation for the distribution of the associative responses offered by participants. De Groot (1989) argued that highly imageable words have relatively strong connections with at least one associated node and that these strong links are shared by a large number of individuals. Abstract words, on the other hand, have weaker links with related concepts. No single potential associate has a particularly strong link to the node for the cue word. This has two effects on the word association data. First, the associative strength of the most frequently recorded response is higher for concrete words. The same associative response is salient and easy to retrieve for many participants. Secondly, the number of different associations elicited by an imageable cue word is lower than for an abstract word. As the discrete association task permits only one response per participant each individual that gives the same response reduces the number of remaining participants that could give an alternative.

Age of acquisition (AoA) refers to the moment in time in which words, objects and faces are first learned. Differences in order of learning or AoA have been shown to affect processing times, accuracy, amplitude of ERP components, eye fixation durations and spatially distinctive brain regions (Cuetos, Barbón, Urrutia, & Dominguez, 2009; Ellis, Burani, Izura, Bromiley, & Venneri, 2006; Gilhooly & Logie, 1982; Juhasz & Rayner, 2006; Morrison & Ellis, 1995, 2000; Pérez, 2007; Weekes, Chan, & Tan, 2008). Evidence shows that early acquired material has an advantage over late acquired material in terms of processing time, accuracy and resistance to brain damage (see reviews in Johnston & Barry, 2006; Juhasz, 2005). Investigations have also indicated that age of acquisition is an important variable in word association as well. Van Loon-Vervoorn (1989, cited by Brysbaert, Van Wijnendaele & De Deyne, 2000) indicated that responses in a discrete association task were recorded reliably faster (240 ms) when the cue was early-acquired. Brysbaert et al. (2000) replicated Van Loon-Vervoorn's (1989) findings. They reported that early-acquired words elicited association responses 279 ms faster than late acquired words. Further, Brysbaert et al. (2000) provided evidence that there is greater agreement among participants in the associations

generated for early-acquired words. This mirrors the effects of imageability in de Groot's (1989) study, and Brysbaert et al (2000) pointed to the interpretation that the strength of the connections from early-acquired word nodes is greater than from nodes for late-acquired words.

In sum, word association response times provide information that has the potential to inform about the strength of the semantic connections and with that illuminate the structure of the semantic system. This might be of particularly relevance for acronyms, a ever growing part of our vocabulary that has been scarcely studied. Word association data can also be used to examine the nature of the association participants make. Word association responses can be grouped into three major categories depending on the relationship between cue word and associative response (Fitzpatrick, 2006; 2007; 2009). These are meaning-based associations (e.g., *bird-robin*), position-based associations (e.g., *blue-moon*) or form-based associations (e.g., *plug-plum*). Meaning-based associations are associations related by meaning and include for example synonyms, antonyms and words from the same lexical set (e.g. *ham* and *berry* are both examples of foods). Position-based associations are related because they co-occur often and together in texts or in the spoken language, but do not share any explicit meaning in themselves. For example, "*abbey*" and "*road*" do not have a semantic link, but may be nevertheless be associated as in the title of the Beatles album. Form-based pairs might share orthography (*chair – choir*) or phonology (*air – heir*), or more commonly a mixture of orthography and phonology (*meet – meat)* but not meaning. Classifying word associations typically shows that the majority of links between cue and response are meaning based, while only very few associations responses tend to be based on form (Fitzpatrick, 2006). De Groot (1989) discussed the potential that the classification of associative responses could have to provide valuable information in relation to the semantic system. Highly imageable cues elicited fast responses in de Groot's (1989) study. She suggested that an analysis of the type of associates offered by participants might reveal that particularly fast responses belonged to a particular response class. The word association task is classed as a semantic task in nature based on the idea that in the majority of occasions associative responses require an understanding of the meaning of the cue word. It might be somehow logical to predict that cues for which the meaning is well-known and familiar would elicit a high proportion of meaning based associates. Similarly, participants may be more likely to generate form based associates for unfamiliar cue words for which meaning is not

immediately available. Some evidence for this position was provided by Stolz and Tiffany (1972). This study collected word association responses for 27 pairs of adjectives from adult participants. Each pair contained a frequent word and a synonym or near-synonym which was far less frequently occurring (e.g. daily-diurnal, or fat-obese). Stolz and Tiffany (1972) reported a higher proportion of sound-alike responses for the infrequent cue words than for their more familiar counterparts.

In the present study word association responses were obtained for the 146 acronyms included in Chapter 3 (also in Izura & Playfoot, under review) in order to examine the effects of frequency, imageability and age of acquisition on word association responses to acronyms. Acronyms are created to abbreviate long or cumbersome phrases using the initial letter from each constituent word (British Psychological Society becomes BPS). This process often results in an acronym with an unusual or illegal orthography. Nevertheless acronyms are meaningful and can become part of our everyday language (e.g., TV, BBC, US, etc.) Results from Chapters 2 and 3 showed that acronyms are integrated into the mental lexicon and they are supported by a number of other studies (Besner, Davelaar, Alcott, & Parry, 1984; Brysbaert, Speybroeck, & Vanderelst, 2009; Coltheart, 1978). The most recent of these studies used acronyms as primes in an associative priming task. Brysbaert et al. (2009) showed that the brief presentation of an acronym could activate the lexical representations of related words and speed up subsequent lexical decision. Thus, it is natural to assume that acronyms are also part of the semantic network. Acronyms have a more restricted number of senses than many English words. Consequently a high level of agreement in their responses is expected. The word association task is a semantic task in nature, therefore effects of imageability and age of acquisition on response latencies are expected since they are variables claimed to be part of the semantic system or the semantic connections. This study is novel in that it is the first to assess the influence of lexical variables on the qualitative types of association response generated by an acronym and to measure response times. It is expected that acronyms that are low frequency, low imageability or late acquired elicit a greater proportion of form based responses because meanings and conceptually linked words may be particularly difficult to retrieve. The relationships between acronym characteristics and word association performance will be informative regarding the structure of the lexicon for an idiosyncratic part of our vocabulary. That is, acronyms.

4.2 Method

4.2.1 Participants

Fifty participants, 18 male and 32 female, were recruited for this study. The participants were students at Swansea University with a mean age of 22 years (range 19 - 29), and all were native speakers of English without reading deficits.

4.2.2 Procedure

The 146 acronyms described in Chapter 3 (also in Izura and Playfoot, under review) were presented as cues in a discrete word association task. Stimulus presentation and randomization was achieved using E Prime software (Schneider, Eschman, & Zuccolotto, 2002). Acronyms were presented centrally in black ink on a white background and with Times New Roman font, size 12 points. Participants were informed that they would be seeing a list of acronyms, individually, and that they should say the first thing that came to their mind in response to each acronym. The instructions indicated that there were no right or wrong answers, and that it was important that responses reflected the first word they associated with the stimulus. Each acronym was presented individually in the middle of the computer screen and remained there until the participant responded. The verbal response from the participant was detected by a microphone placed approximately 10 centimetres in front of the mouth. This triggered the program to show the next screen (blank 500ms) and to record the time that had elapsed between the onset of the presentation of the stimulus and the detection of the response. Then a a screen with an horizontal line in the middle appeared to signal participants to type in the response that they had just given. Participants could type their response in their own time (they were allowed to correct spelling mistakes). Participants signalled that they had completed the typing by pressing the return key. Then an asterisk appear for 500 ms to indicate that the next trial was about to commence. All 146 acronyms were presented to every participant in a random order. The task took between 20 and 25 minutes to complete.

4.3 Results

Three participants offered association responses for fewer than half of the items presented, and were, therefore deleted from further analyses. Thus the analyses reported here are based on the responses from 47 participants. The analysis assessed the impact of acronyms' rated frequency, printed frequency, age of acquisition and imageability on word association behaviour. The values for the acronym characteristics were taken from the norms collected in Chapter 3 (Izura & Playfoot, submitted). This database offers three printed frequency measures based on three internet search engines (AltaVista, Bing and Google). Regression analyses were computed using each of the printed frequency counts in turn. As the results were very similar irrespective of which measure was entered, only the regressions including AltaVista printed frequency are reported. Analyses concerning associative response times, the distribution of word association responses and the qualitative types of association elicited were computed. Each of these will be discussed in turn below.

4.3.1 Reaction time analyses

Response latencies for omissions (14%) were removed prior to reaction time analysis. Trials in which the voice key had malfunctioned (3%) were also deleted from these analyses. Mean and standard deviation of RT was calculated separately for each participant. Responses recorded more than 3 SD above the mean were designated outliers and removed from subsequent analyses. This processes eliminated a further 2% of trials. Mean response latency was then calculated for each acronym cue across all participants. The relationship between imageability, rated and printed frequency, age of acquisition and RTs was assessed using correlation techniques. Correlation coefficients are presented in Table 4.1 below.

Table 4.1 – Pearson's correlation coefficients between lexical variables and word association response latencies.

	RT
Age of acquisition	.508**
Imageability	-.677**
Printed frequency	-.036
Rated frequency	-.385**

** $p < .001$

Significant correlations were found between age of acquisition, imageability, rated frequency and the RT outcome measure. Acronyms which were high frequency, high imageability or early acquired generated association responses more quickly than their low frequency, low imageability or late acquired counterparts. This supports the findings of the de Groot (1989) and Brysbaert et al (2000) association studies using mainstream word cues. To further explore the relationship between the lexical variables and word association latency a multiple regression analysis was performed with RT as the outcome variable. All the predictor variables were entered simultaneously. Beta coefficients for each of the predictor variables are presented in Table 4.2. Imageability and age of acquisition were significant predictors of the latency of the word association responses. The model including all the variables was able to account for over 48% of the variance in RT.

Table 4.2 – Regression coefficients for the multiple regression carried out on word association latencies.

	B	SE b	B
Age of acquisition	26.139	10.755	0.186*
Imageability	-250.075	42.472	-0.554**
Printed frequency	41.866	43.948	0.062
Rated frequency	-23.140	46.047	-0.042

Note: $R^2 = .483$ * $p < .05$ ** $p < .001$

4.3.2 Distribution analyses of word association responses.

Passes were removed from the assessments of word association responses. Spelling mistakes and typographical errors were corrected only if the participant's intended response was clear (e.g. TNT – '*dinamite*'). If the response recorded was potentially a spelling mistake but made another word, this was not altered (MRI – scam) because it was impossible to be certain of the participant's intention. Although it could be argued that the intended response is clear in this example, other instances were not so obvious. Therefore a consistent procedure was employed for all responses to all cues. Following this, the number of participants giving the same response was counted. Singular (e.g. cat) and regular plural (created by adding an "s" as in cats) forms of a word were considered to be the same response. Irregular plurals were counted as a separate response. The complete word association norms are included in appendix 4.1.

Four measures of the distribution of word association responses were computed for each item. The first was associative strength. This refers to the proportion of participants who gave the most popular associate for each acronym. For example, the most frequently given associate for BBC was "television" which was offered by 26 participants. All 47 of the participants recorded a valid association response for BBC. Therefore the associative strength for "television" is 26 out of 47, or 0.55. Further measures of word association distribution were number of idiosyncratic responses achieved by counting the number of responses given by only one participant, N = 1; the number of responses given by more than one participant, N > 1, assumed to have a degree of reliability (Nelson et al., 1995) and the total number of different responses (N) offered as an association for each acronym. .The values for associative strength, N = 1, N > 1 and N are provided in appendix 4.1. Correlations between imageability, rated and printed frequency, age of acquisition and the four measures of word association distribution are presented in Table 4.3.

Table 4.3 – Pearson's correlation coefficients between lexical variables and measures of the distribution of word association responses.

	Associative strength	Number of different responses (N)	Number of idiosyncratic responses (N = 1)	Number of repeated responses (N > 1)
Age of acquisition	-.384**	.399**	.424**	.026
Imageability	.445**	-.440**	-.487**	.021
Printed frequency	.092	-.006	-.012	.012
Rated frequency	.206*	-.251*	-.323**	.130

* $p < .05$ ** $p < .001$

Significant correlations between the lexical variables and the measures of word association distribution were found. Age of acquisition correlated negatively with associative strength, while frequency and imageability showed positive correlations. That is, a greater proportion of the participants gave the same response if the cue acronym was early acquired, high frequency and/or high imageability. A larger number of different associations were recorded in response to low frequency, low imageability or late acquired cues. The same pattern was shown in relation to the number of idiosyncratic responses. The relationship between the characteristics of the cue word and word association responses was further explored using another series of simultaneous multiple regression techniques. Four analyses were performed using the measures of the distribution of responses as dependent variables. Each analysis assessed the impact of imageability, printed frequency, rated frequency and age of acquisition. The results of these regressions are summarised in Table 4.4 below.

The N and N = 1 scores were significantly predicted by imageability and age of acquisition. Late acquired or low imageability acronyms elicited a greater number of different responses and more responses unique to one participant. Imageability also emerged as a significant predictor of the strength of association between the cue acronym and the most popular response among the participants. The greatest associative strength was observed for highly imageable acronyms.

Table 4.4 – Standardised (β) regression coefficients for the four analyses concerning word association response distribution.

	Associative strength	Number of different responses (N)	Number of idiosyncratic responses (N = 1)	Number of repeated responses (N > 1)
Age of acquisition	-.178	.232*	.249*	.011
Imageability	.379**	-.275*	-.267*	-.084
Printed frequency	.058	.064	.087	-.041
Rated frequency	-.072	-.068	-.149	.197
R^2	.227	.208	.262	.004

* $p < .05$ ** $p < .001$

4.3.3 Categorisation of word association responses

Word association responses were classified into three categories: form based, meaning based, and position based associates in line with previous research (Fitzpatrick, 2006). The meaning based category included responses that were synonyms of the acronym cue in at least one sense (e.g. ASAP – quickly) or complete forms (ASAP – as soon as possible) of the acronym. Responses were also included in the meaning based category if they had a hyponym or co-hyponym relationship with the cue. These are items from the same lexical set (see e.g. Fitzpatrick, 2006). For example, one meaning of the acronym RPG is rocket propelled grenade. It is a type of weapon, thus "weapon" is a hyponym of RPG. "Rifle" is also a type of weapon. As the hyponym for RPG and rifle is the same, they come from the same lexical set. A further type of meaning based association was derived from the fact that acronyms abbreviate several words in a phrase. Any response that was a constituent word from the full term of the cue acronym (e.g. KFC – chicken) was classed as a meaning associate. Many responses which did not fall into the above groups were nevertheless obviously meaning based associations (ECG – hospital or heart, for example). These were also included. Position based responses were those where the participant's response immediately followed the cue acronym in common sentences (as in SCUBA – diving). Associations were classed as form based when the response shared orthography or phonology with the cue, but not

meaning. These were commonly instances where letters had been transposed (FBI – FIB), substituted (TFT – TNT), added (BST – best) or omitted (RNIB – nib).

Examination of the responses indicated that in some instances associations may have been made in two steps. For example, when presented with CCCP, eight participants responded with "camera." The participants could potentially have arrived at this response by a two stage process, first transforming CCCP to the orthographically and phonologically similar CCTV and then providing the constituent word "camera." Responses of this type were counted as a separate category. Associations for which no clearly discernable link between cue and response could be found were classed as erratic responses and counted separately. Circumstances where the participant had invented a new full form for the acronym were classified as erratic responses.

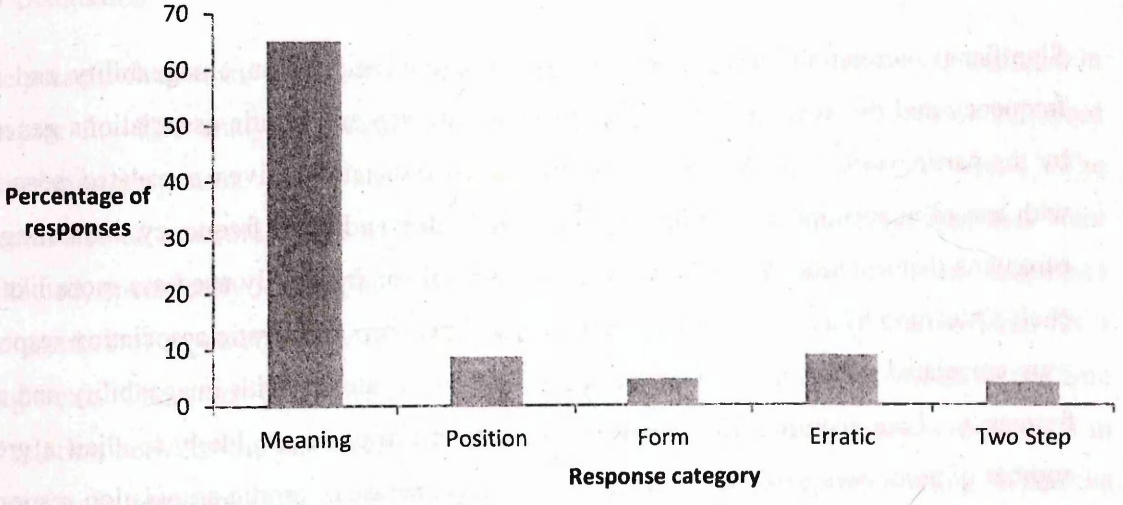


Figure 4.1 – Percentage of the total number of word association responses in each response category. The greatest number of responses was meaning based associations. Only very few association responses were based on the form of the cue.

The total number of responses classified as members of each category are presented in Figure 4.1. The majority of responses were meaning based, with only very few associations being based on form alone. Correlations between age of acquisition, rated and printed frequency and imageability and the type of association made were computed (Table 4.5). The number

of form based, position based and two step associations were log transformed prior to analysis to reduce skew.

Table 4.5 – Pearson's correlation coefficients between lexical variables and the numbers of responses categorised as being based on meaning, form and position.

	Meaning based	Form based	Position based	Two step	Erratic
Age of acquisition	-.426**	-.060	.273**	.186*	.400**
Imageability	.684**	.118	-.615**	-.403**	-.629**
Printed frequency	.112	.131	-.035	-.096	-.143
Rated frequency	.393**	.079	-.346**	-.234*	-.447**

* $p < .05$ ** $p < .001$

Significant correlations were observed between age of acquisition, imageability and rated frequency and the number of meaning, position, two step and erratic associations generated by the participants. The number of meaning based associations given correlated negatively with age of acquisition but positively with imageability and rated frequency, indicating that acronyms that are acquired early, are highly imageable or frequently used are more likely to elicit a meaning based association. Position based, two step and erratic association responses were correlated positively with age of acquisition but negatively with imageability and rated frequency. Late acquired, low frequency or abstract acronyms are likely to elicit a greater number of associates based on position, or to elicit complex or erratic association responses. The relative involvement of the lexical characteristics of the acronyms in the type of response generated by the participants was further assessed by simultaneous multiple regression as before. The regression coefficients are presented in Table 4.6. The only significant predictor to emerge in any of the analyses was imageability which successfully predicted the number of meaning based, position based, two step and erratic associations. The regression model was unsuccessful in predicting the number of form based responses.

Table 4.6 – Standardised (β) regression coefficients for the five analyses concerning word association response categorisation.

	Meaning based	Form based	Position based	Two step	Erratic
Age of acquisition	-.047	.032	-.119	-.150	.090
Imageability	.668**	.390*	-.622**	.382	-.501**
Printed frequency	.028	.048	-.014	-.181	-.029
Rated frequency	-.025	-.178	.023	.164	-.121
R^2	.455	.089	.310	.106	.393

* $p < .05$ ** $p < .001$

4.4 Discussion

The present chapter investigated word association responses to the 146 acronyms included in Chapter 3. The analysis focussed on three types of information drawn from the word association responses. First, the time taken to generate a response was examined. The second set of measures were concerned with the distribution of the responses that were collected, specifically looking at associative strength, the number of idiosyncratic responses the number of repeated responses and the total number of different responses offered for a single cue. This study is the first to include an examination of item characteristics on the type of relation between the cue and the associative response. The current study is also novel in that it uses acronym cues rather than mainstream words. An important finding is that the majority of responses elicited in a discrete association task using acronyms are related to the meaning of the cue. In contrast only a small proportion of word association responses are form based. This mirrored the findings reported by Fitzpatrick (2006) in a study using mainstream words, and supports the conclusions of researchers who have previously indicated that acronyms are integrated along with mainstream words into the mental lexicon (Besner et al., 1984; Brysbaert et al., 2009; Coltheart, 1978).

Studies of the influence of lexical variables on word association RT and distribution of associative responses have already been published (Altarriba et al., 1999; Brysbaert et al.,

2000; de Groot, 1989; Hall & Ugelow, 1957; Postman, 1964; 1970). The present study as in previous reports has found that participants are faster to respond to words which are frequent, imageable or early acquired. In addition, highly imageable cues and those that are learned early in life are also likely to produce a greater agreement between participants (i.e. a greater associative strength for the most popular response) and fewer unique responses. The same pattern was exhibited in the present study in the correlation patterns between cue characteristics and associative strength, total number of different responses and number of idiosyncratic responses. RT, number of total different responses and number of unique responses correlated positively with age of acquisition but negatively with rated frequency and imageability. Associative strength was negatively correlated with age of acquisition and positively correlated with rated frequency and imageability. Correlations with age of acquisition, imageability and rated frequency were also observed in the categorisation data. Acronyms which were highly imageable elicited a greater number of meaning based associations, as did high rated frequency and early acquired acronyms. Imageability is often described as a semantic variable, so the correlation between imageability and the number of semantic associations was predictable. The relationship observed between age of acquisition and the semantic measures used here is supportive of the suggestion made by Brysbaert et al. (2000) that age of acquisition is a semantic variable.

One finding of particular interest is that none of the word association scoring measures showed a significant correlation with printed frequency. Word association is argued to be one of the tasks best suited to examine semantic knowledge. The generation of word associations requires lexical and semantic access. In studies with mainstream words, high frequency words are recognised and named more quickly than low frequency words because the retrieval of the lexicon entry is achieved rapidly (Connine et al., 1990; Oldfield & Wingfield, 1965; Whaley, 1978; Yonelinas, 2002). Thus an effect of frequency would be expected in word association RT. The nature of acronym creation and use may be responsible for the absence of any significant correlations with printed frequency. The correlation between rated and printed frequency in the acronyms listed in Chapter 3 was significant, but relatively low at .346. Acronyms are created to abbreviate cumbersome or technical phrases, and often come from highly specialised fields. As a result acronyms with high printed frequencies may not necessarily be well known to all the participants. Low printed frequency acronyms, on the other hand, may be from a field which the participants

are particularly familiar. It is suggested, therefore, that the non-significant correlations with printed frequency indicate that objective frequency measures for acronyms may not equate to individual experience. Considering the word association task is a semantic task, knowledge of the meaning of an acronym is integral to the successful completion of the task. The fact that rated frequency correlated significantly with several aspects of word association behaviour is interpreted as evidence that subjective frequency estimates are, for acronyms at least, a better representation of lexical knowledge than objective frequency measures. Rated frequency is more likely to reflect the level of familiarity that undergraduate students have with the items. However, neither rated nor printed frequency was a significant predictor of any of the measures of word association behaviour analysed. This finding supports the interpretation of de Groot (1989) that frequent encounters with words and their assumed automatic distributed activation to related representations might not be sufficient to strengthen the connection.

The measures of acronym association behaviour were subjected to simultaneous multiple regression analyses to further examine the importance of cue frequency, imageability and age of acquisition in associative responses. Frequency, as discussed above, was not a significant predictor in any of the analyses. In contrast, imageability was a significant predictor in all of the regression models. De Groot (1989) found that imageability was an important factor in RT and associative strength in a mainstream word association task, but that frequency did not have a significant effect. De Groot (1989) argued that highly imageable words have relatively strong connections with at least one associated node and that these strong links are shared by a large number of individuals. Thus the associated concept is retrieved quickly and the same associate is offered by a larger number of participants. The same interpretation would appear to apply in the present study. Highly imageable acronyms produced more meaning based associates and fewer position-based, two step or erratic responses. It is thought likely that this effect reflects the strength of the links stemming from the nodes for imageable acronyms in semantic networks. Stolz and Tiffany (1972) showed that a greater number of meaning based associates were generated in response to familiar words than to unfamiliar synonyms. It is possible that a similar discrepancy is the foundation for the effect of imageability on acronym associations reported here. As the connections between a high imageability acronym and its related concepts are strong and salient, meaning based responses are easily generated. In contrast, the links stemming from abstract acronyms are

relatively weak. As a result they are harder to retrieve, and there is more competition between prospective associates. Under these circumstances it is possible that the first associate to be generated is based on something other than semantics.

Another factor previously shown to be influential in word association tasks is age of acquisition. Both van Loon-Vervoorn (1989) and Brysbaert et al. (2000) reported that early acquired words were quicker to produce an association response than words acquired later in life. Brysbaert et al. (2000) also found a significant effect of age of acquisition on associative strength. The authors suggested that age of acquisition had a similar influence on word association as imageability does. Specifically, Brysbaert et al (2000) pointed to the interpretation that the strength of the connections from early-acquired word nodes is greater than from nodes for late-acquired words. In the present study, age of acquisition was a significant predictor of association RT. However, no significant effect of age of acquisition was observed in the analysis concerning associative strength. Brysbaert et al. (2000) proposed that late acquired words are learned by relating the new concept to a previously existing word representation. As a result of this learning process the representations for early acquired words are accessed more often, and therefore the links to and from an early acquired node are stronger than for late acquired words. This could be used to account for the age of acquisition effects in associative strength for mainstream words. The absence of such an effect in acronym association may be a consequence of the fact that acronyms are created to abbreviate novel concepts. Thus in many cases learning a new acronym requires the acquisition of orthographic and phonological form at the same time as learning the semantic concept. Under these circumstances no earlier acquired concept node can be activated, and hence the effect of age of acquisition is attenuated. It is plausible that the effect of age of acquisition on acronym association RT reflects a difference in the speed with which early and late acquired acronyms are recognised rather than the relative strength of the intra-lexical links. This position is supported by the absence of any significant effects of age of acquisition on the category of the association responses gathered in this study. If the links between early acquired acronyms and connected concepts were strengthened with each subsequent activation, then it would be possible to expect a greater number of meaning based association responses for acronyms learned early in life.

This study has provided useful information concerning the concepts commonly associated with acronyms. The normative responses collected here will be of use in the design of associative priming experiments using acronym primes and memory tasks. Further research using acronyms and mainstream words in a word association paradigm could attempt to tease apart the speed of recognition from the latency of associate generation. A clear picture of the structure of the semantic system is yet to be achieved. A continued assessment of the characteristics of the cue word which have an impact on association behaviour could illuminate the nature of semantic networks and inform models of the lexicon.

CHAPTER 5

ACRONYM PROCESSING IN SEMANTIC DEMENTIA

5.1 Introduction

Although there are only a few studies in the literature which have assessed the lexicality of acronyms, results from Chapters 2, 3, and 4 and other studies suggest that acronyms are integrated alongside mainstream words in the lexicon (Besner, Davelaar, Alcott & Parry, 1984; Brysbaert, Speybroeck & Vanderelst, 2009; Prinzmetal & Millis-Wright, 1984). Besner, Davelaar, Alcott and Parry (1984; see also Laszlo & Federmeier, 2007) demonstrated that participants were significantly better at identifying letters embedded in acronyms than an illegal string of letters. This parallels the finding that letters in words are better identified (Gibson, Bishop, Schiff & Smith, 1964). Besner et al. (1984) also reported that, like words, acronyms were better recognized when presented in the right visual field than when presented in the left visual field. Prinzmetal and Millis-Wright (1984) provided evidence that acronyms were recognized as a whole unit in the same way as words appear to be. They found that participants made a greater number of errors when asked to name the colour of a given letter in an acronym (each letter was a different colour) than if the letters were illegal strings. This too mirrors the findings in identifying the colour of a letter in a word. Further compelling evidence for the integration of acronyms in the mental lexicon comes from the finding that acronyms can significantly facilitate lexical decision responses to semantically related words (Brysbaert, Speybroeck, & Vanderelst, 2009).

Given that acronyms are integrated in the mental lexicon, and that they have peculiar orthographic, phonological and semantic characteristics, they may prove to be a particularly useful tool in the examination of a number of issues in word reading and recognition research. In this chapter, acronyms have been included in tasks administered to a patient with semantic dementia. The term "semantic dementia" was coined by Snowden, Goulding and Neary (1989) to describe a progressive degenerative disorder of the semantic system. Semantic dementia patients exhibit atrophy in a number of fronto-temporal regions. Chan,

Fox, Scahill, Crum, Whitwell, Leschziner, Rossor, Stevens, Cipolotti, and Rossor (2001) conducted MRI scans of 10 semantic dementia patients and then detailed a pattern of tempolateral atrophy which was greater in the left hemisphere than the right, and greater in anterior regions than in posterior areas. Chan et al. (2001) highlighted that the most severe atrophy was in the entorhinal cortex, amygdala, middle and inferior temporal gyri and the fusiform gyrus. This pattern of atrophy is distinct from that observed in other frontotemporal dementias like Alzheimer's. The pattern of neurological damage in semantic dementia is coupled with a distinctive pattern of behaviour. Hodges, Patterson, Oxbury, and Funnell (1992), after the description of five semantic dementia patients, argued that it was a "clinically recognizable" (pp. 1785) disorder. The authors identified that semantic dementia was characterized by a semantic impairment while other aspects of cognitive performance are preserved. Thus, semantic dementia patients are often anomic and exhibit considerable deficits in single word comprehension and category fluency tests while their autobiographical memory and non-verbal problem solving abilities remain within the normal range (Hodges et al., 1992). Semantic dementia patients consistently score poorly on tasks tapping into semantic knowledge such as picture naming (Hodges, Graham, & Patterson, 1995), word-picture matching (Lambon Ralph & Howard, 2000) and tests of semantic association such as the Pyramids and Palm Trees test (Howard & Patterson, 1992). At the same time, these patients perform poorly on tasks traditionally considered as "lexical." These tasks do not explicitly require semantic information, but necessarily use other aspects of word knowledge such as reading (Patterson & Hodges, 1992), spelling (Graham, Patterson, & Hodges, 2000) and lexical decision. Concurrently poor performance in semantic and lexical tasks has been observed in most of the semantic dementia cases documented in the research literature. Patterson, Lambon Ralph, Jefferies, and Woollams (2006) described 14 cases of semantic dementia in which there was a strong correlation between semantic test scores and accuracy in atypical item trials in 4 lexical and 2 non-lexical tasks. This consistent relationship between semantic deficits and lexical problems in semantic dementia has been offered as evidence for the existence of a single integrated lexico-semantic system (Dilkina, McClelland, & Plaut, 2008; Patterson et al., 2006). The idea is, therefore, that this system is damaged in semantic dementia and the damage affects lexical and semantic task performance alike. It is important to mention that cases showing a considerable deficit in semantic tasks and no significant difficulties in lexical tasks have been reported (Blazely, Coltheart, & Casey, 2005; Cipolloti & Warrington, 1995; Schwartz, Saffran, & Marin, 1980). However,

Dilkina et al. (2008) highlighted that longitudinal study of the same patients has revealed that the lexical deficits are eventually observed.

Another salient feature of semantic dementia is a commonly associated deficit in reading known as surface dyslexia (Hodges et al., 1992). Surface dyslexia is a reading deficit characterised by "impaired oral reading of words where the pronunciation cannot be inferred from general knowledge of the sound structure of the reader's written language" (Jefferies, Lambon-Ralph, Jones, Bateman, & Patterson, 2004, pp.290) while the ability to read aloud stimuli that have a predictable pronunciation is preserved. Simply put surface dyslexic patients are inaccurate when asked to read aloud irregular words (particularly low frequency irregular words), but perform well when reading words with regular spelling to sound correspondences (e.g. Behrmann & Bub, 1992; Bub, Cancelliere, & Kertesz, 1985, McCarthy & Warrington, 1986; Patterson & Hodges, 1992; Shallice, Warrington, & McCarthy, 1983). Further, reading errors in these patients tend to be "regularisations" (Marshall & Newcombe, 1973) or "legitimate alternative rendering of components" (LARC) errors. Surface dyslexics pronounce irregular words as if they followed typical spelling to sound conversion processes (e.g. "pint" to rhyme with "mint"). This pattern of reading difficulty has been explained in terms of the non-connectionist dual route models of reading as an over-reliance on sublexical grapheme to phoneme correspondence processes.

The two routes of the dual route cascaded model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) use different methods to arrive at a pronunciation. Using the lexical route, the reader accesses the stored orthographic and phonological representations of the stimulus which guide them towards the correct pronunciation. Using the non-lexical route, the pronunciation of the stimulus is computed by the application of a set of spelling to sound conversion rules. For irregular words the pronunciation suggested by these two methods will be different and only the lexical route option would be the correct pronunciation. In semantic dementia, the degradation of the semantic system leads to a failure in lexical access, and an over-reliance on the non-lexical pathway. The use of the grapheme-phoneme correspondence principles results in regularisation errors (e.g. "pint" being pronounced to rhyme with "mint") and inaccurate irregular word reading. As semantic memory declines and semantic dementia progresses reading performance becomes worse. It is argued that word frequency modulates

the degeneration (Marshall & Newcombe, 1973; Paap & Noel, 1991), such that low frequency items are lost sooner than high frequency items and are susceptible to incorrect reading earlier. A similar influence of age of acquisition has also been reported. The ability to name words acquired early in life appears to be more resistant to the damage to the semantic system that late acquired words (e.g. Lambon Ralph, Graham, Ellis, & Hodges, 1998; Woollams, Cooper-Pye, Hodges, & Patterson, 2008).

There are two findings regarding acronym processing which are of particular importance in the rationale for this study. Some researchers have previously assumed that the unusual orthography and phonology of acronyms would mean that they had to be processed in a similar way to irregular words (Laszlo & Federmeier 2007a; 2007b; 2008). Irregular words do not follow the spelling to sound rules of the language and the appropriate pronunciation, according to dual route models, must be retrieved from the lexicon. However, results from Chapter 3 (also in Izura & Playfoot, under review) indicated that acronyms which are pronounced by naming each constituent letter in turn are named accurately even when participants reported no knowledge of the meaning of the acronym they were reading. Under these circumstances the reading cannot be achieved by the lexical route, as a previously unknown acronym will not be stored in the lexicon. Second, results from Chapter 3 also reported that lexical and semantic factors had a differential impact on naming responses for acronyms with different spelling to sound characteristics. Factors such as frequency, age of acquisition and imageability have an influence on lexical processing, but relatively little impact on sublexical processes. The finding that the magnitude or direction of the effects of lexical variables on acronym naming latency depends on acronym print to pronunciation characteristics may indicate that reading some acronyms requires more involvement of the lexical system than others. A parallel with mainstream word reading can be drawn here. It is commonly reported that responses to words with predictable pronunciations are not strongly affected by age of acquisition or frequency (Hino & Lupker, 2000; Jared, 1997; Monaghan & Ellis, 2002; Seidenberg, Waters, Barnes & Tanenhaus, 1984). Thus, it was argued in Chapter 3 that processing acronyms may be more complex than first thought, and that it is certainly not possible to consider all acronyms as the same type of word. It is possible that acronyms have a spelling to sound regularity which is peculiar to this type of word, and is based on a letter naming rule. If this is the case, then the naming of a subset of acronyms which follow

the letter naming rule may remain relatively unaffected by the progression of the semantic dementia.

Accounts of the deficits in semantic dementia have also been offered using connectionist models of reading. In the connectionist triangle framework (Plaut, McClelland, Seidenberg, & Patterson, 1996), a single system is used to read every word and non-word. An orthography-phonology pathway deals with stimuli with varying efficiency depending on their characteristics. Items that are high in frequency are processed more efficiently than their low frequency counterparts; items adhering to spelling to sound correspondences are processed more efficiently than items that do not follow the spelling to sound rules. This orthography to phonology pathway is adept at reading regular words and non-words. In semantic dementia reading responses for regular words and non-words remains accurate. This is argued to be because the orthography to phonology processes are unaffected by the damage to the semantic system. Crucially the pathway between orthography and phonology can be meditated by input from the semantic system. This semantic input acts to adjust the pronunciation for exception words. The semantic system learns the arbitrary connections between the spelling of a word (e.g. DOG) and the concept associated with it (e.g. a dog is an animal often kept as a pet). Therefore semantic system is less sensitive to unsystematic links between spelling and sound, and is particularly effective when the word presented for reading is an exception to the spelling rules, especially when the word is low frequency. It is argued that high frequency or regular words can be read successfully with or without semantic input. Low frequency irregular words are likely to be regularized by the direct orthography-phonology pathway alone. Thus the mediated semantic pathway is integral to correctly pronouncing low frequency irregular words correctly. This semantic contribution to reading is damaged in semantic dementia patients and becomes more severe over time. The integrative layer becomes increasingly damaged, and less support is offered for the reading of irregular words (Dilkina et al., 2008). Therefore, as semantic dementia progresses, patients' accuracy when reading exception words becomes increasingly poor.

There is an important distinction between dual route and triangle model accounts of semantic dementia and surface dyslexia which underlies the current study. Connectionist models argue that a single system is responsible for reading all words and non-words. This system uses

semantic information to mediate the conversion from orthography to phonology in irregular words. According to this model, damage to the semantic system affects the ability to perform semantic and lexical tasks at the same time. This accounts for the observed relationship between lexical and semantic deficits in semantic dementia patients (e.g. Patterson, Lambon Ralph, Jefferies, Woollams, Jones, & Hodges, 2006; Woollams, Lambon Ralph, Plaut, & Patterson, 2007). Further, this model predicts that a semantic deficit will inevitably lead to a difficulty in reading irregular words for which the mediation by the semantic system is crucial. In contrast, dual route models allow for the possibility that irregular word reading may be normal even if the semantic system is damaged. The Dual Route Cascaded model (Coltheart et al., 2001) proposed a lexical non-semantic route in which a stored representation of the orthography of a word is mapped directly onto the phonological representation, as well as a lexical semantic pathway which uses conceptual knowledge to assist in the reading process. Damage to the semantic system would affect the lexical semantic pathway, but would not necessarily have an impact on the lexical non-semantic pathway. Thus, the lexical non-semantic pathway in semantic dementia patients may still be relatively intact and available to successfully read irregular words even if comprehension for the same words was impaired (e.g. Coltheart, Saunders, & Tree, 2010). A number of cases of impaired single word comprehension with preserved irregular word reading have been described in the literature (e.g. Blazely et al., 2005; Cipolotti & Warrington, 1995; McKay et al., 2007; Schwartz et al., 1980). The dual route framework also allows for lexical decision performance to be relatively well preserved after semantic deficits are exhibited.

The present chapter used a semantic categorization task, a lexical decision task and a naming task to explore acronym processing in JD, a semantic dementia patient, and healthy control participants matched on age and education. The tests were presented to JD on three occasions across a 15 month period; the control group performed the tasks only once. The semantic categorization task required a classification of acronyms into two groups: "science and technology" or "general". As this type of categorization response explicitly requires an assessment of the meaning of an acronym, it was expected that JD would find the task particularly difficult. Previous studies have reported significant differences between the accuracy of categorization responses in semantic dementia patients and healthy controls (e.g. Bonner, Vesely, Price, Anderson, Richmond, Farag, Avants, & Grossman, 2009; Laisney, Giffard, Belliard, de la Sayette, Desgranges, & Eustache, 2011). A similar disparity was

therefore expected here. From a dual route perspective, the lexical decision task does not necessarily require a healthy semantic system in order to complete it successfully. This is because the lexical but non-semantic route would allow for successful lexical decision responses even without comprehension of the word. Connectionist models, however, would predict that JD will have difficulties with the lexical decision task once the semantic system has been damaged. From a connectionist perspective the observed influence of the semantic variable, imageability, in the lexical decision responses of healthy undergraduate participants (see Chapter 3) may indicate that JD's accuracy in lexical decision for acronyms decreases more quickly than for words. Rogers, Lambon Ralph, Hodges, and Patterson (2004) reported a study of lexical decision in 22 semantic dementia patients. The two alternative forced choice paradigm was used. In this task, two letter strings are presented simultaneously. One string is a word and the other is a non-word. The patients had to decide which string was the real word. In their study, Rogers et al (2004) presented pairs of homophones. One of the pair was a word and the other a non-word. They varied the relative orthographic typicality of the word and non-word based on bigram frequency. In one condition, the spelling of the non-word was more typical than the word (the non-word "trist" has a higher bigram frequency than the word "tryst"). In the other, the word was of higher bigram frequency ("grist" is a word with higher bigram frequency than the homophonic non-word "gryst"). The semantic dementia patients in the study tended to make their decisions based on the typicality of the spelling. Thus they performed poorly in the condition in which the non-words had higher bigram frequency than the words. Acronyms, in general, have low bigram frequencies by virtue of the way that they are created. If JD's performance is influenced by bigram frequency as shown by the patients in Rogers et al.'s (2004) study then her accuracy will be higher for mainstream words than for acronyms. Semantic dementia patients typically exhibit reading difficulties which are more severe for irregular words than for regular words. As mentioned above, it seems possible that acronyms have a peculiar kind of regularity based on their adherence to a letter by letter naming rule. The results reported by Izura and Playfoot (under review) suggest that naming responses for acronyms named one letter at a time are accurate even when participants did not previously know the acronym, and therefore lexical reading is impossible. The performance of JD on the acronym naming task may help to clarify whether some acronyms require lexical reading (as stated in the dual route model) or pronunciations constrained by the semantic system (as stated in the connectionist triangle model). The results of this study may also speak to the debate between single and dual system accounts of semantic dementia. The connectionist framework suggests that the

unusual orthography to phonology conversion in acronyms would require semantically mediated reading. Thus, acronyms and irregular words would be read with a similar level of accuracy. On the other hand, the dual route model can be used to suggest that acronym reading could potentially remain accurate after the semantic system has been damaged.

5.2 Methods

5.2.1 Patient JD

JD (born 1949) approached her GP in November 2007 with memory problems. In the next 3 months she was referred to a neurologist and then to a clinical neuropsychologist. JD was formally diagnosed with semantic dementia in November 2008. At the time of diagnosis, JD was 59 years of age. She was working as a legal secretary and had had a university education. JD is married and has two daughters in their 20s. JD was tested on the acronym tasks described in this study three times over a period of 15 months. The first session was in April 2009. During the preceding 3 months JD had performed standardized tests examining the accuracy of her reading and her ability to complete semantic, phonological and perceptual tasks. She showed the characteristic language specific impairment associated with semantic dementia (see Table 5.1). Specifically, JD had difficulty in picture naming tasks, word comprehension and verbal fluency. Her accuracy in tasks of visual perception, rhyme judgment and word repetition ability remained high. One year later, JD's accuracy in a number of the standardized tests had decreased, particularly those tasks involving semantic processes. This decrease in performance provided a foundation for the acronym tasks, which were repeated in February 2010 and again in July 2010.

5.2.2 Semantic categorisation task

5.2.2.1 Control group

Three male and 3 female native English speakers (age range 56 to 66 years, mean = 62) were recruited to complete the semantic categorisation task. All of them had normal or corrected to. normal vision, and had been successfully completed an undergraduate degree. None of the control participants had been diagnosed with any language deficit.

Table 5.1 – JD's performance in standard tests (% Accuracy) at two different points in time.

		Feb-April 2009	Feb-April 2010
Semantic	**Pyramids and Palm Trees**	83	81
	Pyramids and Palm Trees (written)	79	56
	Picture Naming (PALPA)	75	53
Reading	**Regular**	98	98
	Irregular	65	63
	Non-words	98	83
Visual Perception	**BORB – foreshortened**	100	92
	BORB – minimal features	100	92
Phonology	**Non-word repetition (PALPA)**	100	100
	Word repetition (PALPA)	100	100
	Rhyme Judgement (PALPA)	92	78

Note: Pyramids and Palm trees (Howard and Patterson, 1992), reading tasks (Castles and Coltheart, 1993), PALPA (Psycholinguistic Assessments of Language Processing in Aphasia, Kay, Lesser and Coltheart, 1992), BORB (Birmingham Object Recognition Battery, Riddoch and Humphreys, 1993).

5.2.2.2 Materials

One hundred acronyms were selected from the norms collected in Chapter 3 (also in Izura & Playfoot, under review). Acronyms were between 3 and 5 letters long (mean = 3.3). Fifty of the targets could be categorised as being related to "science and technology." This

encompassed acronyms pertaining to medicine (HIV, MMR), computing (DOS, CPU) and electronics fields (FET, TFT). The remaining 50 acronyms were part of a "general" category. General acronyms included names of organisations (BBC, BDA), abbreviations used in correspondence (RSVP, PTO) and phrases in common use such as BLT or BYOB. The two sets of acronyms were matched on printed frequency from Izura and Playfoot (under review). The mean frequency of science-related acronyms did not differ significantly from the general acronyms [$t(98) = .607$, $p > .1$). The participants were given definitions of the categories and two two-letter acronym exemplars of each before the commencement of the experimental trials. JD categorised the same materials in three sessions: one in April 2009, the second in February 2010, and JD was tested for the final time in July 2010 (see appendix 5.1).

In order to minimise the number of incorrect responses due to lack of acronym knowledge an effort was made (see below) to select acronyms that JD and the control participants would be likely to know. This was done in order to ensure that if errors occurred they would be indicative of lexical dysfunction and not simply the result of lack of acronym knowledge. Three methods were used to achieve this.

Firstly, all acronyms were selected from the normative study presented in Chapter 3 (also in Izura & Playfoot, under review). This database only included acronyms that were learned by the majority of participants (more than 50%). As acronyms are a dynamic part of the English vocabulary and new acronyms appear each year, relying on the knowledge of acronyms from a young age group (Izura and Playfoot's ratings were collected by a group with a mean age of 25 years old) might not guarantee knowledge in JD or her cohort group. Therefore, rated frequency measures for the acronyms were collected from a group of ten native English speakers (4 male and 6 female, age range 57 to 67, mean = 60.3). Ratings were made on a 7 point scale (1 = "rarely/never encountered" to 7 = "encountered more than twice a day"). The minimum rating given for the acronyms selected was 2.1 (a rating of 2 indicated "on odd occasions"). The acronym rated most familiar was encountered once a week on average (mean = 4.1). This indicates that the acronyms chosen are encountered by people of JD's age. Finally, another group of ten native English speakers (4 male and 6 female, age range 57-69, mean = 61.7) were asked to indicate whether they knew the meaning of the acronyms. All of the acronyms chosen were known by at least 8 of the 10 participants.

5.2.2.3 Procedure

Acronyms were presented centrally in black uppercase letters, Times New Roman font, size 12 points, on a white background shown on a 15.1 inch laptop screen. Stimulus presentation was controlled using E-Prime (Schneider, Eschman & Zuccolotto, 2002). Trials began with the presentation of a central fixation cross. The cross remained onscreen for 1500ms. This was replaced by a randomly selected acronym in uppercase letters. Targets remained onscreen until the participant had made a response. Responses were indicated by a button presses on a serial response box. Participants pressed the button under their right index finger if the acronym was from the "science and technology" category. Pressing the button under the index finger of the left hand indicated that the acronym belonged to the "general" category. Buttons were labelled according to the category definitions. The latency of a response was measured from the presentation of the target until the detection of a button press. The programme logged the accuracy of the response automatically.

5.2.3 Results

The percentage of correct responses given by JD and the control group in the categorisation task are presented below in Table 5.2.

Table 5.2 – Accuracy rates for JD in the semantic categorisation tasks, along with mean accuracy for the controls.

	Correct Responses (%)			
	JD			
	April 2009	**Feb 2010**	**July 2010**	**Controls**
Science	63	53	39	61
General	60	44	29	80
Overall accuracy	61	48	33	72

Overall, JD's accuracy decreased between the first session in April 2009 and the third session in July 2010. It should be noted that in the initial session only 61% of the total set of acronyms were correctly classified. Some caution may be required in the interpretation of the data from this initial session as it is possible that, in spite of the care taken in selecting the stimuli, there might have been a number of items that JD had not known the meaning of before the onset of the semantic dementia. JD's first session performance for those acronyms belonging to the 'science' category did not differ much from the control group performance. A more different outcome between JD and the control group can be detected for those acronyms belonging to the 'general' category. Nevertheless, taking the first assessment as a baseline it is possible to evaluate JD's progression of performance.

Chi square analyses for the category and time of test factors were computed separately. There was no significant difference in JD's accuracy for the science and general categories in any of the test sessions [April 2009, χ^2 (1) = .190, p >.1; February 2010, χ^2 (1) = 1.624, p > .1; July 2010, χ^2 (1) = 2.234, p > .1]. JD's overall accuracy was significantly poorer in July 2010 than it had been in April 2009, [χ^2 (2) = 30.740, p < .001]. The control participants were significantly less accurate in identifying acronyms as being related to science and technology that they were in responding to acronyms in general usage [χ^2 (1) = 8.797, p < .01]. The difference in accuracy between JD and the control participants approached significance in the initial test session [χ^2 (1) = 3.618, p = .057]. Controls were significantly better at the semantic categorisation task than JD for the remaining test sessions [February 2010, χ^2 (1) = 20.284, p < .001; July 2010, χ^2 (1) = 54.666, p < .001].

5.2.4 Discussion

Control participants performed poorly in categorising the science and technology acronyms but did better at classifying acronyms as having a 'general' meaning. There are two potential explanations for this finding. The first is that control participants did not know the science and technology acronyms prior to the experiment. This is thought to be unlikely, as care was taken to select acronyms which had been rated as known and familiar by raters of a similar age and demographic background. Alternatively, it is possible that the acronyms were known to the participants, but that their knowledge was not particularly deep. Specifically, it is

suggested that it is possible to recognize an acronym as being frequently occurring without knowing the meaning that it represents. It is also possible to acquire the form of an acronym, and the sense in which it is used, without ever having to learn the full phrase it abbreviates. In any case, it is necessary to bear in mind that JD's accuracy rate needs to be compared to a low accuracy rate in healthy participants. In the first test session, JD's performance on the semantic categorisation was only approaching a statistical difference to that of the controls. However, in the follow up test sessions her accuracy decreased dramatically. This decrease follows the pattern which would be predicted by a progressive degradation of the semantic system.

5.2.5 Lexical decision task

5.2.5.1 Control group

Six native English speakers (2 male, 4 female) were recruited to provide a comparison group. They were aged between 56 and 66 (mean = 62). All participants had university education. None of the control group had been diagnosed with language impairment.

5.2.5.2 Materials

A total of 28 words were used in the lexical decision task. Half were mainstream words, and half were acronyms. Fourteen acronyms were chosen from Izura and Playfoot (under review). Each acronym had 3 to 4 letters (mean = 3.2). It has been assumed that when the non-words in a lexical decision task resemble words (e.g. ROP) access to the stored representation of the target item is necessary before correctly identifying a word as a word. However, when the non-words are orthographically illegal (e.g. RQP) words can be visually identified based on the familiarity of the letter combinations, without the need of lexical access (Richardson, 1976). The inclusion of acronyms in the lexical decision task means that any item in the list could potentially necessitate a "word" response irrespective of orthographic legality. Thus a lexical search would be required to determine the appropriate response for every item.

The acronyms selected did not use any numerical characters (4WD), lower case letters (kJ) or consecutive letters from any of the words it abbreviates (BSc, PhD). Further, none of the acronyms chosen created a mainstream word (AIDS). Fourteen words were also selected from the CELEX database (Baayen et al, 1993). All the words were regular according to the GPC rule system and 3 letters in length. The regular words and acronyms were matched in frequency (frequency for the regular words from the CELEX database, Baayen et al. 1993; frequency for the acronyms from the AltaVista search engine, Izura & Playfoot, under review). Further, 28 non-words were created. Half were illegal non-words and were formed by changing one letter from an acronym not used in the experimental stimuli. They were 3 letters long and consisted only of consonants. The other half, were legal non-words obeying the orthographic and phonological rules of English. These were created by changing one letter of a real word not used as experimental targets. Legal non-words were 3 or 4 letters long (mean = 3.4). A list of all the stimulus items for the lexical decision task is included in appendix 5.2. The stimuli remained the same in each of the three test sessions.

5.2.5.3 Procedure

The instructions were the same for JD and for the control participants. They were told that they were about to see a series of real words and invented words, and that they had to make a decision as to whether what they saw had a meaning or not. Stimuli were presented centrally in black Times New Roman font (size 12 points) on a white background shown on a 15.1 inch laptop screen. Words and non-words appeared one at a time in a random order controlled by E-Prime (Schneider et al., 2002). Targets were separated by a fixation cross presented for 1,500 milliseconds. The stimuli remained onscreen until the participant made a response. Responses were made via a 5 button serial response box. "Yes" responses were indicated by pressing rightmost button on the response box with the right index finger. "No" responses required that the leftmost button was pressed with the left index finger. Buttons were labelled with the words "yes" and "no." The time elapsed between the presentation of the target and the participants' button press was automatically logged by the computer. Response accuracy was also recorded by E-Prime.

5.2.6 Results

The analysis here will address three basic issues. First JD's performance in terms of the type of word presented (word, acronym or non-word) will be examined. Second a comparison of JD's performance at each of the three test sessions (April 2009, February 2010 and July 2010) will be performed. This will indicate how her responses have been affected by the progression of her semantic dementia. Third JD's responses will be compared to those of the control group. JD's accuracy (percentage correct) for each type of word in each of the test sessions is presented in Table 5.3, along with the control group data.

Table 5.3 – Percentage of correct lexical decision responses for each stimulus type in each of JD's test sessions. Mean accuracy from the control group is also included.

	JD			
	Apr 2009	**Feb 2010**	**July 2010**	**Controls**
Word (e.g., ADD)	100	64	93	95
Acronym (e.g., HIV)	79	79	86	91
Illegal nonword (e.g., RQP)	86	50	64	88
Legal nonword (e.g., PAG)	57	64	43	83
Overall % accuracy	81	64	72	89

JD's accuracy changed from test to test following a u-shaped curve for all the stimuli apart from acronyms. Thus, for word trials she performed considerably worse in the February 2010 session than she did in the previous session (April, 2009) or in the subsequent session (July, 2010). Lexical decision accuracy for illegal non-words decreased from April 2009 to February 2010 and improved again in the last test session. For the legal non-words, JD made a large number of errors in April 2009. Her legal non-word accuracy improved in February 2010 before declining again. Acronym accuracy was constant across the first two sessions and improved in July 2010. JD's overall accuracy was significantly higher in April 2009 than it was in February 2010 [χ^2 (1) = 3.653, $p < .05$]. Only the decrease in accuracy for

mainstream words was significant [χ^2 (1) = 8.027, $p < .05$]. Overall, JD's performance in July 2010 was statistically similar to that in the other two sessions (both $p > .1$).

In April 2009, there was a significant difference between stimulus types in terms of accuracy [χ^2 (3) = 10.333, $p < .05$]. Thus the stimulus type had a bearing on the accuracy of JD's response. Comparison of the accuracy rates in pairs of stimulus types revealed that JD was more successful in her responses to words than to legal non-words [χ^2 (1) = 9.975, $p < .05$]. No other comparisons reached statistical significance (all $p > .1$). There was also a significant difference between stimulus types on the accuracy data collected in July 2010 [χ^2 (3) = 10.5, $p = .015$]. This time JD's responses to both acronyms and words were significantly more accurate than for legal non-words [χ^2 (1) = 5.894, $p < .05$ and χ^2 (1) = 8.838, $p < .05$, respsectively]. No other comparisons reached significance (all $p > .1$). No significant differences between stimulus types were observed in the February 2010 test session, in which χ^2 (3) = 2.489, $p > .1$. In this test session JD was equally accurate regardless of the type of item presented.

The control participants performed with equal accuracy for each stimulus type [χ^2 (3) = 1.558, $p > .1$]. JD's overall accuracy was as good as the control group in the initial test session [χ^2 (1) = 1.756, $p > .1$], but worse than the control group in February [χ^2 (1) = 10.242, $p < .01$] and July 2010 [χ^2 (1) = 5.830, $p < .05$]. Closer inspection indicated that these significant differences in accuracy were the result of an increase in the number of legal non-words which JD incorrectly accepted. The comparison of JD's accuracy for each type of stimulus in the February test session with that of the control participants revealed no significant differences (all $p > .1$). In July 2010, JD was significantly poorer at rejecting legal non-words than the controls [χ^2 (1) = 4.363, $p < .05$]. All other $p > .1$.

5.2.7 Discussion

Rogers et al. (2004) reported a two alternative forced choice lexical decision task in which semantic dementia patients were shown to respond based on the orthographic typicality (as measured by bigram frequency) of the stimuli. That is, semantic dementia patients reported that they recognized items which had common spelling patterns, and rejected those which were orthographically unusual. JD was least accurate when presented with legal non-words,

especially in July 2010. This mirrors Rogers et al.'s (2004) findings. It appears that as her semantic system degraded further, JD began to rely on visual cues. That is, in cases where JD did not recognize the item, as decision was made based on the orthography.

JD's performance was assessed on three separate occasions, and her accuracy was compared to that of a control group. A degree of caution is required in the interpretation of these results. As only a small number of items were included in each condition what appears to be a substantial improvement from 64% accuracy in identifying words in February 2010, to 93% in the July test session only constitutes an additional 4 correct answers. The control participants were able to correctly identify a high percentage of the words and acronyms presented here as being meaningful. As in the semantic categorisation task, JD's performance was comparable with that of healthy participants in the initial test session (April, 2009), but worse than controls in February 2010 and July 2010. This could be taken as evidence of the progression of the semantic dementia having an effect on performance on a task which does not specifically require semantics. However, it is important to recognize the pattern of JD's performance across the three test sessions. JD was significantly less accurate in February 2010 than she had been in April 2009. This supports the interpretation that lexical decision performance was affected by her disorder. It should be noted that overall JD performed better in the third session than she had in the second, though this increase did not reach statistical significance. Statistically, JD was as accurate overall in July 2010 as she had been in the initial test session 15 months earlier. Thus, the results reported here could be simultaneously used to argue that lexical decision performance has been adversely affected by the progression of the semantic dementia (JD versus controls), and that lexical decision can be successfully performed in spite of semantic dementia (JD's longitudinal performance).

5.2.8 Naming

In the first test session in April 2009, JD was required to read aloud 40 acronyms. Also included for naming were 40 regular words and 40 irregular words from the Bird, Howard, and Franklin (2001) database. Acronym, regular and irregular word sets were matched on spoken and written frequencies (z-scores transformations). JD's accuracy in reading mainstream words was generally very good (90% correct responses in irregular word trials, 97.5% for regular words). Her accuracy for acronym reading was considerably poorer (70%). During testing it was noted that JD was particularly prone to error when reading acronyms

containing vowels. Of the 40 acronyms, 17 included both vowels and consonants. JD performed just above chance on these acronyms reading 53% (9 out of 17) of these incorrectly. In contrast, she was correct for all but 3 of the acronyms containing consonants only (87% accurate). This result led to the distinction amongst acronyms based on their print to pronunciation patterns. Acronyms are created by taking initial letters from each of the words in a phrase and placing them side by side. This often results in groupings of consonants (BBC, GPS, CCTV). In cases such as this the only way to achieve a "sensible" phonological output is to name each of the letters in turn. Acronyms formed by only consonants could be considered *unambiguous* since their orthography dictates their pronunciation. Some acronyms, however, contain vowels and consonants in combinations which resemble English words (HIV, NATO). The presence of a vowel does not imply that the acronym would be pronounced as any other word. NATO, for example, requires a "word-like" pronunciation while HIV requires that each letter is named individually. Thus acronyms consisting of both consonants and vowels are termed *ambiguous*. The majority of acronyms can be named correctly by pronouncing each letter name in turn (the *typical* acronym pronunciation), while others such as NATO and NASA have pronunciations that are *atypical* for acronyms. The classification of acronyms according to their ambiguity and typicality gives rise to three subtypes of acronyms. These are; unambiguous typical, ambiguous typical, and ambiguous atypical acronyms. By definition, unambiguous acronyms cannot have atypical pronunciations.

Thus, for the second and third test sessions (February and July 2010) the naming task was redesigned so that the three subtypes of acronyms were equally represented. Assuming that surface dyslexic reading reflects a dysfunction of the lexical system and that reading acronyms aloud requires the lexical route, JD's accuracy ought to be equally poor for all acronyms. However, the naming of unambiguous typical (e.g., BBC) and ambiguous typical (e.g., HIV) acronyms can be achieved by the application of a letter naming rule. This leads to specific predictions for JD's responses to the acronyms. The existence of a sub-lexical letter naming route would enable JD to be accurate for unambiguous and ambiguous acronyms which are typically pronounced. This could be achieved without lexical access. In contrast, her reading would be inaccurate for ambiguous atypical acronyms which may still require lexical reading.

As ambiguous atypical acronyms are the least common, it was the selection of these which determined how the other stimuli were chosen. In total, 13 ambiguous atypical acronyms were listed in Izura and Playfoot (under review). Ten of these items were included in the naming task. To accompany them, 10 ambiguous typical and 10 unambiguous typical acronyms were selected from the Izura and Playfoot (under review) database. Twenty words (10 regular, 10 irregular) were also selected from Bird et al. (2001). Surface dyslexics have a particular difficulty in reading irregular words while regular word reading is preserved (Behrmann & Bub, 1992; Bub et al., 1985; Hodges et al., 1992; McCarthy & Warrington, 1986; Patterson & Hodges, 1992; Shallice et al., 1983). It was expected that JD would be accurate for the regular words, but make errors in the irregular word trials. Further, the inclusion of regular and irregular words allows a comparison between lexical and sublexical reading ability against which to assess acronym reading. The five sets of stimuli (regular words, irregular words, ambiguous typical acronyms, ambiguous atypical acronyms and unambiguous acronyms) were matched for z score written frequency and letter length. The same items were used in the last two test sessions (see appendix 5.3).

5.2.8.1 Control group

Three male and 3 female native English speakers were recruited for the naming task. Control participants ranged in age from 56 to 65 (mean = 61 years). None had been diagnosed with language deficits, and all had normal or corrected to normal vision.

5.2.8.2 Procedure

Each target was presented on a 15.1 inch laptop using black colour Times New Roman (size 12 point) letters on a white background. Stimulus presentation was controlled using E-Prime (Schneider et al., 2002). Participants' responses were detected by a microphone placed 10 cm from the mouth. The detection of a response sent a signal to the computer programme which initiated the presentation of the next trial. Trials were separated by a fixation cross presented for 1500ms. The latency of responses was measured from the presentation of the target until the detection of the vocal response by the microphone. Sessions were audio recorded to allow for the analysis and removal of erroneous responses.

5.2.9 Results

As the naming task was redesigned following the April 2009 test session, only two time points are represented in this analysis. JD's response accuracy in February and July 2010 sessions are shown below in Table 5.4, along with those of the control group.

Table 5.4 – Accuracy rates for JD in the naming task. Mean percentage accuracy for healthy controls is also included.

	Correct Responses (%)		
	JD		
	Feb 2010	**July 2010**	**Controls**
Ambiguous atypical (NASA)	20	10	82
Ambiguous typical (HIV)	80	90	90
Unambiguous (BLT)	90	100	100
Regular word (DRUG)	80	30	98
Irregular word (DEBT)	90	30	100

A striking decrease in accuracy was apparent in response to irregular and regular words, while performance for ambiguous typical and unambiguous typical acronyms was near ceiling. Accuracy was poorest for ambiguous atypical acronyms in both sessions.

Chi square analyses of the time of test and stimulus type factors were computed to further explore the data. In the February test session, JD's accuracy for regular word, irregular word, unambiguous acronym and ambiguous typical acronym trials were not significantly different (all $p > .1$). Ambiguous atypical acronyms were more prone to error than any other stimulus type (all $p < .05$). In July, unambiguous acronyms and ambiguous typical acronyms were responded to with equivalent accuracy [χ^2 (1) = .392, $p > .1$], and both were significantly less

prone to error than all other stimulus types (all $p < .005$). JD's accuracy for naming the stimuli did not decrease significantly for any type of item. That is to say that JD was just as successful in naming unambiguous acronyms in July 2010 as she had been in February 2010, and just as poor when faced with ambiguous atypical acronyms (all $p > .05$). In short, the type of stimulus item affected the accuracy of JD's reading but no significant decrease in performance between test sessions was observed. JD was, however, significantly less accurate in her overall reading than the control group, both in February 2010 [χ^2 (1) = 9.185, $p < .01$] and July 2010 [χ^2 (1) = 24.720, $p < .01$]. JD was significantly less accurate than healthy controls in reading each of the types of word presented in February 2010 (all $p < .01$). In July 2010, her accuracy in typically pronounced acronym trials (ambiguous and unambiguous) was equal to that of the controls. In each of the other conditions, JD performed at lower levels of accuracy than healthy participants (all $p < .01$).

5.2.10 Discussion

Control participants were particularly accurate in their reading of the words and acronyms presented, performing at or near ceiling for regular words, irregular words and unambiguous acronyms. JD's performance was also generally good in February 2010. The exception to this was ambiguous atypical acronyms, which JD read accurately only 20% of the time. Interestingly, JD's accuracy was equal to the controls for typically pronounced acronyms (both ambiguous and unambiguous) in July 2010 in spite of the decreased accuracy in other conditions. JD applied a letter naming strategy to the majority of the items in the naming task in the last test session. For the typical acronyms, this resulted in near ceiling performance. Such a strategy was inappropriate for the words and ambiguous atypical acronyms. This is taken as evidence for a possible letter-naming rule system for reading.

The suggestion of a viable letter naming route in the reading system relates to another form of acquired dyslexia, specifically alexia. Alexic patients' oral reading of words is achieved by a serial decoding of individual letters, and it is only once the final letter is named that they pronounce the word as a whole (e.g. h, e, n, hen). This results in a remarkably slow process, and linear relationship between the number of letters in word and the time taken to name a word (e.g. Patterson & Kay, 1982). It has been argued that letter-by-letter readers use this

strategy in order to compensate for an inability to access whole word forms in the lexicon (Warrington & Shallice, 1980). In the case of JD described here, it has been demonstrated that she has limited access to the lexicon, and that a letter naming system is intact and available to her when reading acronyms. Her ability to read regular words is also preserved. This may suggest that there are separate routes for letter naming and for grapheme phoneme conversion rules, and is of great importance to theories of word reading.

JD's overall success in reading the presented items was significantly poorer than the control group in both test sessions, suggesting that her reading has been adversely affected by the progression of the semantic dementia. It should be noted, however, that due to the small number of items in each condition even a single error constituted a statistically significant difference in accuracy.

5.3 General discussion

This chapter set out to examine the performance of a semantic dementia patient in one semantic, one lexical and one reading task. This study is novel in that it included acronyms among the experimental stimuli. Acronyms have been shown to be an integral part of the mental lexicon (e.g. Besner et al., 1984; Brysbaert et al., 2009; Prinzmetal & Millis-Wright, 1984). In previous research, it has been assumed that the unusual orthography and phonology of acronyms means that they are processed in a similar way to irregular words (Lazslo & Federmeier, 2007a; 2007b; 2008). The reported experiments examined this assumption. Semantic dementia is characterized by deficits in single word comprehension and word recognition, as well as a difficulty in reading aloud irregular words (Hodges et al., 1992). In the case of JD reported here, accuracy data for semantic categorization, lexical decision and naming tasks were gathered in three test sessions between April 2009 and July 2010. Overall, the results from all three tasks and all three test sessions can be summarized by three main points. First, semantic performance decreased over time. Secondly, JD's ability to perform lexical decision did not follow the same pattern of degeneration as semantic categorization performance. Thirdly, JD was able to continue to read some acronyms aloud accurately even after her irregular word reading was impaired. Each task will be discussed in turn below.

In the semantic categorization task, JD was asked to decide which of two categories an acronym belonged to. This was an explicit test of her semantic knowledge. When first tested, JD was as successful in her category decisions as the control group. In the second test session (February 2010), JD's performance was significantly poorer than the controls. This is taken to be illustrative of the damage to the semantic system caused by the disorder. As JD's semantic system degraded further and the severity of JD's dementia worsened, so too did her performance on the semantic categorization task. By the third test session in July 2010 JD was significantly poorer at the semantic categorization task than she had been 15 months earlier, and performed less accurately than controls. Similar findings have been reported in previous studies of categorization tasks in semantic dementia (Bonner et al., 2009; Laisney et al., 2011). JD's overall accuracy followed a similar pattern in the lexical decision task. She was able to recognize items with a similar level of accuracy to the control participants when the lexical decision task was first administered in 2009. However, her accuracy was significantly poorer than controls in subsequent test sessions. It is common for semantic dementia patients to exhibit deficits in lexical tasks as well as semantic tasks (Patterson et al., 2006; Woollams et al., 2007). From a connectionist standpoint, this relationship between lexical and semantic performance is inevitable as a single system underpins lexical and semantic processing. At first glance, the results of the semantic categorization and lexical decision tasks appear to support the connectionist interpretation. However, JD's accuracy in recognizing acronyms and words was not significantly poorer than that of the control participants in any of the lexical decision test sessions. The differences between JD and controls were driven by the rate of accuracy in the legal non-word trials. As the dementia progressed, JD became more likely to incorrectly classify legal non-words as being meaningful. This is similar to the findings of Rogers et al. (2004) who demonstrated that orthographic typicality was an important factor in lexical decision in semantic dementia. The dual route cascaded model of reading allows for the possibility that lexical tasks may be successfully completed in spite of semantic deficits by including a lexical non-semantic route (Coltheart, Saunders & Tree, 2010). The lexical non-semantic route may be sufficient for the completion of lexical tasks which do not require semantic information. Thus it is plausible for accuracy to remain high (e.g. Blazely et al., 2005; Cipolotti & Warrington, 1995; McKay et al., 2007; Schwartz et al., 1980). In the present investigation, JD maintained a high level of accuracy in lexical decision for acronyms which she was no longer able to categorise according to their meaning. This is supportive of the dual route model of reading.

Semantic dementia patients typically exhibit a surface dyslexic reading pattern (Hodges et al., 1992). In surface dyslexia irregular word reading is impaired while regular word and non-word reading is preserved. Surface dyslexic readers often make regularization or LARC errors, pronouncing irregular words as though they followed regular pronunciation rules. In the present study, JD became increasingly inaccurate in her reading of irregular words. This is consistent with cases described in the literature (see Woollams et al., 2007). Acronyms have been considered as a type of word which requires lexical reading, because their spelling to sound conversion is neither regular in terms of grapheme to phoneme correspondences nor consistent with word body neighbours (Laszlo & Federmeier, 2007a; 2007b; 2008). If this was the case JD would have been inaccurate in acronym naming. The connectionist triangle model posits that reading for irregular and exception words, particularly those low in frequency, is reliant on mediation of the orthography to phonology pathway by the semantic system. Thus irregular word reading will inevitably suffer as the semantic dementia progresses. A worsening semantic system would be expected to be detrimental to acronym reading too because semantic constraint would be required to alter the pronunciation of typically pronounced acronyms (particularly those which could be pronounced as whole word units). Pronouncing acronyms based on the spelling to sound conversions in mainstream words would usually result in incorrect readings. Thus semantic constraint would be required. However, JD's reading was accurate for acronyms which are pronounced by naming each letter in turn even when irregular word reading was impaired. This was true whether or not the acronyms had ambiguous spellings. This is not easily reconcilable with the connectionist framework. The architecture of the DRC, on the other hand, does potentially allow for lexical reading without semantic influence (Coltheart et al., 2010). This is due to the existence of a lexical non-semantic route. Assuming that the damage caused by the dementia has been limited to the semantic system and has left the remainder of the reading system intact, it is possible to access a stored representation from the orthographic lexicon and map it on to a representation in the phonological lexicon even if the meaning of the word is not understood. JD's continued success in reading typically pronounced acronyms could potentially be explained in this way. It is argued that such an interpretation is inappropriate here. First, the lexical non-semantic route would also be available for reading irregular words and ambiguous atypical acronyms. JD was inaccurate in irregular word and ambiguous atypical acronym reading (and indeed regular word reading). It seems unlikely that typically pronounced acronyms were read using the lexical non-semantic route while other stimuli were not. Further, JD applied a letter naming strategy to the majority of

the items presented in the naming task. For typically pronounced acronyms like HIV or BBC, such a strategy resulted in the correct pronunciation. For words and ambiguous atypical acronyms (NASA) the pronunciation of each letter in turn was inappropriate, and accuracy suffered as a consequence. The reliance on a letter by letter naming strategy for all types of stimulus is argued to parallel the patterns of regularization or LARC errors commonly reported in semantic dementia and surface dyslexia. JD's performance suggests that at least some types of acronym have a sort of regularity particular to themselves.

There is precedent for the notion of a letter by letter naming rule in the neuropsychological literature. Alexia is a form of acquired dyslexia in which patients are able to achieve the pronunciation of a word only after each letter is pronounced in turn (e.g. h, e, n, hen). This results in extremely long latencies in reading aloud mainstream words, and a linear relationship between the number of letters in the string and response time. Such length effects are usually not observed in skilled readers (New et al., 2006). In alexia, the serial decoding of the letters in the word can eventually lead to word recognition (Patterson & Kay, 1982). This has been seen as evidence that the lexicon is being accessed via a somewhat strangled route involving the spelling system. It has been argued that the letter by letter strategy is instantiated in these patients in order to overcome an inability to access visual word forms in the usual manner (Warrington & Shallice, 1980). In this way, the underlying cause for alexia is potentially similar to that which is proposed for surface dyslexia. The performance of JD in this particular study departs from the alexia literature findings in that JD was not able to access the meaning of the acronyms presented here even though her ability to sound them out was intact. This could indicate that surface dyslexia is the result of damage to the lexical store itself, and not of a disruption to the way in which the store is accessed.

In sum, the evidence gained in this investigation indicates that damage to the semantic system does not inevitably affect lexical performance, and that certain types of acronyms may not require semantic or lexical input to be named correctly. Neither connectionist nor dual route models as they currently stand are able to adequately account for JD's performance. It is argued that the connectionist interpretation of semantic dementia as a reflection of the damage to a single unified semantic system fails to accommodate the lexical decision and

naming results reported here. The dual route cascaded model is slightly more successful in that the findings of both the semantic categorization task and the lexical decision task can be explained within this framework. The damage to the semantic system was detrimental to JD's semantic categorization performance, but it is plausible that no damage had been caused to the lexical non-semantic pathway. Thus JD's ability to recognize words and acronyms was preserved. JD's naming performance, however, remains problematic for the DRC. Two possibilities are apparent. The first potential explanation is that the dual route model requires another sublexical rule system based on a letter naming rule (or a mechanism to switch from grapheme-phoneme correspondences to letter naming within the same sublexical system). The existence of such a route would allow JD to read most acronyms aloud without lexical or semantic access. However, further studies are required before firm conclusions can be drawn. A major assumption that had to be made in this case was that JD had known the acronyms selected prior to the onset of the semantic dementia. To increase the chances of meeting this assumption, acronyms were only selected if they were rated as familiar by healthy participants of a similar age. Thus, by definition, acronyms were of reasonably high in frequency, and so too were matched sets of words. Evidence suggests that high frequency words are more resistant to the progression of dementia (Lambon Ralph et al., 1998; Woollams et al., 2008). Therefore it is possible that JD's preserved lexical decision could be due to the frequency of the items presented.

CHAPTER 6

THE EFFECT OF CONTEXT ON ACRONYM NAMING PERFORMANCE

6.1. Introduction

In Chapter 5, acronyms were included in a series of tasks administered to a patient with semantic dementia. Semantic dementia is a degeneration of the semantic system which results in increasingly poor performance in semantic and lexical tasks. Associated with this semantic deficit is a pattern of reading performance referred to as surface dyslexia. Surface dyslexia is characterized by inaccuracy in reading irregular words while regular word and non-word reading is preserved. From the perspective of the dual route cascaded model (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) surface dyslexic reading is considered as an over-reliance on sublexical processes to compensate for damage to the lexical-semantic route. In Chapter 5, JD successfully read typically pronounced (letter by letter) acronyms aloud, although she was poor at classifying them according to their meaning in the semantic categorisation task. It seemed that JD was unable to access stored information about these acronyms. If this was the case, according to the dual route model, the successful pronunciation could not have been generated by the lexical semantic route. The DRC (Coltheart et al., 2001) model includes a lexical non-semantic route which allows for the preserved lexical reading in the absence of semantic information. It seems unlikely that JD's accuracy in reading acronyms could be attributed to the lexical non-semantic route, because the same pathway could have been used for reading irregular words which JD pronounced incorrectly. The grapheme to phoneme correspondence system would also offer incorrect pronunciations for most acronyms. Thus, it is possible that an alternative sublexical rule system based on letter naming is available for acronym reading. Izura and Playfoot (under review) found that healthy undergraduate participants made few reading errors for acronyms pronounced one letter at a time even if they reported not to know what the acronym meant. This cannot have been achieved via the lexical route as lexical representations will not exist for previously unknown acronyms. Since the majority of acronyms are pronounced by naming each constituent letter in turn it would be possible to correctly read most acronyms by applying a simple rule. This could require a modulation of the sublexical route proposed by

dual route models or it may add a third route to current dual route models (the lexical route, the GPC route and the acronym letter naming route). An alternative explanation is that acronym reading is handled by a completely separate reading system tailored to the orthographic and phonological peculiarities of acronyms.

One way of evaluating these interpretations of naming performance is assessing the effect of context on acronym reading. Research has shown that naming performance can be affected by the context in which items are read (Baluch & Besner, 1991; Reynolds & Besner, 2005a; 2005b; 2008; Zevin & Balota, 2000). One contending explanation for the influence of context on reading is the pathway control hypothesis (Baluch & Besner, 1991). It is based on the notion that there are two routes for reading aloud written stimuli (i.e. the DRC model) and states that this dual route reading system is flexible enough to allow skilled readers to strategically change the emphasis placed on either pathway to suit the items to be read. Specifically, the lexical pathway of the DRC is emphasised when exception words are included, as this would be the only accurate route available. In contrast, the sublexical pathway is emphasised when non-words are included in the reading task as non-words cannot be read lexically. Baluch and Besner (1991), for example, presented participants with Persian words varying in their phonological opacity. The Persian language has two written forms that vary in their print to pronunciation consistency. In one form the vowels are specified and included in the written word as diacritics above or below the word form. In the other form the diacritics are omitted. The overall word shape is the same in both forms. Baluch and Besner (1991) used the diacritic form of written Persian to consider phonologically transparent words and non-words for which the pronunciation was signalled clearly by the written form. Phonologically opaque words were written using the form of Persian without diacritics. The same orthographic form (Baluch & Besner used the example of *shp*) could represent more than one word (e.g.,ship or shop). Baluch and Besner (1991) presented opaque and transparent Persian words in two naming tasks manipulating word frequency. The first naming task included transparent and opaque words and transparent non-words. Word reading times did not exhibit effects of frequency for transparent words but did for the opaque words, such that frequent words were named more quickly. They concluded that the transparent words were processed using the non-lexical route. Reading opaque words required lexical processing to disambiguate the orthographic form and select the appropriate output. Frequency is a lexical effect which affects the speed with which the representation of

a word is accessed. The sublexical route processes the written form serially and is not sensitive to the frequency of the whole word form. Thus frequency affected the access of the opaque words from the lexicon, but had no impact on the transparent words which did not require lexical reading. In their Experiment 2, Baluch and Besner (1991) also asked participants to read opaque and transparent words aloud, but this time non-words were not presented. Frequency effects were seen this time in responses to transparent as well as opaque words. Further supportive evidence for the pathway control hypothesis was reported in a series of studies by Reynolds and Besner (2005a; 2005b; 2008) using the alternating runs paradigm. In this paradigm, stimuli are presented in a predictable sequence of conditions (AABB). The comparison is made between stay trials (a trial in condition A followed by another trial in condition A) and switch trials (A followed by B or B followed by A). Assuming that the processes required to deal with items in one condition differ from the other condition, that condition A and B are equally difficult and that changing from one process to another takes some time, it follows that responses should be slower in switch trials than in stay trials. Reynolds and Besner (2008) applied this logic to the two reading pathways. They selected irregular words and non-words for oral reading in English. Irregular words require lexical reading, as their pronunciation does not follow the grapheme to phoneme correspondences proposed by dual route models. Non-words cannot be read via the lexical route as no representations have been stored, and must therefore be processed using a sublexical route. Responses on switch trials were significantly slower than on stay trials. This is consistent with the pathway control hypothesis and was argued to reflect the alternation between the lexical and sublexical routes. In another experiment, Reynolds and Besner (2008) extended their investigation by including regular words. Within the dual route framework, a correct pronunciation for regular English words can be generated by both lexical and sublexical pathways. Thus, the assumption here is that when the lexical route is emphasised by presenting irregular words, regular words would also be read lexically and therefore no switch cost between regular and irregular words should be observed. Similarly, no switch cost between regular words and non-words should result when only non-words and regular words are presented and the sublexical route can process all types of stimuli. Reynolds and Besner (2008) reported no difference between response latencies in switch and stay trials when regular and irregular words were presented (experiment 4) or when regular words were presented with non-words (experiment 5).

Many acronyms are made up only from consonants but there are a number of acronyms that contain both vowels and consonants. Of the acronyms which include vowels a proportion are pronounced in a way which resembles mainstream words (e.g. NATO, NASA) and the rest are read by naming a letter at a time (e.g. HIV, IBS). Thus, acronyms containing consonants and vowels can be considered as ambiguous in their print to pronunciation conversion. Consonant-only acronyms (e.g. BBC, CNN) can only be read by naming each letter in turn. This type of acronym can be described as unambiguous as the orthography determines pronunciation. Naming each letter aloud is the most common, typical way of pronouncing acronyms. Acronyms like HIV and IBS can therefore be described as being ambiguous and typically pronounced. On the other hand, NATO and NASA ought to be pronounced using grapheme to phoneme correspondence rules. They are ambiguous and their pronunciation is atypical for acronyms. The combination of these characteristics (i.e. ambiguity and typicality) affords the opportunity to examine the effects of reading context on acronym naming and to investigate the potential reading routes and/or mechanisms employed when reading acronyms. Assuming that ambiguous typical acronyms (e.g., HIV) are read via a sublexical route based on a letter naming rule and that ambiguous atypical acronyms (e.g., NASA) are read by another route (GPC or lexical) the reading speed and accuracy to these ambiguous acronyms could be altered by the nature of the other words included in the task. Thus, if a large number of unambiguous acronyms (e.g., CNN) are presented along with the ambiguous acronyms the letter naming rule system would be emphasised. In these circumstances, ambiguous typical acronyms like HIV ought to be named more quickly than ambiguous acronyms with atypical acronym pronunciations like NASA. In contrast, if the majority of the stimuli in the naming task can be pronounced using grapheme to phoneme correspondences (i.e. regular words), the advantage in processing speed and accuracy should favour ambiguous atypical acronyms (NASA) over ambiguous typical acronyms (HIV). Importantly, the differential cost of switching routes for typically and atypically pronounced acronyms will only be observed if acronyms and mainstream words are accommodated within one reading system. If there is a separate system catered to acronym processing then the switch is not between one route and another, but between one entire processing system and another. Thus alternating between one system used to read mainstream words and a second system used for acronyms will incur a processing cost, and result in a slower response. This processing cost will be equivalent for ambiguous typical and ambiguous atypical acronyms, as reading either stimulus will necessitate a different set of processes from the mainstream words. That is, the cost of switching from one system (word reading) to a

second system (acronym reading) would be the same irrespective of the pronunciation of the acronym.

6.2 Method

6.2.1 Participants

Thirty native English speakers with a mean age of 20 (range 18 – 26) were recruited as participants in this study. The 3 male and 27 female participants were undergraduate psychology students at Swansea University. None of the participants had been diagnosed as dyslexic or suffered from other reading deficits, and all had normal or corrected-to-normal vision. Participants were given course credit for their participation in this experiment.

6.2.2 Materials

Twenty ambiguous acronyms were selected from Izura and Playfoot (under review). These were the same twenty ambiguous items as were presented to JD in Chapter 5. Ambiguous acronyms were presented in two contexts. One context consisted of 80 regular words. The second context comprised 80 unambiguous acronyms. Both contexts were presented alongside the ambiguous acronyms. Ambiguous acronyms are formed by vowels and consonants such that a mainstream word-like pronunciation is possible (HIV, NATO). Ten of the ambiguous acronyms chosen for this study were pronounced by naming each letter in turn (HIV, typical pronunciation for acronyms). The remaining 10 ambiguous acronyms (NATO) were pronounced according to grapheme to phoneme correspondences (atypically pronounced acronyms). The ambiguous typical (HIV) and ambiguous atypical (NATO) acronym sets were matched for printed frequency, rated frequency, summed bigram frequency, and age of acquisition as determined by non-significant t-tests (all $p > .1$). Values for these variables were taken from Izura and Playfoot (under review, http://psy.swan.ac.uk/staff/izura/acronyms.asp). The ambiguous acronyms were the stimuli of interest in this study. Participants read aloud the ambiguous acronyms in both contexts. The order of presentation of the reading contexts was counterbalanced across participants. The regular word context contained eighty mainstream words selected from the CELEX database (Baayen et al., 1993). Mainstream words were regular according to the grapheme to

phoneme correspondence rules of the DRC model of reading (Coltheart et al., 2001). Regular words contained between 3 and 5 letters (mean = 3.24). The second context used 80 three or four letter (mean = 3.49) unambiguous acronyms drawn from Izura and Playfoot (under review). Unambiguous acronyms are always pronounced in an acronym-typical manner (i.e. naming the letters). Unambiguous acronyms did not differ from the regular words in terms of length [$t < 1$], or printed frequency [$t < 1$]. Frequency values for the acronyms were taken from Chapter 3 (also Izura & Playfoot, under review); regular word frequency from CELEX (Baayen et al., 1993). The stimuli used can be seen in appendix 6.1.

6.2.3 Procedure

Stimuli were presented in black colour Times New Roman font (size 12 points) on a white background. All stimuli were presented in upper case letters. Trial randomisation and stimulus presentation was controlled using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). Participants were instructed to read aloud stimuli as they would do under any other circumstance, such as reading aloud from a magazine article, and that they should do this as quickly and accurately as possible. Once they had understood the instructions, participants began the experiment by pressing the space bar. Participants' responses were detected by a microphone placed about 10 cm from the mouth. The detection of a response initiated the presentation of a fixation cross which remained onscreen for 1500ms. This was replaced by the next target for reading. The latency of responses was measured from the presentation of the target until the detection of the vocal response by the microphone. Sessions were audio recorded to allow for the offline analysis and removal of errors. Participants were given 5 practice trials (mainstream words) at the start of the experiment to allow them to better understand the procedure and avoid practice effects. Half of the participants performed the acronym context task followed by the word context. The order of the contexts was reversed for the remaining participants. The total time taken to complete the experiment was approximately 15 minutes (five minutes for each context separated by a five minute rest period).

6.3 Results

Reading errors (2.2%) and voice key malfunctions (4.3%) were removed prior to analysis of the reaction times. Following this, the mean and standard deviation for response latencies were calculated for each participant. Responses times more than 3 standard deviations above the mean or prior to 300ms were designated as outliers and deleted. This process removed a further 1.7% of all responses. Overall accuracy was high, but two participants were deleted from the analyses because of very low (< 75%) accuracy in reading ambiguous atypical acronyms in the unambiguous acronym context. Therefore the analyses reported here were performed on the data from 28 participants.

Table 6.1 shows the mean reaction times and accuracy rates for ambiguous typical and ambiguous atypical acronyms when presented in the context of regular words or unambiguous acronyms. When the majority of the items required sequential letter naming (the unambiguous acronym context), ambiguous typical acronyms were read faster than ambiguous atypical acronyms. Participants were also more accurate for typically pronounced acronyms in this context. In contrast, ambiguous atypical acronyms enjoyed an advantage both in reaction time and accuracy when the majority of the items presented were regular words.

Table 6.1 – Mean response latencies (M) and standard deviations (SD) for ambiguous typical (HIV) and ambiguous atypical (NATO) acronyms presented in different contexts. Percentage accuracy is also included (Accuracy%).

	CONTEXT					
	Unambiguous acronym (BBC)			**Regular word (SAT)**		
	M	**SD**	**Accuracy%**	**M**	**SD**	**Accuracy%**
Ambiguous typical (HIV)	647	114	96	588	115	89
Ambiguous atypical (NATO)	722	154	92	565	87	93

Reaction time data was entered into two ANOVAs (2x2). Pronunciation typicality and reading context were submitted as within-subjects factor in the analysis by subjects. In the by-items analysis, pronunciation typicality was considered a between-subjects factor and context was treated as within-subjects. The overall main effect of context was significant [F_1 (1, 27) = 41.916, MSe = 7791.186, $p < .001$, $\eta^2 = .608$; F_2 (1, 18) = 38.674, MSe = 2793.768, $p < .001$, $\eta^2 = .682$] by subjects and by items. Responses were significantly faster in the regular word context than in the acronym context. The main effect of acronym pronunciation typicality [F_1 (1, 27) = 4.242, MSe = 4369.931, $p < .05$, $\eta^2 = .136$] was significant in the analysis by subjects, but not by items [F_2 (1, 18) = 2.525, MSe = 5065.086, $p > .1$]. The interaction between acronym pronunciation typicality and context was significant by subjects [F_1 (1, 27) = 21.043, MSe = 3124.558, $p < .001$, $\eta^2 = .438$] and approached significance by items [F_2 (1, 18) = 3.882, MSe = 2793.768, $p = .064$]. Post hoc t-test analyses (Bonferroni correction applied at $\alpha/4 = .0125$) indicated that naming times for ambiguous atypical and ambiguous typical acronyms were not significantly different when surrounded by regular words (t (27) = 1.85, $p > .1$). However, when the reading context consisted of unambiguous acronyms, ambiguous atypical acronyms had significantly longer response latencies than ambiguous typical acronyms (t (27) = 3.784, $p < .005$). The interaction is presented in Figure 6.1 below.

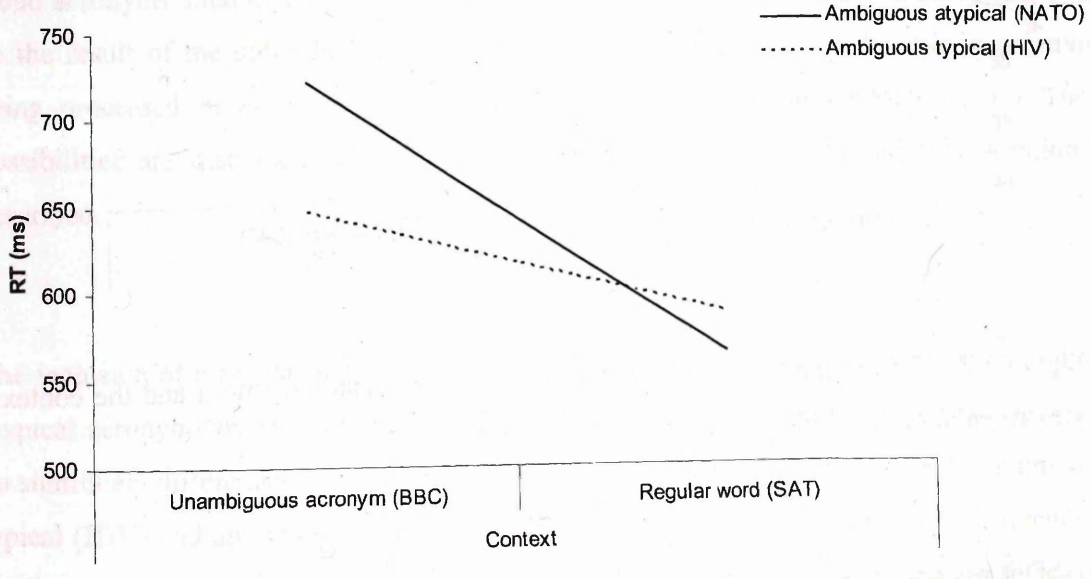


Figure 6.1 – Interaction between acronym print to pronunciation pattern and the context of the presentation for reading in RT.

Accuracy rates were arcsine transformed prior to ANOVA analysis. Two ANOVAs (2x2) were performed. Pronunciation typicality and context were treated as within-subjects factors in the analysis by subjects; pronunciation typicality was considered a between-subjects factor in the analysis by items while context was a within-subjects variable. The main effect of context was not significant by subjects [F_1 (1, 27) = 2.808, MSe = 5.284, $p > .1$] but was by items [F_2 (1, 18) = 6.291, MSe = 8.095, $p < .05$, $\eta^2 = .259$]. The main effect of pronunciation typicality was not significant by subjects or by items. A significant interaction between pronunciation typicality and context was observed in both the by subjects and by items analyses [F_1 (1, 27) = 8.411, MSe = 6.988, $p < .01$, $\eta^2 = .238$; F_2 (1, 18) = 9.047, MSe = 8.095, $p < .01$, $\eta^2 = .334$]. Responses to ambiguous atypical acronyms were more accurate when presented in the context of regular words while ambiguous typical acronyms were pronounced with greater accuracy in the unambiguous acronym context. This interaction is depicted in Figure 6.2.

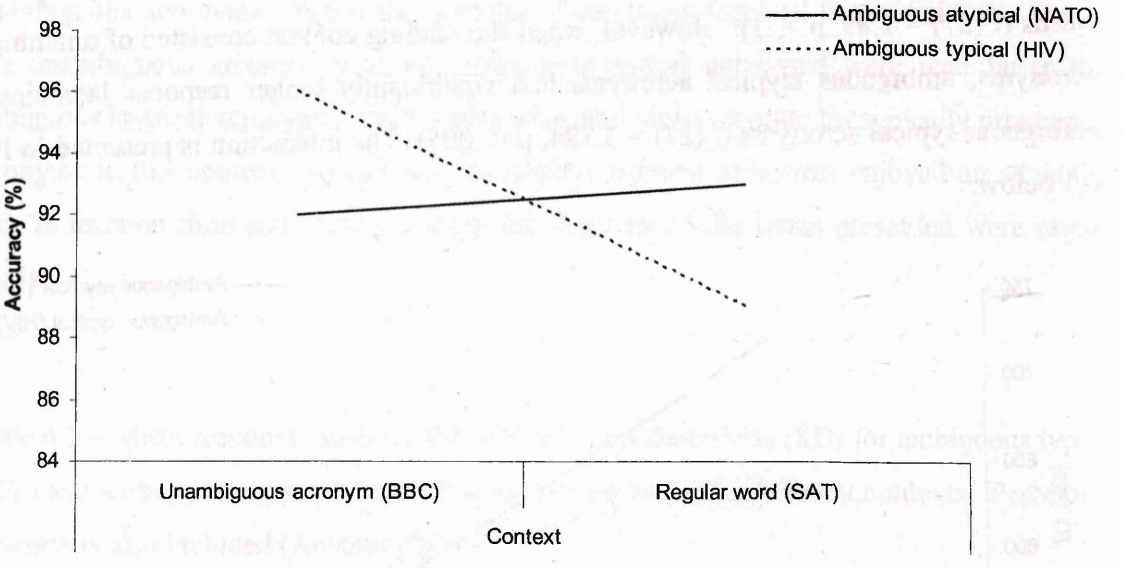


Figure 6.2 – Interaction between acronym print to pronunciation pattern and the context of the presentation for reading in accuracy

6.4 Discussion

Acronyms containing combinations of consonants and vowels orthographically plausible in English (HIV, NATO) were presented for reading aloud. Of these acronyms, half were pronounced by naming each constituent letter in turn (i.e., a typical acronym pronunciation as

in HIV), and the remainder were pronounced by grapheme to phoneme correspondences (i.e., an atypical acronym pronunciation as for NATO). Thus their orthography to phonology mapping was ambiguous. The effect of reading context on response times and accuracy was assessed by presenting either regular words or consonant-only acronyms (BBC) to examine whether acronym naming was accommodated by the standard reading system or whether the orthographic and phonological peculiarities of acronyms required a dedicated reading system of their own.

Evidence suggests that reading processes can be affected by the types of stimuli to be read (e.g. Baluch & Besner, 1991; Reynolds & Besner, 2005a; 2005b; 2008; Zevin & Balota, 2000). According to the pathway control hypothesis one of the two available routes in dual route models (Coltheart et al., 2001) can be strategically emphasised to best suit the reading material. The cost of switching from one reading pathway to another should be observable when the individual is required to name two words that allegedly require a different reading process. It was expected, therefore, that ambiguous acronyms with typical (letter by letter) pronunciations would be processed faster and more accurately when other letter-by-letter pronounced acronyms formed the context. Results showed that this was the case. Reading aloud acronyms such as HIV or IBS in the context of similarly pronounced acronyms could be the result of the individual using a sublexical pathway or it could be due to acronyms being processed in a separate system catered to their particular characteristics. These possibilities are discussed below, and a potential method for answering this question is described.

The inclusion of a regular word context was intended to create an advantage for ambiguous atypical acronyms by emphasising the grapheme to phoneme conversion system. However, no significant differences were observed in the naming times or accuracy rates for ambiguous typical (HIV) and ambiguous atypical (NATO) acronyms. The non-significant difference in reading time and accuracy for typical and atypical acronyms when presented with regular words is open to two interpretations. One possible explanation for this finding is that all the items were processed lexically. As the same pathway was utilised to process both sets of ambiguous acronyms there was no switching between grapheme to phoneme correspondences and letter naming rules. This interpretation is consistent with the pathway control hypothesis.

Baluch and Besner (1991) reported that transparent words (i.e. those with obvious spelling to sound mappings) were processed using the sublexical route when presented alongside non-words. However, when the non-words were removed from the experiment, both transparent and opaque words were read lexically. Opaque words always required lexical reading to provide the correct pronunciation irrespective of the task context. The processes used to read aloud transparent words varied according to the surrounding items. When the sublexical route was required for the task of pronouncing non-words, using the same route for transparent words was efficient. In the absence of the non-words, the lexical route could successfully process all items. Thus the most appropriate strategy was to use lexical reading. This parallels the interpretation that all items were processed lexically when regular words formed the context for reading. In the context of naming a large number of unambiguous acronyms, the use of a letter naming strategy is an efficient way of quickly and accurately completing the task. An alternative strategy is only required for atypically pronounced acronyms such as NATO. Potentially, these were processed using the lexical route (as opaque words were in Baluch & Besner's study). Replacing unambiguous acronyms with regular words altered the context, and made the lexical route the most efficient pathway for reading. The position that all items in the regular word context were processed in the lexical pathway also supports Reynolds and Besner's (2008) experiment 4 in which no switch cost was observed when naming regular and irregular words. Equally, the lack of any significant difference between reaction times in ambiguous typical (HIV) and ambiguous atypical (NATO) acronym trials could reflect an alternation between word reading and acronym reading systems. The regular words which were presented were processed by the word reading system. If acronyms are not accommodated by mainstream word reading processes, then it would be necessary to change to the reading system tailored to acronyms. The switch from word to acronym reading would result in an increase in naming time. However, this was not the case since acronyms were read faster under the regular word condition making this alternative unlikely.

One way to further examine whether acronyms are processed in the mainstream word system would be to use a task switching paradigm such as that used by Reynolds and Besner (2005a; 2005b; 2008). In this paradigm, two types of stimuli are presented in a predictable sequence. Two trials of one type (e.g. irregular words) are presented in turn, followed two trials using a different type of stimulus (e.g.non-words). This sequence is repeated. The comparison of

interest is between the reaction times in the first and second trials using the same stimulus. In the first trial, the type of stimulus that is being processed has switched from the previous trial (i.e. a non-word trial has been immediately preceded by an irregular word trial). In the second trial, the type of stimulus has stayed the same as in the previous trials (a non-word follows a non-word). The common finding is that the reaction time on a switch trial is slower than on a stay trial if different systems are needed to process the different stimulus types. The change of procedure incurs a switch cost. If all the stimuli in the experiment are processed using the same system, then reaction times in all trials are roughly equal. There is no need to alternate between procedures, and no associated cost. This paradigm offers an opportunity to explore whether acronyms are processed by a sublexical pathway in the word reading system, or whether they have their own acronym-specific reading system. Two experiments would be required. In the first, the type of stimulus presented would alternate between unambiguous acronyms (BBC) and ambiguous typical acronyms (HIV). No switch cost would be expected in this experiment irrespective of whether or not acronyms were processed in the mainstream word reading system. The second experiment would alternate presentation of irregular words (PINT) and ambiguous typical acronyms (HIV). Irregular word reading is only possible via lexical look up processes. Familiar acronyms have been argued to have lexical representations as well (Besner et al., 1984; Brysbaert et al., 2009; Noice & Hock, 1987). This means that a lexical reading procedure would allow for the correct reading of all the stimuli in the experiment, and no switch cost should be observed. This would only be the case if acronyms were accommodated within the mainstream word reading system. The existence of an acronym-specific reading system would result in a cost of switching from word to acronym reading processes in switch trials, and increased reaction times.

It should be noted that switching from one system to another does not always incur the same processing cost. For example, Meuter and Allport (1999) reported a study in which bilingual participants were required to name numerical digits in either their dominant language (L1) or second language (L2). The required response language was indicated by the colour of the screen on each trial. Meuter and Allport (1999) reported that reaction times for the second consecutive trial in the same language were faster than in trials which required a language switch. However, the size of the difference between switch and non-switch trials was affected by the language that participants were switching to. Specifically, switching from L1 to L2 incurred a relatively smaller increase in RT compared to switching from L2 to L1. The

authors explained their findings in relation to the inhibitory control model (Green, 1998). This model states that in order to perform a task in one language, lexical items in the other language need to be suppressed to prevent interlingual interference. Meuter and Allport (1999) argued that the level of inhibition required to prevent L1 knowledge from interfering with L2 responses was large. In contrast, only a small amount of L2 inhibition is required to allow successful performance in the dominant language. This has a knock-on effect on the subsequent responses given in languages that had been inhibited. Relative to L2, trials requiring L1 had to overcome a greater level of inhibition before the response could be made. A parallel with the current study could be drawn in that the majority of any English text will be made up of mainstream words, with only a few acronyms. Thus it could be argued that an acronym reading system separate from that used for mainstream words would require only a small amount of inhibition, and that the cost of switching from mainstream word reading to acronym reading would be small as a result. Again, this interpretation seems unlikely because viewing acronym reading and mainstream word reading as two distinct systems would predict no difference in RT for ambiguous atypical acronyms and ambiguous typical acronyms in the unambiguous acronym context. As all acronyms would be handled by a single system, no switch costs would be incurred. This is not borne out by the data collected in the current experiment.

The present RT data also displayed a significant main effect of context such that responses were faster in the regular word task than in the acronym task. This finding can only be reconciled with one of the potential explanations discussed here. If the non-significant differences between typical and atypical acronyms in the regular word context reflected an equivalent cost of switching from a word reading system to an acronym specific system it would follow that responses should be slower than in the acronym context when no switch is required. Dual route models contend that the lexical route is particularly quick to process common words, and that the GPC route is slower to complete processing. It would be reasonable to assume that common acronyms would also be accessed quickly in the lexical route. If a sublexical letter naming route was also integrated into the reading system it would be likely to process slowly and serially like the GPC pathway does. Thus, when the sublexical processes were emphasised by the predominance of unambiguous acronyms the overall response times would be slower. This prediction is supported by the data in the

present study, and indicates that acronym reading may be accommodated within the same reading system as mainstream words.

CHAPTER 7

THE EFFECT OF REPETITION ON ACRONYM NAMING AND LEXICAL DECISION AND AN INVESTIGATION OF LEXICALITY EFFECTS IN EVENT RELATED POTENTIALS

7.1 Introduction

Acronyms are abbreviations created by selecting the initial letters from the words in a phrase and combining them. In this way the acronym for British Broadcasting Corporation is BBC. This process means that some acronyms might be made up entirely of consonants (BBC, DVD) while others may include consonants and vowels in combinations which can be illegal in English (FBI, USB). Nevertheless, acronyms can become highly familiar to the language user and be commonly used as any other mainstream word. Evidence gathered in the present thesis along with a number of studies have attempted to determine whether acronyms are as fully lexicalised as words (Besner, Davelaar, Alcott, & Parry, 1984; Coltheart, 1978; Brysbaert, Speybroeck & Vanderelst, 2009). Although the number of studies which have integrated acronyms into word reading and word recognition experiments is small, the prevailing evidence indicates that they are lexical items. Previous researchers have presumed that the unusual orthography and phonology of acronyms would necessitate lexical reading (Laszlo & Federmeier, 2007a; 2007b; 2008). However, Chapters 5 and 6 of this thesis described two experiments which indicated that acronyms may be read via an alternative set of sublexical rules within the reading system. In Chapter 5, the performance of a patient with semantic dementia and a specific deficit in reading irregular words (surface dyslexia) was examined. It was shown that JD was able to accurately read aloud acronyms which are pronounced a letter at a time even though she was unable to identify them as familiar, or to categorise them according to their meaning. It was argued that this could not be a result of lexical reading processes. In Chapter 6, undergraduate participants' speed and accuracy in reading aloud orthographically ambiguous acronyms (HIV vs NATO) was significantly influenced by the context in which they appeared. When the majority of the items to be read were consonant-only letter by letter acronyms, participants were faster to read HIV than NATO. When the stimuli were predominantly lexically read (regular words) no difference was observed between ambiguous acronyms. This was attributed to the cost of switching between two pronunciation routines within a single system.

The interpretation discussed above that acronyms are accommodated within the mainstream word reading system is integral to the rationale for this study. In Chapter 3 the print to pronunciation characteristics of acronyms were discussed. For most acronyms, pronunciation is achieved by naming each letter in turn. This is the typical acronym pronunciation. However, some acronyms (NATO, NASA) are pronounced following the spelling to sound correspondences of English. This is the atypical acronym pronunciation. It is also the case that when acronyms do not contain vowels (BBC, DVD) naming the letters, the typical pronunciation, is the only available option. These acronyms have been thought of as unambiguous. Other acronyms contain vowels and consonants in patterns which have the potential for word-like pronunciation (HIV, NATO). However, the inclusion of a vowel does not indicate that a word-like pronunciation is appropriate. For example, HIV is pronounced by naming each letter while NATO is not. Therefore acronyms such as these have been coded as ambiguous. The combination of orthographic ambiguity and pronunciation typicality creates three types of acronym; unambiguous and typical, ambiguous and typical and ambiguous and atypical. The definition of orthographic ambiguity does not allow for unambiguous acronyms which are pronounced atypically.

It was reported in Chapter 3 that ambiguous acronyms with atypical pronunciations were named significantly more slowly than other acronyms. In that study only acronyms were presented within the reading list. It was therefore possible that some of the differences between acronym types were attributable to the context of the experiment. Specifically, the finding that ambiguous atypical acronyms (NATO) were named more slowly might have been a result of the predominance of letter by letter acronyms, as was the case in Chapter 6 of this thesis. This study aims to examine the role of the print to pronunciation characteristics of acronyms in a naming task which includes acronyms alongside mainstream words. An equal number of mainstream words and ambiguous acronyms will be presented to assess to what extent the pattern of responses may be significantly influenced by the experimental design. Furthermore, in the present chapter the same items will be shown in four consecutive blocks so the effect of repetition can be examined.

In naming experiments, interactions between regularity and frequency are commonly reported (Coltheart & Rastle, 1994; Paap & Noel, 1991; Rastle & Coltheart, 1999; Seidenberg, 1985; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Waters & Seidenberg,

1985). When words are low frequency, irregular words are read aloud at significantly greater latencies than regular words. Regularity does not affect response to high frequency words. As highlighted by Visser and Besner (2001), the regularity by frequency interaction is a consequence of the different processes in the two routes of the dual route model (Coltheart, Perry, Rastle, Langdon & Ziegler, 2001). Two points are of particular importance here. First, it is assumed that the lexical route is able to process high frequency words very quickly, but takes longer to access low frequency words. Thus the lexical route produces outputs for high frequency irregular words quickly enough that the GPC route has not been able to fully assemble the phonology. In the case of low frequency irregular words the lexical route is relatively slow to offer an output, and hence the pronunciations generated in both routes are available at the same time. The second point is that the lexical route is able to produce an accurate pronunciation for both regular and irregular words, while the GPC route will always read irregular words incorrectly. Hence, when lexical reading is slow and the output of the GPC route is available at the same time, two conflicting pronunciations of an irregular word are offered. The resolution of this conflict increases response latencies. Other factors may also influence the speed of lexical access, and age of acquisition (e.g Monaghan & Ellis, 2002) and imageability (e.g. Strain, Patterson and Seidenberg, 1995) have also been shown to interact with regularity in word naming. In each case, more difficult words (i.e. low imageability or late acquired) show a greater regularity effect. Visser and Besner (2001) demonstrated that the deficit for low frequency irregular words was attenuated by repeated presentations. Participants were presented with 80 words (20 high frequency regular, 20 high frequency irregular, 20 low frequency regular, and 20 low frequency irregular) to read aloud. The interaction between regularity and frequency was observed. Participants were then asked to read all 80 words a second time. Analysis of the RT data revealed a three way interaction between regularity, frequency and repetition such that the regularity effect in low frequency words was significantly smaller in the second presentation block. Visser and Besner (2001) accounted for this by explaining that the speed of the lexical route was increased by the repetition, and that there was therefore less opportunity for the output of the phonological route to interfere with the pronunciation of low frequency irregular words. This study aims to examine the influence of repetition on acronym naming times and accuracy in the expectation that ambiguous acronyms (particularly those which are pronounced one letter at a time) might be particularly benefitted by practice. It is predicted that the repeated presentations will speed the access of the lexical representation and decrease the opportunity for sublexical processes to influence the naming responses.

7.2 Method

7.2.1 Participants

Thirty Swansea University undergraduate students (3 male, 27 female) were recruited for this study. Participants were between 18 and 26 years old (mean 20) without diagnosed dyslexia or other reading deficit. All had normal or corrected-to-normal vision and were native speakers of English. Participants were given course credit for their participation in this experiment.

7.2.2 Materials

A total of 50 different stimuli were used in this experiment. The stimuli were presented four times in four different blocks. Stimuli consisted of ten regular words (e.g., DRUG), ten irregular words (e.g., DEBT), ten ambiguous typically pronounced acronyms (e.g., HIV), ten ambiguous and atypical acronyms (e.g., NATO) and ten unambiguous typical acronyms (e.g., LCD). These are presented in appendix 7.1.

7.2.3 Procedure

Targets were presented in black colour Times New Roman font (size 12 point) on a white background. All stimuli were presented in upper case letters. Stimulus presentation was controlled using E-Prime (Schneider, et al., 2002). Participants' responses were detected by a microphone placed 10 cm from the mouth. The detection of a response initiated the presentation of a fixation cross which remained onscreen for 1500ms. This was replaced by the next target for reading. The latency of responses was measured from the presentation of the target until the detection of the vocal response by the microphone. Sessions were audio recorded to allow for the analysis and removal of errors. At the end of each block, participants were presented with a screen instructing them that they should take a short break before pressing spacebar to begin the next block of trials. Before the experiment, participants were given 10 practice items (5 words, 5 acronyms) to give them an idea of the procedure and to allow them to decide how loud their responses had to be for the microphone to detect them.

7.3 Results

Participant errors (3.7%) and voice key malfunctions (3.5%) were deleted from the RTs analyses. Following this, a mean RT and standard deviation of responses was calculated for each individual participant. Outliers were designated as responses which were more than 3 standard deviations above the mean for each participant. The removal of outliers calculated in this way led to the deletion of a further 8.4% of responses. One participant was removed from further analysis on account of an excessive number of errors (above 30% of their responses were incorrect). Response times and accuracy rates of the remaining 29 participants were entered into by subjects (F_1) and by items (F_2) ANOVAs. ANOVAs were carried out on the responses of the first block first and on the results including the four blocks later.

7.3.1 RT analysis – Block 1 only

Mean response latencies for each stimulus type in block 1, along with their standard deviations, and percentage of accuracy are reported in Table 7.1.

Table 7.1 – Descriptive statistics for RT and accuracy to targets in each condition (ms)

	RT		Correct responses
Stimulus Type	**Mean**	**SD**	**%**
Regular Words (DRUG)	561	82	100
Irregular Words (DEBT)	571	64	99
Ambiguous Atypical (NASA)	645	77	91
Ambiguous Typical (HIV)	629	82	87
Unambiguous Typical (LCD)	604	101	99

Regular words elicited the fastest responses, while those acronyms with ambiguous and atypical pronunciations had the slowest responses. The highest proportion of correct responses came in regular word trials, with irregular word trials following close behind. Participants were least accurate when naming ambiguous acronyms with typical pronunciations.

Two ANOVA analyses (by subjects and by items) were calculated to examine the effect of the type of word on naming latencies. Type of word was treated as a within-subjects variable in the analysis by subjects and a between-subjects factor in the analysis by items. Significant main effects of type of word were found both by subjects [F_1 (4, 112) = 19.311, MSe = 1933.45, $p < .001$, $\eta^2 = .408$] and by items [F_2 (4, 45) = 8.865, MSe = 1399.497, $p < .001$, $\eta^2 = 441$]. Bonferroni corrected ($\alpha/10$) follow up t-tests by subjects indicated that regular words (561ms) were read significantly more quickly than the three acronym types (unambiguous typical, 604ms; ambiguous typical, 629ms; ambiguous atypical, 645ms). Irregular words were also shown to elicit responses significantly faster than ambiguous acronyms (typical and atypical, $p < .001$), but the latencies did not differ significantly from those of regular words or unambiguous typical acronyms. Responses to ambiguous typical acronyms did not differ in latency from the other two types of acronyms (unambiguous typical acronyms or ambiguous atypical acronyms, $p > .1$). However, unambiguous acronym trials elicit responses significantly more quickly than ambiguous atypical trials ($p < .005$).

In the by items follow up t-tests, regular words (563ms) were again read significantly faster than ambiguous acronyms (both atypical (645ms) and typical (627ms)), but responses did not differ significantly from unambiguous acronyms (602ms) or irregular words (570ms). Irregular words were named significantly faster than ambiguous acronyms (both atypical ($p < .001$) and typical acronyms ($p < .001$)). The three types of acronym were read with statistically similar latencies (all $p > .1$). Mainstream word types were statistically similar in latency ($p > .1$). In order to have a clear view of the results, a graph showing mean latencies for each condition in the analysis by subjects and by items is shown in Figure 7.1.

7.3.2 Accuracy analysis – block 1 only

Arcsine transformed accuracy percentages were entered into by subjects and by items ANOVA analyses. As in the RT analysis, the type of word was entered as a within-subjects variable in the by subjects analysis and as a between-subjects factor in the analysis by items. The main effect of type of word was not significant in the analysis by subjects [$F_1 < 1$] but reached significance by items [F_2 (4, 45) = 5.287, MSe = 2378.216, $p < .01$].

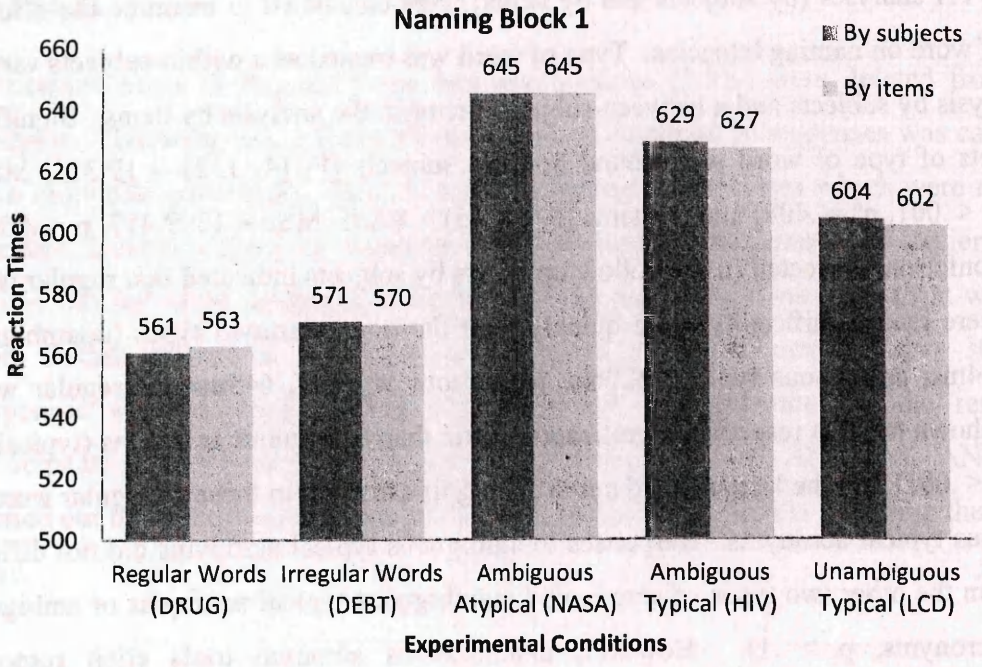


Figure 7.1 – Mean naming reaction times by subjects and by items for the five conditions of Experiment 7.1

7.3.3 RT analyses - All blocks

Table 7.2 shows the participants' mean RTs for each type of word in each presentation block. The trend shows faster responses in block 4 than in block 1. Average response times were fastest to regular words and slowest for ambiguous typical acronyms. Two ANOVA (5 x 4) analyses were carried out with type of word and block as within-subjects factors in the analysis by subjects. Type of words was a between subjects factor while block was a within subjects factor in the analysis by items.

Results indicated that the main effect of block was significant by subjects [F_1 (3, 84) = 18.513, MSe = 2748.37, $p < .001$] and by items [F_2 (3, 135) = 38.044, MSe = 437.228, $p < .001$, $\eta^2 = .458$]. Both the by subjects and by items follow up t-tests (Bonferroni correction applied at $\alpha/6 = .008$) indicated that responses in block 1 were significantly slower than those

Table 7.2 – Mean (M), standard deviation (SD) and percentage accuracy (Acc(%)) for each block and condition of Experiment 7.1.

		Regular Words (DEAL)	Irregular Words (DEBT)	Ambiguous atypical (NASA)	Ambiguous typical (HIV)	Unambiguous typical (LCD)
Block 1	M	561	571	645	629	604
	SD	82	64	77	82	101
	Acc (%)	95	94	86	79	92
Block 2	M	529	540	618	606	596
	SD	65	58	82	78	96
	Acc (%)	94	94	90	84	94
Block 3	M	524	550	605	591	566
	SD	80	78	82	95	85
	Acc (%)	96	94	90	89	92
Block 4	M	529	536	596	576	558
	SD	68	70	81	76	77
	Acc (%)	97	96	90	86	97

in blocks 2, 3 or 4 ($p < .001$). Responses in block 2 were also significantly slower than block 4 ($p < .001$), but not significantly different from block 3 ($p > .1$). A significant main effect of type of words was significant in both the by subjects [F_1 (4, 112) = 45.431, MSe = 2907.022, $p < .001$, $\eta^2 = .619$] and by items analyses [F_2 (4, 45) = 12.766, MSe = 3696.923, $p < .001$, $\eta^2 = .532$]. By subjects post hoc t-tests with a Bonferroni correction applied ($\alpha/10$) indicated that the ambiguous and atypically pronounced acronyms (e.g. NASA) were read slower than regular words, irregular words and unambiguous acronyms in the analyses by subjects and by items ($p < .001$). Regular and irregular words were also responded to faster than ambiguous typical and unambiguous acronyms ($p < .005$). By items analyses showed faster responses for regular words (536ms) and irregular words (549ms) than for ambiguous typical acronyms (603ms) and ambiguous atypical acronyms (617ms). The difference between unambiguous typical acronyms and regular words was also significant ($p < .001$). No other comparisons reached statistical significance. No interactions were significant. A graph showing mean latencies for each condition and each block is shown in Figure 7.2.

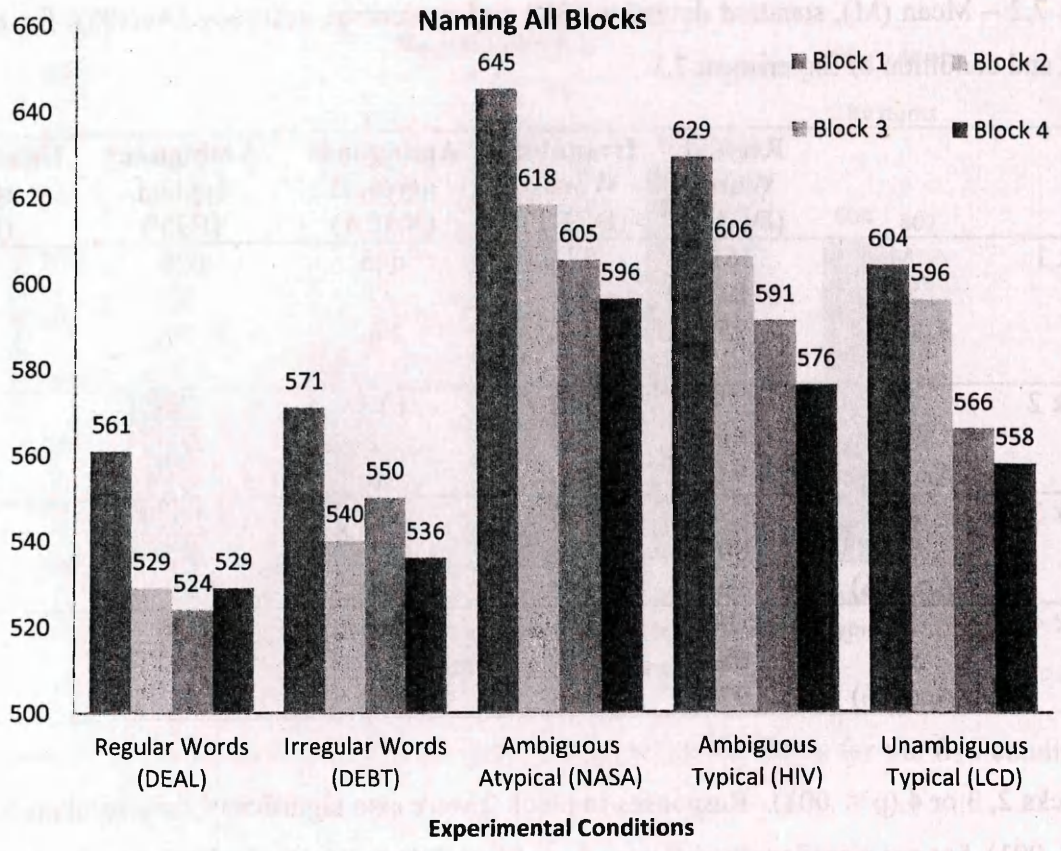


Figure 7.2 – Mean naming reaction times across block for the five conditions of Experiment 7.1

7.3.4 Accuracy analysis - All blocks

Two ANOVA (4 x 5) were carried out using arcsine transformed error percentages. The main effect of block was significant by subjects and by items [F_1 (3, 84) = 7.532, MSe = 7.292, $p < .001$, $\eta^2 = .212$; F_2 (3, 135) = 4.684, MSe = 10.284, $p < .005$]. Follow up by subjects t-tests using a Bonferroni correction at $\alpha/6 = .008$ level indicated that participants were less accurate in block 1 than in block 4 ($p < .001$). No significant pairwise comparisons were revealed in the analysis by items. The main effect of type of words was significant by subjects [F_1 (4, 112) = 17.091, MSe = 18.722, $p < .001$, $\eta^2 = .379$] but not by items [F_2 (4, 45) = 1.789, MSe = 86.313, $p > .1$]. By subjects post-hoc t-tests (Bonferroni correction applied at $\alpha/10$, $p = .005$ level) showed that accuracy for ambiguous typical acronyms (HIV) was significantly worse than for regular words, irregular words and unambiguous typical acronyms (DVD, $p < .001$ in each case). Ambiguous atypical acronyms (NATO) resulted in significantly fewer

correct responses than regular words ($p < .001$) or irregular words ($p < .001$). Ambiguous typical acronyms were also shown to be significantly less accurate than regular words in the by items analysis ($p < .001$). The interaction between block and type of word was not significant in either the analysis by subjects or the analysis by items [$F1 (12, 336) = 1.263$, $p > .1$; $F2 < 1$].

7.4 Discussion

This study set out to assess whether the differences in the print-to-pronunciation characteristics of acronyms showed some differences in acronym naming when the reading context is a mixture of mainstream words and acronyms. In Chapter 3 participants were presented with 146 acronyms for reading aloud, and reported that response latencies for ambiguous atypically pronounced acronyms (NATO) were significantly longer than for acronyms named letter by letter. However, that study contained only a small proportion of ambiguous atypical acronyms. Thus it was argued that the difference could be attributed to the context. In order to examine this possibility, naming RTs and accuracy rates were analysed in Experiment 7.1 where mainstream words were presented along with acronyms. Mainstream words were read aloud at the shortest latencies, and with the fewest errors. There was no difference between regular and irregular word trials. The lexical route was able to retrieve the addressed pronunciation with sufficient speed that no interference was caused by the output of the phonological route. Acronyms of any type elicited responses at significantly longer latencies than mainstream words. This is thought to reflect the small proportion of acronyms in every day English, and that the system is therefore not as efficient in processing them as it is with mainstream words.

Supporting the results found in Chapter 3, responses to ambiguous atypical acronyms were significantly slower than to ambiguous acronyms with typical pronunciations (see Figures 7.1 and 7.2). Both types of ambiguous acronym were slower to elicit responses than unambiguous acronyms. Unambiguous acronyms have orthographic representations which immediately signal how they should be pronounced. Thus the responses are always easier to generate than for acronyms which require the resolution of a phonological conflict.

According to Visser and Besner (2001) findings it was predicted that repetition would be of greatest benefit to ambiguous atypical acronyms. However, no interaction between type of word and presentation block was observed. The decrease in response latency was equal for all types of word. It may be the case that all the stimuli presented in Experiment 7.1 were processed via the lexical route and that no conflict from the GPC route emerged since GPC conversions cannot be applied to acronyms. If, as suggested in Chapter 6, there is a third route to enable letter by letter naming or a switching mechanism within the sublexical route to enable changing from GPC reading to letter by letter naming, this was too slow to interfere with lexical reading. Therefore all stimuli benefitted equally from repetition.

The interpretation that the differences in RT for naming various types of word is, at least in part, a consequence of the ease with which the lexical representations was again evaluated with a lexical decision task. This is because lexical decision tasks seldom reveals effects of phonology unless the task has been specifically designed to emphasise phonological information (Hino & Lupker, 1996; 2000; Seidenberg, Waters, Barnes & Tanenhaus, 1984; Waters & Seidenberg, 1985). Therefore, if the results from Experiment 7.1. are due to an 'exclusive' lexical access this would be replicated in the lexical decision since the phonological help is less needed A lexical decision task including mainstream words and acronyms was therefore devised. It could be expected that significant differences in RT would be observed amongst items in a word recognition task with mainstream words being recognised more quickly than acronyms, paralleling the findings in naming. The repeated presentation of the lexical decision stimuli might help to illuminate the effect of repetition described in the naming task.

Many of the findings relating to acronym performance suggest that they are a type of word which is less readily accessible from the lexicon (Chapters 2 & 3). A number of studies in the literature have used ERPs to examine the differences between words and non-words. These studies have identified patterns of activity which appear to differentiate between items according to their lexicality. In order to assess whether it is possible to detect differences in the electrical activity between mainstream words, nonwords and acronyms Experiment 7.2 also collected and analysed ERPs. The study is described below.

7.5 Introduction

Theoretical accounts of reading (e.g. DRC and Triangle models) are based on knowledge of the target items and of the typical responses that are collected from participants. The processes that occur in between have been inferred. Put another way, information about the items that were presented is known (i.e., their frequency, their orthographic or phonological length, their imageability value, etc.). Information about how the participants responded is also available, which items take the longest before a response is offered, and which are most susceptible to errors (Balota, Yap, Cortese, Hutchison, Kessler, Loftis, Neely, Nelson, Simpson, & Treiman, 2007). Any number of possible processing strategies or protocols could, theoretically, provide us with the same pattern of responding to the targets. Indeed, Coltheart et al. (2001) acknowledged that "even if a cognitive theory is expressible as a computer program that actually runs...some other theory of the same cognitive process may also be expressible as a computer program that actually runs" (p. 204). To constrain and inform the development of computational models and to further our understanding of reading processes it would be useful to have information about the time course of the processes involved between target presentation and participant response. In order to do this, electrophysiological data is particularly valuable.

In recent years the use of the event-related potential (ERP) technique has become increasingly common and useful in the study of language processing. The ERP technique allows brain activity to be measured with millisecond accuracy. It can therefore in principle provide information on the time course of reading with a level of detail impossible to observe with behavioural experiments. Grand average ERP waves can differ between two sets of items with particular characteristics. For example, words with high bigram frequency elicit greater amplitudes than low bigram frequency words in the P100 component (Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006; Hauk, Patterson, Woollams, Watling, Pulvermüller, & Rogers, 2006). In a recent review article Dien (2009) highlighted a number of ERP components that have been commonly identified in language studies. The literature describes two main ERP components that appear to be sensitive to the lexicality of a string of letters (i.e., whether a letter-string is a word or not). These are the N170 and the Recognition

Potential (RP). Intuitively, the major difference between words and non-words is that words are familiar items that have been experienced at least once and have a meaning while nonwords are completely novel letter structures without meaning. Therefore the study of lexicality effects can provide important information regarding the initial stages to lexical access.

The N170 is a negative deflection detected in occipito-temporal regions occurring around 150-200ms after stimulus onset. The N170 has been reported to be sensitive to lexicality because consonant strings have been shown to elicit greater N170 negativity than words (Compton, Grossenbacher, Posner, & Tucker, 1991; McCandliss, Posner, & Givon, 1997, but see Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999). Further, Maurer, Brandeis and McCandliss (2005) reported that N170 amplitude for orthographically and phonologically plausible non-words was significantly greater than for words.

One view is that the N170 reflects prelexical letter processing, as it has been reported that amplitudes in the N170 are sensitive to orthographic typicality. Evidence comes from McCandliss et al.'s (1997) study. They presented participants with three types of written stimulus. These were English words, illegal consonant strings and items from the Keki language. Keki is an artificial language created by Yang and Givon (1993). The Keki language contains 67 nouns, verbs and adjectives, and is based on a rigid subject-object-verb grammatical structure. Keki word forms resemble English orthography excepting that all words end in vowels, and contain bigrams uncommon in the English language. Participants were trained on the meaning of words in the unfamiliar language for 50 hours over a 5 week period such that their word identification ability in Keki matched that in English. Each participant took part in three ERP test sessions (before training, after 2 weeks of training, and post-training). During these test sessions, participants were presented with English words, Keki words, Keki non-words (i.e. items which followed Keki orthography but had never been trained) and consonant strings. McCandliss et al. (1997) reported that negativity was the greatest for consonant strings and the least for English words. Keki words and Keki non-words had intermediate negativities. The use of Keki allowed the researchers to track the influence of semantics on the N170. Specifically, if semantics had a role in the N170 then significantly different potentials ought to be exhibited in Keki words and Keki non-words following the 50 hour training period. No such differences were found. It was concluded

that a prelexical effect of orthography and not semantics was at work in the N170. This is also supported by the finding that activation in the N170 time window is similar for words from different semantic categories (Bentin et al., 1999; Dehaene, Le Clec, Poline, Le Bihan, & Cohen, 2002; Vigneau, Jobard, Mazoyer, & Tzourio-Mazoyer, 2005).

An alternative interpretation is that the N170 reflects lexical access. An advantage in terms of speed and accuracy for high versus low frequency words in lexical decision tasks is a commonly reported finding (Connine et al., 1990; Howes & Solomon, 1951; Oldfield & Wingfield, 1965; Whaley, 1978; Yonelinas, 2002). Gernsbacher (1984) argued that this frequency effect is the result of lexical access processes. High frequency words have higher levels of resting activation, and hence require less additional activation to reach a criterion for recognition. Frequency effects have also been reported in ERP recordings of the N170 component. For example, Hauk and Pulvermuller (2004) presented participants with a lexical decision task in which word length and word frequency were orthogonally manipulated. Monosyllabic (short) and disyllabic (long) words were selected to have low, medium or high frequencies. A main effect of frequency on ERP amplitude was found between 150 and 190ms after stimulus onset. High frequency words elicited significantly smaller negative amplitudes and faster reaction times than low frequency words. Similar frequency effects in early ERPs have been reported by a number of studies (Assadollahi & Pulvermuller, 2001; Hauk et al., 2006a; Sereno, Rayner, & Posner, 1998). Hauk and Pulvermuller (2004) concluded that early frequency effects in the ERP indicated neuronal plasticity in visual word recognition systems, such that as a word is encountered more often the level of activation that is required to retrieve it becomes lower. They concluded that lexical access was an early process, completed less than 200ms after the presentation of a written word, and that later frequency effects in ERPs were likely to be post-lexical processes. In sum, the N170 could be an index either of the familiarity of the letter patterns within a written stimulus, or of the recognition of the stimulus as a word.

The Recognition Potential (RP, Rudell, 1990) is a negative deflection occurring around 250ms after the presentation of a word. The latency of the RP peak can be affected by the stimuli which are presented. For example, Rudell and Hua (1995) presented participants with five types of image varying in visual quality. Items were presented in a rapid stream, each being onscreen for 100 milliseconds. Ten high frequency words were selected from Kucera and Francis (1967) and were presented as complete and unaltered (non-degraded) images.

The second condition randomly deleted 15% of the pixels from the non-degraded word images and replaced them with an equal number of pixels in order to create degraded word stimuli. Two sets of ten control stimuli were created by rearranging small sections of the degraded word images. The control stimuli had the same number of lit pixels as either type of word image but were not recognisable as meaningful. Finally, the rapid stream stimulation paradigm required 100 background images, created in the same way as the control stimuli. Background stimuli were presented every 100ms for between 1 and 1.4 seconds, at which point either a control, degraded or non-degraded word image appeared. The alternation of background stimuli and experimental stimuli continued for 70 seconds per stream. Participants were required to lift their index finger from a phototransistor when they detected a word image. The average RP peak was observed at 231ms after the presentation of a non-degraded word image. The peak was observed significantly later (266ms) in degraded word image trials. The authors argued that the RP was an index of recognition which varies in latency depending on the difficulty of the visual perceptual task. Supportive findings were reported by Rudell and Hua (1997) in two experiments examining the RP. In experiment 1, participants were presented with four types of stimuli - easy words, hard words, random letter strings and control images (i.e., 4 letters plus one non-letter character). Word difficulty was an estimation of the 'level of development that seem more appropriate for each word' (Rudell & Hua, 1997, p.1172). Targets were presented using the rapid stream stimulation procedure, and participants indicated that a word had been presented by removing their index finger from a phototransistor. Rudell and Hua (1997) reported that while the RP in easy and hard words did not differ in amplitude, peak latency was detected significantly earlier for less difficult words. In experiment 2, RP latency to recognise 10 'easy' words was compared with reading ability as scored on the verbal section of the Graduate Record Examination test (GRE, Graduate Record Examinations Board, 1992). Results showed that RP latency was related to verbal ability, with lower scores on the GRE having the latest RP peaks. Rudell and Hua (1997) concluded that RP latency was a reflection of the speed of recognition, and that the ease with which information could be extracted from the visual image was based on language skill. Easy words are more readily perceived to be words than hard words, and hence the latency of the RP is shorter. Likewise, perception of a word is faster for someone with greater language skill and this too reduces the RP latency.

Other studies have interpreted RP as an index of semantic processing. RP differences have been found when processing words belonging to different semantic categories (Mari-Beffa, Valdes, Cullen, Catena, & Houghton, 2005; Martin-Loeches, Hinojosa, Gomez-Jarabo, & Rubia, 2001), as well as when individuals are exposed to words varying in their level of concreteness (Martin-Loeches, Hinojosa, Fernandez-Frias, & Rubia, 2001). Interestingly, the RP appears to reflect automatic semantic processing. Mari-Beffa et al. (2005) measured reaction times in a primed lexical decision task. Primes were either related or unrelated in meaning to the targets. In one condition participants were asked to categorise the prime as living or non-living. The other condition required the participants to detect the presence of the letter "E" or "A" in the prime. Lexical decision responses to subsequent targets were recorded. When asked to categorise the prime, participants' responses were facilitated by semantically-related primes (i.e. responses were significantly faster than to unrelated primes). However, no priming was observed in the letter search condition. Mari-Beffa et al. (2005) also analysed the electrophysiological activity following the presentation of the primes in the RP time window. RP amplitudes were significantly smaller for living than non-living primes as had been previously reported (Martin-Loeches et al., 2001a). This difference in the RP amplitude was observed irrespective of whether the participants were performing the letter search or the categorisation task. Thus the RP was argued to be a reflection of automatic semantic processing for words.

Rudell and Hua (1997) acknowledged that the patterns of results they found related to the RP could also be because it was sensitive to semantic processing of the stimuli, or because the processes reflected in the electrophysiological response were related to orthographic analysis. To address this issue, Martin-Loeches, Hinojosa, Gomez-Jarabo, and Rubia (1999) carried out a study using rapid stream presentation of single words. They presented five types of stimuli varying in orthography and semantics. First, familiar Spanish words (as indicated in Alameda & Cuetos, 1995) were selected. These were both orthographically legal and meaningful. The second type of stimuli was Spanish pseudo-words which were orthographically legal, but devoid of meaning. Orthographically illegal non-words were created by randomly rearranging the letters from the familiar Spanish words selected above. A third type of non-words (control non-words) included letters and non-letter characters, so that they were both meaningless and orthographically impossible. Background stimuli resembling the control non-words were also used. A succession of 6 or 7 background stimuli

was presented, followed by a test stimulus (word, pseudoword, illegal non-word or control non-word). Participants were instructed to press a button whenever they saw a meaningful word. Analysis of the ERP recordings indicated that words elicited significantly greater amplitudes than orthographically legal non-words. RP amplitudes for random letter strings were non-significantly lower than for orthographically legal non-words. Martin-Loeches et al. (1999) concluded, therefore, that the RP was sensitive to both orthography and semantics, gradually increasing in amplitude with each stage of the reading process. In a review of the literature, Martin-Loeches (2007) highlighted a parallel between the RP and the visual word form area (VWFA), as both appeared to originate in the left mid-fusiform gyrus (Price, 2000; Martin-Loeches et al., 2001a; Dien, Frishkoff, Cerbone, & Tucker, 2003), and both show sensitivity to semantics and word form. Following this interpretation, Martin-Loeches (2007) suggested that the involvement of phonology in the RP required investigation, as the VWFA has been shown to be affected by phonological features (see Price & Devlin, 2003). This was one aim of the present experiment.

The orthographic and semantic characteristics of acronyms can be of use in reading research, especially in the context of the two ERP components mentioned before, the N170 and the RP. Describing acronyms by their print to pronunciation characteristics allows an examination of the lexicality effects reported in the N170 and Recognition Potential components. By including acronyms it is possible to manipulate orthographic legality within lexical, meaningful stimuli. Unambiguous acronyms (BBC) resemble illegal consonant strings, yet the acronym represents a specific meaning while random consonant strings have no semantic content. Ambiguous acronyms, on the other hand, more closely resemble mainstream words in their orthography. The combination of meaning and orthography in acronyms allow specific predictions to be made regarding the amplitudes in N170 and the RP time windows. Acronyms with ambiguous orthographies (e.g. HIV, NATO) can be predicted to have N170 amplitudes similar to those in mainstream words. This does not differentiate between an orthographic typicality account of the N170 and the lexical access explanation, because the letter structure of ambiguous acronyms is similar to the letter structure of mainstream words, and because acronyms and mainstream words both have lexical representations. However, the N170 for unambiguous acronyms (like BBC) will only support one of the two accounts. The hypothesis that the N170 component reflects orthographic typicality would predict that unambiguous acronyms (like BBC) and consonant strings without meaning (like RQP) would

have similar patterns of activation in the N170 time window. Both consonant strings and unambiguous acronyms contain letters in combinations which are uncommon in English. This unusual orthography would be predicted to elicit greater N170 negativity than the commonly encountered letter patterns in mainstream words. On the other hand, if the N170 component reflects lexical access unambiguous acronyms should have similar amplitudes to mainstream words of the same frequency, and significantly less negative N170 amplitudes than consonant strings without lexical representations.

The predictions for the RP window are a little more complex. RP peaks have been reported to gradually increase as the stimulus becomes more "word-like" in orthography, and more meaningful. It has therefore been suggested that orthography and semantics have a part to play in the recognition potential. Following this interpretation, an increase in RP amplitude could be predicted from each stimulus type to the next. Illegal letter strings would be expected to elicit the smallest amplitudes in the RP window. The illegal orthography of an unambiguous acronym (BBC) coupled with its semantic content would be likely to lead to an increase in amplitude relative to non-words. Mainstream words and ambiguous acronyms (HIV, NASA) have similar orthography, and all represent specific meanings and concepts. Thus it is expected that the RP amplitudes will be highest for these stimuli. The inclusion of items with differing pronunciation methods may help to illuminate any role of phonology in the RP peak. Ambiguous typical acronyms are pronounced one letter at a time, regular words (and most ambiguous atypical acronyms) are pronounceable following grapheme-phoneme correspondences and irregular words require lexical reading. A difference in RP amplitude between these types of word may indicate an influence of phonology.

This study, therefore, sets out to address three questions. First, the reaction time and accuracy data from the lexical decision task will be examined to assess whether findings from Experiment 7.1 can be replicated in a task without a direct need of the phonological representations. Secondly, an attempt will be made to determine whether the N170 component reflects sensitivity to orthographic typicality or early lexical access. The amplitudes recorded in unambiguous acronym (BBC) trials are of particular interest here, as they have a definite meaning even though their orthography is similar to non-words. Finally, the influence of orthography, meaning and phonology on the recognition potential will be

assessed with reference to the RP amplitudes observed in ambiguous acronym and mainstream word trials.

7.6 Method

7.6.1 Participants

Sixteen right handed native English speakers with a mean age of 25 years (range 19 – 46) were recruited as participants in this study. The 7 male and 9 female participants were undergraduate or postgraduate students at Swansea University. None of the participants had been diagnosed as dyslexic or suffered from other reading deficits, and all had normal or corrected-to-normal vision. Participants were paid £15 for their time.

7.6.2 Materials

A total of 100 stimuli were selected for the lexical decision. Items were between 3 and 5 letters in length. Half of the stimuli were words and half were non-words invented for this study. Of the words thirty were acronyms (the same as those used in Experiment 7.1). The acronyms represented the three print-to-sound patterns found in acronyms as a result of combining their pronunciation ambiguity and typicality. Unambiguous and typical acronyms are made up entirely of consonants (e.g. BBC). Their configuration dictates that they must be pronounced by naming each letter in turn. Ambiguous acronyms contain consonants and vowels in combinations such that word-like pronunciations are possible. Ambiguous acronyms may be pronounced either as a typical acronym (by naming each letter e.g. HIV) or as an atypical acronym (following grapheme-phoneme conversion rules e.g. NASA). Specifically, there were 10 unambiguous typical acronyms, 10 ambiguous typical acronyms and 10 ambiguous atypical acronyms. Acronyms did not contain more than one consecutive letter from any of the words they abbreviated nor did they contain numerical characters. A full list of the stimuli is available in appendix 7.2. Twenty words (10 regular, 10 irregular) were selected from Bird, Franklin and Howard's (2001) database on the basis of frequency. Words were the same as those used in Experiment 7.1.

Fifty non-words were created so that equal numbers of yes and no responses were required from the participants. It was important to create non-words such that orthography alone did not indicate the appropriate response. If the only consonant strings presented were unambiguous typical acronyms, for example, a yes decision could be achieved for these items without lexical access. Therefore 10 non-word items were created by changing one letter of an acronym not used in this experiment. These were made up solely of consonants and are referred to as illegal non-words hereafter. The 2 word and 2 ambiguous acronym sets included consonants and vowels in combinations which are plausible in English. Therefore 40 non-words were generated by changing one letter of a word such that their consonant vowel structure would also be plausible. The non-words created in this way were pronounceable by application of grapheme – phoneme correspondence rules, but had no meaning. These are referred to as legal non-words. Care was taken to ensure that the non-words created were not, in fact, acronyms. Stimuli are presented in appendix 7.2.

7.6.3 Procedure

Targets were presented centrally in upper case black colour, size 12, Times New Roman font on a white computer screen measuring 19 inches in diameter. Participants were required to decide whether a presented letter string was meaningful and indicate their decision via a serial response box. Each trial proceeded as follows. First, a blank screen was presented for 1500ms. This was replaced by a central fixation cross. This was an indication to the participant that a target item was about to be presented, and that they ought not to blink until after they had made their response. The fixation cross remained onscreen for 500ms, whereupon the target was presented in its place. Participants were required to press the blue button on the response box with their right middle finger when the target was meaningful (i.e. a standard word or acronym) and the red button under their right index finger if the target had no meaning (i.e. a non-word). Once participants made a response, the program automatically recorded the response time and the next blank screen appeared. Participants were instructed that they should blink while the blank screen was presented. Prior to the commencement of the experimental trials, each participant was presented with 15 practice items, 5 words, 5 acronyms and 5 non-words. Practice items were not repeated in the experimental materials. During practice, automated feedback was offered to the participants. Depending on the accuracy of the response, "correct" or "incorrect" was printed onscreen for 1000ms before the blank screen appeared. This feedback was not available during the experimental trials. It

was made clear to the participants that they should respond as quickly and as accurately as they could. Participants were also made aware of the importance of remaining still during the experiment. Stimulus presentation was controlled using E-Prime (version 1.1.4.1, Psychology Software Tools Inc., 2002). The 100 items were repeated in four experimental blocks, thus participants made a total of 400 lexical decision responses. At the end of a block, participants were allowed a short interval to rest. They signalled that they were ready to continue by pressing the "meaningful" response button. Targets were presented in a different randomised order in each block.

7.6.4 Electrophysiological Recording

Continuous electroencephalographic (EEG) traces were recorded from 28 Ag/AgCl electrodes positioned according to the 10/20 system. Data was sampled at a rate of 500 Hz with a band pass filter at 30Hz, 12db/oct roll off, using SynAmps amplifiers (NeuroScan Labs, Sterling, USA). Impedances for each channel were less than 50 kΩ. A reference electrode was placed on the earlobe of the participant. Electrodes placed on the forehead were used to reject eye blinks. The EEG recording included triggers indicating target presentation type and response accuracy. The continuous recording was split into 600ms epochs ranging from 200ms before the onset of the target until 400ms after target presentation. Only correct trials were included in the analyses. For each channel the mean amplitude recorded in the 200ms prior to target onset was subtracted from all time points and the data were common average re-referenced. Grand average event related potentials were computed for each stimulus type. Amplitude analysis was based on windows surrounding the latency of the peaks +/- 30ms.

7.7 Results

7.7.1 Behavioural Data

Participant errors (6.1% of all trials) were deleted from the data set before continuing with the analyses. For each participant, mean response times (RT) and standard deviations were calculated based on correct trials. Any responses occurring more than three standard deviations above the mean RT for each participant were considered outliers and removed

from further analysis (1.9%). Participant response times and accuracy rates were entered into both by subjects (F_1) and by items (F_2) ANOVAs. Only responses in acronym and word trials were analysed as these were the conditions of interest. ANOVAs were carried out on the responses of the first block first and on the results including the four blocks later.

7.7.1.1 RT analysis – Block 1 only

Mean response latencies for each stimulus type in block 1, along with their standard deviations, and percentage of accuracy are reported in Table 7.3.

Table 7.3 – Mean, standard deviation (SD) and percentage accuracy (%) for all conditions in block 1 in Experiment 7.2.

	RT		Correct responses
Stimulus Type	**Mean**	**SD**	**%**
Regular Words (DRUG)	668	174	99
Irregular Words (DEBT)	706	177	98
Ambiguous Atypical (NASA)	766	135	94
Ambiguous Typical (HIV)	863	206	77
Unambiguous Typical (LCD)	828	173	89

Regular words elicited the fastest responses, while those acronyms with ambiguous and typical pronunciations (e.g., HIV) had the slowest responses. It is apparent that the highest proportion of correct responses came in regular word trials, with irregular word trials following close behind. As in the RT data, the worst performance was observed in ambiguous and typical acronym trials.

To examine the RT data further, two ANOVAs (one by subjects and one by items) were computed. Type of word was treated as a within-subjects factor in the by subjects analysis and a between-subjects factor in the analysis by items. Greenhouse-Geisser corrections were used wherever the assumption of sphericity was violated to adjust the degrees of freedom and reduce the possibility of incorrectly accepting the null hypothesis. A main effect of type of word was observed [F_1 (4, 60) = 16.036, MSe = 11260.483, $p < .001$, $\eta^2 = .517$; F_2 (4, 45) = 6.435, MSe = 15095.903, $p < .001$, $\eta^2 = .364$]. Post hoc t-tests were computed to further explore the effect that type of word had on decision times. Bonferroni correction at $\alpha/10$ level (0.005) was applied for all follow up t-tests to control for Type I errors. In the analysis

by subjects, results showed that participants identified regular words significantly faster than the three types of acronyms: ambiguous but typical acronyms such as HIV ($p < .005$), unambiguous and typical acronyms such as DVD ($p < .001$) and ambiguous and atypical acronyms such as NATO ($p < .005$). Irregular words were also recognised significantly faster than ambiguous and typical acronyms (HIV, $p < .005$) and unambiguous and typical acronyms (DVD, $p < .005$). The 60ms difference in RT between irregular words and ambiguous atypical acronyms did not reach significance. The response latencies for the three types of acronym were not significantly different from each other. The RT recorded in regular and irregular trials did not differ significantly. A graph with the mean latencies for each condition and each block can be seen in Figure 7.3.

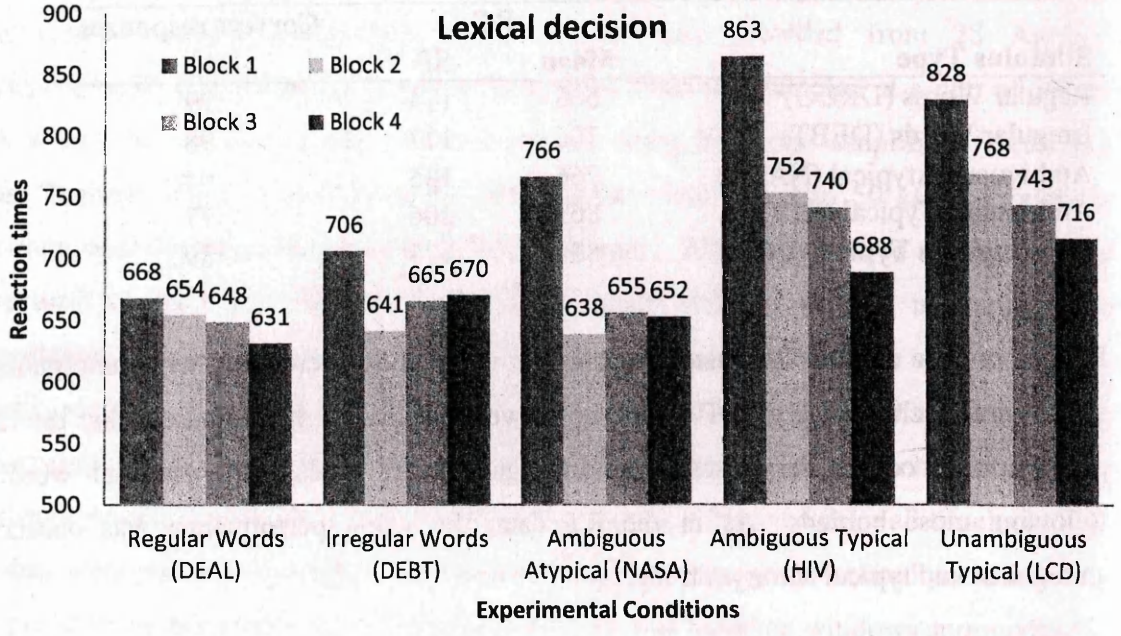


Figure 7.3 – Mean latencies across repetitions and conditions for Experiment 7.2

7.7.1.2 Accuracy analysis – Block 1 only

Error percentages were arcsine transformed prior to analysis (untransformed Figures are presented in Table 7.3 above) to account for the constraints of non-continuous variables. Percentages are constrained to fall between 0 and 100. The arcsine transformation shifts particularly high or low percentages towards the middle giving greater theoretical scope for variance. Performing ANOVA on untransformed percentages can lead to Type I errors. ANOVA analyses with type of word as a within-subjects factor in the analysis by subjects

and between-subjects factor in the analysis by items were carried out (Greenhouse-Geisser correction applied). A main effect of type of word was found [F1 (4, 60) = 14.021, MSe = 170.676, $p < .001$, $\eta^2 = .483$; F2 (4, 45) = 4.511, MSe = 108.292, $p < .005$, $\eta^2 = .286$]. Post-hoc t-tests (Bonferroni correction applied at $\alpha/10$, $p = .005$ level) revealed that accuracy for ambiguous typical acronyms (HIV) was significantly lower than for regular words (DEAL), irregular words (DEBT) or ambiguous atypical acronyms (NATO, $p < .001$ in each case). Accuracy for unambiguous typical acronyms was also significantly poorer than in regular word trials. No other comparisons were significant at $p < .005$.

In the analyses of data from Block 1 alone, significant main effects of type of word used were observed throughout, both for accuracy and RT. When recording ERP data, an important consideration is the signal-to-noise ratio. The EEG trace records brain activity which is specific to the task being performed (signal) as well as background brain activity (noise). While the task-specific activity happens at roughly the same time in each trial, the background activity is random. Taking an average of the EEG activity across a number of trials eliminates the problem of background activity, cancelling it out. Adding extra trials to the average does not alter the signal, but does reduce the noise. Signal to noise ratio is an important consideration in ERP experiments and this dictates the number of trials required per condition. With the small number of available stimuli, it was necessary to repeat items in four blocks to provide sufficient trials for an acceptable signal to noise ratio. This repetition affords also the opportunity to assess the impact of practice on lexical decision performance for mainstream words and acronyms. As the response times were considerably slower for ambiguous typical than for regular and irregular words it was predicted that this type of acronyms would benefit most from repeated presentation. A second series of ANOVA analyses were performed including Block as an additional factor.

7.7.1.3 RT analyses - All blocks

Table 7.4 shows the participants' mean RTs for each type of word in each presentation block. The trend shows, as expected, faster responses in block 4 than in block 1. As in the analysis of Block 1, overall average responses were fastest to regular words and slowest for ambiguous typical acronyms.

Table 7.4 – Mean reaction times (M), standard deviations (SD) and percentage accuracy (Acc(%)) for all the conditions and repetitions in Experiment 7.2

		Regular Word (DEAL)	Irregular Word (DEBT)	Ambiguous atypical (NASA)	Ambiguous typical (HIV)	Unambiguous typical (LCD)
Block 1	M	668	706	766	863	828
	SD	174	177	135	1206	173
	Acc(%)	99	98	94	77	89
Block 2	M	654	641	638	752	768
	SD	164	122	99	143	202
	Acc(%)	99	100	97	89	89
Block 3	M	648	665	655	740	743
	SD	134	158	121	151	122
	Acc(%)	99	97	97	88	91
Block 4	M	631	670	652	688	716
	SD	149	186	123	129	130
	Acc(%)	100	98	99	85	89

Two ANOVA (5 x 4) analyses were carried out with type of word and block as within-subjects factors in the analysis by subjects. Type of words was a between subjects factor while block was a within subjects factor in the analysis by items. Results indicated a significant main effect of block by subjects [F_1 (3, 45) = 7.027, MSe = 43550.366, $p < .01$, $\eta^2 = .319$ (Greenhouse Geisser correction at $\varepsilon = .488$)] and by items [F_2 (3, 135) = 25.606, MSe = 5417.970, $p < .001$, $\eta^2 = .363$ (Greenhouse Geisser correction at $\varepsilon = .806$)]. Bonferroni corrected follow up t-tests ($\alpha/6 = .008$) indicated a significant difference in response latency between responses in block 1 and block 2 ($p < .008$), but not between any other pair of blocks. A significant main effect of type of words was evident in both the by subjects [F_1 (4, 60) = 23.979, MSe = 7701.693, $p < .001$, $\eta^2 = .615$] and by items analyses [F_2 (4, 45) = 9.374, MSe = 14735.937, $p < .001$, $\eta^2 = .455$]. Post hoc t-tests with a Bonferroni correction applied ($\alpha/10$) indicated that ambiguous typical acronyms (HIV; 761ms) and unambiguous typical acronyms (LCD; 763ms) were recognised significantly slower than regular words (650ms), irregular words (670ms) or ambiguous atypical acronyms (678ms; all $p < .005$). The RT in mainstream word and ambiguous atypical acronyms were not significantly different from one another. The interaction between type of word and block was marginally significant by subjects [F1 (12, 180) = 2.401, MSe = 14695.084, $p = .051$], significant by items [F2 (12, 135) = 2.619, MSe = 5417.970, $p < .01$, $\eta^2 = .189$]. The interaction is shown below in Figure 7.4.

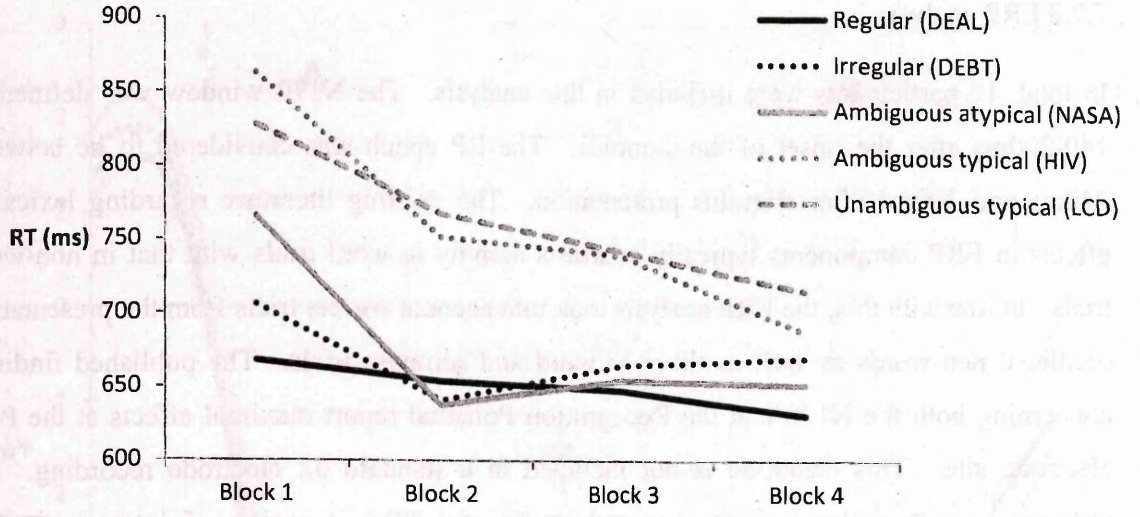


Figure 7.4 – Mean reaction time in milliseconds for each type of word in each presentation block.

7.7.1.4 Accuracy analysis - All blocks

Two ANOVAs (4 x 5) were carried out using arcsine transformed error percentages. The main effect of block was significant by subjects but not by items [F_1 (3, 45) = 4.152, MSe = 31.842, $p < .05$, $\eta^2 = .217$; F2 (3, 135) = 2.611, MSe = 40.977, $p > .05$]. Follow up t-tests using a Bonferroni correction at $\alpha/6 = .008$ level indicated significant differences between the accuracy of responses in block 1 and block 2 ($p < .008$), but not between any other pair of blocks. The main effect of type of words was significant by subjects [F_1 (4, 60) = 26.148, MSe = 348.162, $p < .001$, $\eta^2 = .635$ (Greenhouse-Geisser $\varepsilon = .537$)] and by items [F_2 (4, 45) = 7.658, MSe = 201.641, $p < .001$, $\eta^2 = .405$]. By subjects post-hoc t-tests (Bonferroni correction applied at $\alpha/10$, $p = .005$ level) showed that accuracy for ambiguous typical acronyms (HIV) and unambiguous typical acronyms (DVD) was significantly worse than for regular words, irregular words and ambiguous atypical acronyms like NATO ($p < .005$ in each case). Participants were equally accurate in recognising regular word, irregular words and ambiguous atypical acronyms. The interaction between type of word and block was not significant in either analysis.

7.7.2 ERP analysis.

In total, 16 participants were included in this analysis. The N170 window was defined as 140-200ms after the onset of the stimulus. The RP epoch was considered to be between 240ms and 300ms after stimulus presentation. The existing literature regarding lexicality effects in ERP components typically contrasts activity in word trials with that in non-word trials. In line with this, the ERP analysis took into account correct trials from the presentation of illegal non-words as well as those in word and acronym trials. The published findings concerning both the N170 and the Recognition Potential report maximal effects at the PO7 electrode site. This electrode is not included in a standard 32 electrode recording. By averaging together the activity recorded at T5 and PO1, a region of interest roughly equivalent to PO7 was created. ERP traces for each of the types of stimulus are presented in Figure 7.5 below. In the N170 window (panel "a" of Figure 7.5), the greatest negativity was recorded in illegal non-word trials while regular word trials elicited the least negative potentials. Analysis of the activity in the PO7 region of interest revealed a significant main effect of stimulus type on the N170 [$F (6, 180) = 10$, $MSe = .347$, $p < .005$, $\eta p^2 = .250$, Greenhouse-Geisser $\varepsilon = .201$]. Following Bonferroni corrected t-tests it was noted that both illegal and legal non-words elicited amplitudes which were significantly more negative than for mainstream words or ambiguous atypical acronyms. The N170 amplitudes for regular words, irregular words and ambiguous atypical acronyms did not differ from one another. Unambiguous acronym trials led to amplitudes which were only significantly different from those in illegal word trials, with the latter being more negative. Ambiguous typical acronyms elicited N170 activity which was not significantly different from non-words, but significantly more negative than mainstream words and ambiguous atypical acronyms. Turning to the RP window (panel b), the most negative amplitudes in the PO7 region of interest were observed for irregular words. Illegal non-words elicited the smallest negative amplitudes. The effect of stimulus type on RP activity was significant [$F (6, 180) = 100.704$, $MSe = .072$, $p < .001$, $\eta p^2 = .770$, Greenhouse-Geisser $\varepsilon = .357$]. Irregular words elicited significantly greater negativity than any other stimulus type ($p < .001$) as revealed in Bonferroni corrected follow up t-tests. The amplitudes observed in ambiguous typical acronym and regular word trials were not significantly different from one another. Legal non-word trials elicited PO7 activity which was not significantly different from unambiguous acronym or illegal non-word trials. All other comparisons revealed significant pairwise differences.

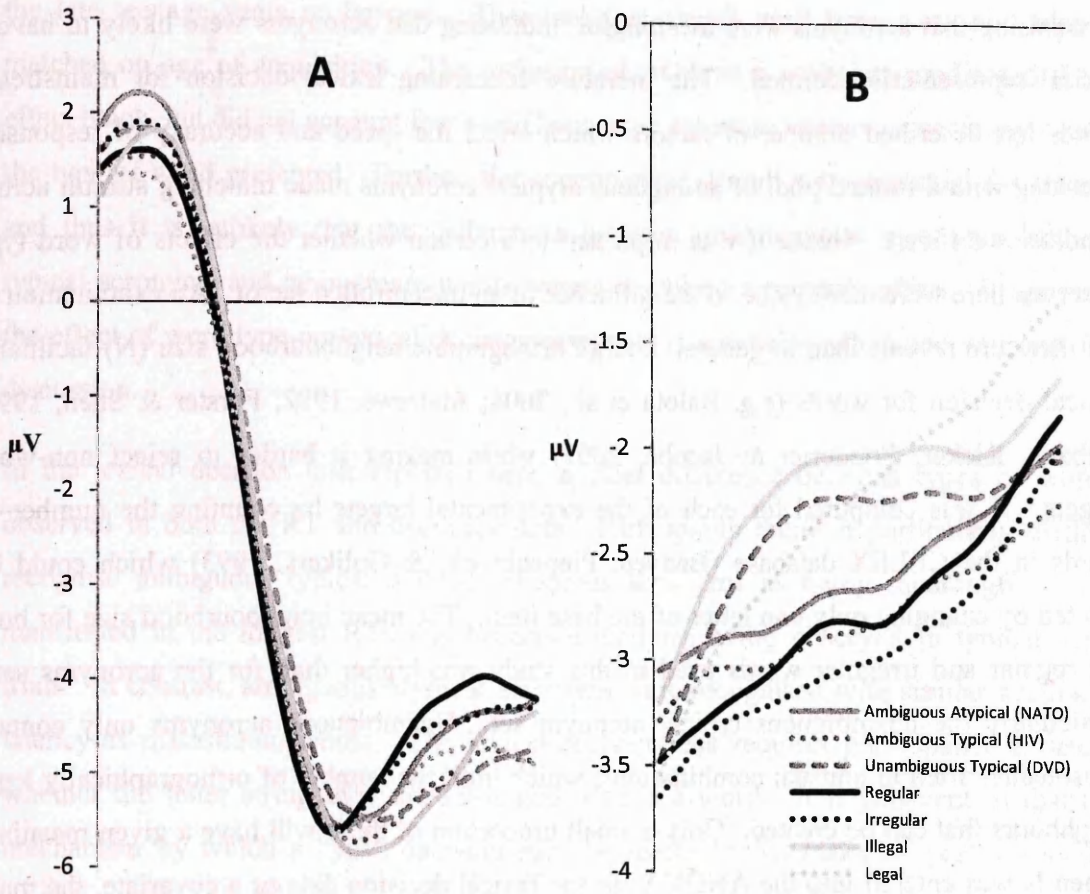


Figure 7.5 – Grand average ERP waves for the PO7 region of interest. Panel A shows the activity in the N170 time window. Panel B shows the RP epoch. Negative voltage is plotted downward. PO7 ERPs were created by averaging together activity recorded at T5 and PO1 electrode sites.

7.8 Discussion

The present study set out to further examine the roles of orthography, phonology and meaning in lexicality effects using behavioural and ERP components as the measures of interest, specifically the N170 and the Recognition Potential. The behavioural data will be addressed first, before moving on to the interpretation of the ERP findings.

The first important finding to note is that the accuracy with which acronyms were recognised was generally high. Ambiguous atypical acronyms like NATO were recognised correctly on 94% of trials in the initial presentation block, and had reached 99% accuracy by the end of the experiment. For the unambiguous acronyms (BBC) and the ambiguous typical acronyms (HIV) accuracy reached 89%. It appears, therefore, that participants were good at

recognising that acronyms were meaningful, indicating that acronyms were likely to have a lexical representation formed. The literature concerning lexical decision for mainstream words has described number of factors which affect the speed and accuracy of responses. Working with a limited pool of ambiguous atypical acronyms made matching stimuli across conditions difficult. Hence it was important to ascertain whether the effects of word type observed here were merely due to the influence of an uncontrolled factor. An examination of the literature reveals that, in general, a large orthographic neighbourhood size (N) facilitates lexical decision for words (e.g. Balota et al., 2004; Andrews, 1992; Forster & Shen, 1996; Fiebach, Ricker, Friederici & Jacobs, 2007) while making it harder to reject non-word targets. N was computed for each of the experimental targets by counting the number of words in the CELEX database (Baayen, Piepenbrock, & Gulikers, 1993) which could be created by changing only one letter of the base item. The mean neighbourhood size for both the regular and irregular words used in this study was higher than for the acronyms sets, particularly the unambiguous typical acronym set. Unambiguous acronyms only contain consonants, often in unusual combinations, which limit the number of orthographically legal neighbours that can be created. Only a small proportion of these will have a given meaning. When N was entered into the ANOVA for the lexical decision data as a covariate, the main effects of type of word and block remained significant. Similarly, research has indicated that bigram frequency influences the processing of low frequency words (e.g. Owsowitz, 1963; Rice & Robinson, 1975 but see also Gernsbacher, 1984). In terms of acronyms, results in Chapter 3 showed that bigram frequency has a robust influence in acronym naming. Bigram frequency counts for the words and the acronyms used in this study were computed using the MCWord Orthographic Wordform Database (Medler & Binder, 2005). Including bigram frequency as a covariate in the analysis of the data collected here also failed to alter the main effects. A more commonly researched factor in word recognition is age of acquisition. The robust finding reported is that words learned early in life enjoy an advantage in processing, and hence participant responses are faster than to late-acquired words (e.g. Butler & Hains, 1979; Morrison & Ellis, 1995; Morrison and Ellis, 2000; Nagy, Anderson, Schommer, Scott, & Stallman, 1989; Whaley, 1978). One peculiarity of acronyms is that they are almost always acquired late. In the Izura and Playfoot (under review) norms, the earliest acquired acronym is BBC, which is learned, on average, during the 6th year of life. Typically, studies of word recognition factors classify any word learned after the age of 5 as "late-acquired." Indeed, as acronyms are coined as and when they are required, often coinciding with technological or scientific developments, it is not uncommon for an acronym to be learned in

the late teenage years or beyond. Therefore the stimuli used here were not adequately matched on age of acquisition. The inclusion of AOA as a covariate eradicated the main effect block, but did not account for the differences in response latency or accuracy caused by the type of word presented. Further, the experimental stimuli were matched for frequency, and thus it is unlikely that the differences between unambiguous acronyms, ambiguous typical acronyms and mainstream words were a disguised frequency effect. It appears that the effect of word type on lexical decision responses is a genuine effect and warrants further discussion.

In the lexical decision task reported here, a clear difference between types of word was observed in both the RT and accuracy data. Participants found it particularly difficult to recognise ambiguous typical and unambiguous acronyms as being meaningful. This is manifested in the longest RTs and highest error rates being observed in typical acronym trials. In contrast, ambiguous atypical acronyms were recognised with similar accuracy and latency as mainstream words. The lexical decision task requires participants to determine whether the letter string they are presented with is a word. It is pertinent to discuss the mechanism by which a "yes" decision may be reached. To make a "yes" response, the participant needs to acknowledge that they recognise the word in front of them. According to the architecture of the DRC model (Coltheart et al., 2001) a visually presented letter string elicits the activation of letter units and hence activation of whole word representations in the orthographic input lexicon. Once the level of activation has reached the criterion level, it is possible to make the assertion that the stimulus has a representation in the lexicon, and that it can be accepted as a word. The logical continuation of this view is that items which reach the threshold more easily are recognised with greater speed. For example, high frequency words are recognised more quickly than low frequency words, and this has been attributed to higher levels of resting activation for commonly occurring stimuli (Perea, Rosa, & Gomez, 2005). A possible explanation for the effects of word type that are reported here is that unambiguous typical (DVD) and ambiguous typical (HIV) acronyms are more difficult to retrieve because of the conflict between their phonology and orthography. Research has shown that phonological information can affect lexical decision responses. For example, consider the pseudohomophone effect. Pseudohomophones are non-words which can be pronounced to sound like real words (e.g. munth equals month). In lexical decision tasks, pseudohomophones take longer to reject than other non-words (e.g. Besner & Davelaar, 1983; Seidenberg, Petersen, MacDonald & Plaut, 1996). The phonology of the

pseudohomophone is assembled automatically and activates the representation of the valid word in the lexicon. This creates a conflict between the phonological activation and the orthographic activation, and the resolution of the conflict increases the latency of the response. A similar conflict between orthography and phonology is created by the presentation of ambiguous typical acronyms. In the case of an acronym like HIV, the orthographic representation resembles mainstream words. The pronunciation, on the other hand, is not like the pronunciation of any mainstream word. For unambiguous acronyms like DVD, both the orthography and the phonology are unlike mainstream words. Resolving the conflict between orthography, phonology and semantics is an effortful process and results in significantly longer latencies. In contrast, the presentation of an ambiguous atypical acronym (NATO) creates little conflict, as orthography and phonology are similar to mainstream words. This interpretation is supported by the significant interaction between type of word and presentation block observed in the lexical decision data. The repetition was of greater benefit to responses to typically pronounced acronyms than for regular or irregular words, or ambiguous atypical acronyms. Findings from priming experiments (e.g. Brysbaert et al., 2009; Meyer & Schvaneveldt, 1975) indicate that the presentation of a stimulus activates its lexical representation, and that the resting activation of that representation remains slightly elevated for a period of time. In the first block, the recognition of ambiguous typical or unambiguous typical acronyms was slow because the representation was difficult to retrieve, and the criterion level of activation took a long time to accumulate. However, the initial presentation of the stimulus temporarily increased its resting activation. Therefore the recognition threshold was reached more easily, and hence more quickly in the second block. A further increase in resting activation was caused by the second encounter with the acronym. This decreased the amount of additional activation that was required before recognition in block 3, which in turn influenced block 4. The mainstream words and the ambiguous atypical acronyms were recognised quickly even at the initial encounter, thus the effect of repetition was not particularly large as the levels of resting activation for these items were already reasonably high.

Turning to the findings of the ERP analyses, the existing literature concerning lexicality effects in the N170 potential, indicate that amplitudes for words are significantly less negative than those for non-words (Compton et al., 1991; McCandliss et al., 1997). This difference has been replicated in this study. Two accounts for the cause of the N170 effect

have been examined in this study by using acronyms. McCandliss et al. (1997) concluded that orthography and not semantics is causing the differences in the N170, because the amplitudes in Keki word and Keki non-word trials did not differ even after participants had received extensive training in the meaning of Keki words. This interpretation is supported by the finding that activation in the N170 time window is similar for words from different semantic categories (Bentin et al., 1999; Dehaene, et al., 2002; Vigneau, et al., 2005). Thus, it has been argued that the typicality of the orthography of a written stimulus is the underlying explanation for lexicality effects in the N170. In the current study, the comparison of amplitudes elicited by unambiguous acronyms (DVD) and illegal non-words (RQP) was of particular importance to evaluating the hypothesis that the N170 is sensitive to orthography and not semantics. Unambiguous acronyms and illegal non-words did not differ in their orthographic typicality (as defined by bigram frequency) yet unambiguous acronyms had significantly less negative amplitudes. The major difference between consonant strings and unambiguous acronyms is that the latter have stored lexical representations that the former do not. According to Hauk and Pulvermuller (2004), lexical access occurs between 150 and 190ms after a written word is presented. Thus it is likely that the difference between unambiguous acronyms and illegal non-words in N170 amplitudes is a reflection of lexical access. Further support for this interpretation of the N170 as a lexical access component comes from the non-significant amplitude differences between mainstream words and ambiguous atypical acronyms (NATO) observed in the current study. A lexical access account would predict equivalent amplitudes for items of similar frequencies.

It is necessary to acknowledge that not all of the findings of the ERP analysis are easily reconciled with a lexical access account of the N170 lexicality effect. First, the amplitudes observed in the ambiguous typical acronym trials (HIV) were significantly more negative than those for ambiguous atypical acronyms (NATO) and mainstream words – in fact the ambiguous typical acronym N170 was equivalent in amplitude to those for illegal and legal non-words despite the fact that ambiguous typical acronyms do not have an awkward orthographic configuration. If the cause of lexicality effects in the N170 is lexical access then ambiguous typical acronyms ought to be akin to other lexical items. Ambiguous typical acronyms trials also showed the longest RTs and highest error rate. It is suggested that this is related to the N170 findings. Lexical representations are activated with help from orthographic and phonological systems. It is suggested that ambiguous typical acronyms do not receive much additional activation from phonology early enough to influence the N170

because of the time taken to resolve the competition between grapheme-phoneme and letter by letter pronunciations.

The analysis of the RP needs to be treated with caution. Clear RP peaks are usually observed, but in this study there was no single prominent amplitude peak. This may be because of the lexical decision task being less than optimal for recording RP. In the experiments reported by Rudell and his colleagues (Rudell, 1992; Rudell & Hua, 1995; 1997) the rapid stream stimulation technique was used. This technique presents a large number of stimuli in quick succession. One reason for doing this, as explained by Rudell and Hua (1997), is that the presentation of any stimulus will cause a change in brain activity related to visual perception. Presenting two stimuli one after the other attenuates the immediate electrophysiological response to the second item. The barrage of irrelevant background stimuli in the rapid stream stimulation paradigm serves to suppress the initial perceptual response of the brain such that it becomes a rhythmic low-amplitude trace which occurs at the frequency that the images change onscreen. The RP peak is left clear and prominent. This technique was not appropriate for this study because the study of lexicality effects using acronyms presumes that the acronyms are represented in the lexicon of the participant. As acronyms can come from specialised fields it is likely that participants will never have encountered at least one of the stimuli, and hence they cannot have created a lexical entry. Using the lexical decision task allowed the potentials evoked by acronyms that participants failed to identify to be ignored when computing their ERPs. Two previously published findings related to the RP may also help to explain the absence of a single prominent peak in the 240-300ms window. First, the latency of the peak recorded can be significantly affected by the task. Rudell and Hua (1995) showed that the RP was observed significantly later when the image of the word had been degraded than when it was clear and intact. Similar increases in peak latency in more difficult tasks have been reported by (e.g. Rudell, 1991; Rudell & Hua, 1997). It may be that the ease with which the stimuli were recognised was different for different participants or items. This can be tentatively supported with reference to the standard deviation of lexical decision RT, which ranged from 99 to 206ms. The procedure for calculating ERPs is designed to maximise the amplitude of potentials which occur at roughly the same time while decreasing the amount of noise caused by random fluctuations in the EEG signal. If the recognition potential response occurred at different latencies across subjects or trials, then the averaging technique would flatten the ERP wave

and obscure the RP peak. This interpretation can be supported with reference to the finding that RP latency has been shown to be a particularly good predictor of RT (Rudell, 1992; Rudell & Hua, 1997).

In spite of the lack of a single RP peak, the amplitude of the ERP for the various types of stimuli diverged considerably shortly after 250ms. The amplitudes recorded between 240 and 300ms were therefore considered analogous to the RP. The finding that the ERP amplitudes for mainstream words (both regular and irregular) were significantly more negative than amplitudes in non-word trials during this time window parallels the amplitude differences in RP reported by Martin-Loeches et al (1999) and Rudell (1991). The greatest negativity was observed in irregular word trials, with illegal non-words eliciting the smallest negative amplitudes. Amplitudes for ambiguous typical acronyms and for regular words were similar, and both were significantly less negative than irregular words. Ambiguous atypical acronyms (NATO) elicited negative amplitudes that were significantly smaller than regular words and ambiguous typical acronyms. Martin-Loeches et al (1999) suggested that the RP component was sensitive to both orthographic and semantic information. This interpretation predicts a series of incrementally greater amplitudes from one stimulus type to the next. First, legal non-words would be expected to elicit greater negativities than illegal non-words as a consequence of orthographic typicality. Real words would be expected to show greater RP amplitude than non-words by virtue of the integration of semantic and orthographic processing. This was borne out in the findings of Martin-Loeches et al (1999), and of the current experiment. In an account based entirely on orthography and semantics, unambiguous acronyms would be predicted to elicit amplitude values that were more negative than for illegal non-words as a result of the potential for semantic processing. Unambiguous acronyms are meaningful but have illegal orthography while legal non-words are orthographically acceptable but are devoid of meaning. If it is assumed that orthography and semantics have equal weight in the creation of the RP, it could be predicted that the amplitudes observed in unambiguous acronym trials would be roughly equivalent to that in legal non-word trials. This prediction was supported by the current data. However, an orthographic-semantic account of the RP would not predict the difference between regular words, irregular words, ambiguous atypical acronyms and ambiguous typical acronyms which was observed in the present study. A potential explanation for this is that the RP is also sensitive to phonology as Martin-Loeches (2007) suggested. According to the DRC

model (Coltheart et al., 2001), the difference between regular and irregular words, all else being equal, is the method of pronunciation. Considering that lexical and phonological routes will offer disparate pronunciations of an irregular word, the integration of phonology might be particularly effortful. For regular words, phonologically assembled and lexically addressed pronunciations are the same, so less effort is required to integrate all the available information. This results in greater negative amplitudes for irregular than regular words as observed here. Ambiguous acronyms also differ in their pronunciations. Ambiguous atypical acronyms are usually pronounced according to grapheme to phoneme correspondences. They may therefore be similar to regular words for which the meaning is equally well known. Ambiguous typical acronyms such as HIV are pronounced letter by letter. It could be expected that this method of pronunciation is more effortful because it is used infrequently in general English, and because a letter by letter reading is phonologically longer. Thus the amplitudes for ambiguous typical acronyms would be expected to be greater than for ambiguous atypical acronyms. This was the case in the current experiment. It is necessary to note how the amplitudes in ambiguous acronym trials related to those in regular word trials. As mentioned above, it could be predicted that ambiguous atypical acronyms would show equivalent RP amplitude values to regular words. In fact it was the ambiguous and typically pronounced acronyms which were statistically similar to regular words in the RP window, with ambiguous atypical acronyms eliciting significantly smaller negativities. This evidence is taken to indicate that there was a difference between words and acronyms in the availability of semantic information to add to the RP. This is related to the significant RT differences observed in the lexical decision data.

7.9 General discussion

The processing of acronyms in tasks including mainstream words was examined. First, a naming task was performed in order to assess whether the differences in reaction time between typical and atypical ambiguous acronyms reported in Chapter 3 was attributable to the experimental design. Following this, the same stimuli were presented to a second group of participants for lexical decision. In both the naming and the lexical decision tasks, each stimulus was presented in each of four consecutive blocks to examine the effect of repeated exposure on participant responses. The main findings can be summarised as follows. A significant effect of type of word was observed in both tasks. Acronyms elicited slower responses than words, though the pairwise differences between acronym subtypes differed in

the two experiments. The practice effect was also significant, such that the speed of naming and lexical decision responses were increased by repeated presentations. An interaction between type of word and presentation block was observed in lexical decision, but not in naming.

Responses to acronyms were significantly slower than to mainstream words in naming and in lexical decision, with the notable exception that ambiguous atypical acronyms (NATO, NASA) were recognised at similar latencies to mainstream words. It is suggested that the generally slow responses to acronym stimuli may reflect that acronyms make up a relatively small proportion of any English text, and hence that the reading system is less efficient in processing them. The differences between individual pairs of acronym types can be explained with this interpretation in mind. The finding that there was a significant difference in RT between types of acronyms in both tasks was attributed to an interaction between orthography and phonology in the acronym stimuli. In the naming task, the slowest responses were observed in ambiguous atypical acronym trials, followed by ambiguous typical acronyms. It is argued that the computation of pronunciation is particularly complex for these acronyms because the appropriate output is not signalled by the written representation. The conflict between lexical and sublexical readings of an acronym arises because the lexical representations are not retrieved quickly enough to supersede the potential pronunciations offered by letter naming or grapheme phoneme correspondence rules. The typical acronym pronunciation, it is suggested, follows acronym-specific rules and hence the conflict is less than for ambiguous atypical acronyms (as in regular versus irregular words). In contrast, the speed and accuracy advantage was observed for ambiguous atypical acronyms over ambiguous typical acronyms in the lexical decision task. Atypical acronyms were, in fact, recognised as quickly as mainstream words. As mentioned above, the slow responses to acronyms are suggested to be a result of the word reading system being relatively unused to processing acronyms. Ambiguous atypical acronyms, though, are orthographically legal and represent a specific meaning facilitating their recognition

The ERP analyses undertaken have been informative about the nature of lexicality effects in the N170 component and in the RP. Previous researchers have argued that the N170 amplitude difference between word and non-word stimuli was a result of orthographic typicality (Bentin et al., 1999; Dehaene et al., 2002; McCandliss et al., 1997; Vigneau et al.,

2005). However, Hauk and Pulvermuller (2004) indicated that lexical access could occur in this time window, and that this could be the root of the lexicality effect in the N170. The data in the current study showed that unambiguous acronyms, made up entirely of consonants and thus low in orthographic typicality, elicited N170 amplitudes statistically similar to those resulting from the presentation of mainstream words. This can only be supportive of the interpretation that the N170 is sensitive to early lexical access. This study also examined amplitudes in the RP window. The RP component has been widely considered to reflect lexical access (Mari-Beffa et al., 2005; Martin-Loeches et al., 2001a; 2001b), and amplitudes recorded in this epoch appear sensitive to orthographic and semantic characteristics of the stimulus. Martin-Loeches (2007) highlighted the similarities between the scalp location of the electrophysiological RP signal and the position of the visual word form area. As the visual word form area appears sensitive to phonology as well as orthography and semantics, he suggested that it will be interesting to examine the effects of phonology on the RP. In the current study the RP amplitude differed between regular and irregular words, and between typical and atypical ambiguous acronyms. The obvious differences between these pairs of stimuli lie in their print to pronunciation characteristics. It is therefore suggested that the RP reflects the integration of information from orthographic analysis, semantic processing and phonological decoding. An increase in the amplitude of this component appears relate to the complexity of the stimulus.

In sum, the evidence collected in this study shows that phonology is an important factor in the processing of acronyms. In light of the present findings, the RP also seems sensitive to phonology. It should be stressed that further research is needed in this area before firm conclusions can be drawn.

CHAPTER 8

ACRONYM NAMING AND RECOGNITION PROCESSES: IMPLICATIONS FOR CURRENT MODELS OF READING AND RECOGNITION.

8.1. Introduction and summary of main findings

This thesis was concerned with the investigation of the processes involved in the reading and recognition of acronyms. Although the study of reading has a long history of research, acronyms are a type of word which has been largely neglected. However, it has been recognised that the specific orthographic, phonological and semantic characteristics of acronyms may be particularly useful in the investigation of reading, and the evaluation of reading models (Laszlo & Federmeier, 2007). The studies described in this thesis aimed to build on the extant literature studies. Specifically, data regarding the speed and accuracy with which acronyms are read and recognised has been collected, and an assessment of the important factors in acronym processing has been performed. The findings from each of the experimental Chapters will be summarised below. Following this, the important evidence will be collated to specifically address the research questions highlighted in the introduction, and the ability of currently influential word reading models (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; Plaut, Seidenberg & McClelland, 1996) to explain the results will be discussed.

A number of published studies have assessed the lexical status of acronyms (Besner, Davelaar, Alcott & Parry, 1984; Brysbaert, Speybroeck & Vanderelst, 2009; Coltheart, 1978; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984), concluding that they are integrated into the mental lexicon alongside mainstream words. The experiments reported in Chapter 2 tested some predictions that are based on the lexical status of acronyms, specifically the influence of frequency on participant responses in lexical decision and naming,. High and low frequency acronyms were included alongside mainstream words in lexical decision and naming tasks. In experiment 1a, participants were told to consider acronyms as words, and respond to them accordingly in a lexical decision task. When given this instruction, significant frequency effects were observed such that high frequency acronyms were recognised more quickly than low frequency acronyms. The frequency effect was eradicated in experiment 1b when participants had to class acronyms as non-words. An advantage in

reaction times and accuracy rates for high versus low frequency acronyms was also observed in the context of a word naming task in experiment 2. Frequency effects have been considered a consequence of differential ease of lexical access (Becker, 1976; Forster, 1976; Morton, 1969). Frequency has relatively little impact on sublexical processing. Therefore the existence of frequency effects in acronym processing indicates that they are somehow represented and stored in the mental lexicon, supporting the results and conclusions of other studies (Besner et al., 1984; Brysbaert et al., 2009; Coltheart, 1978; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984). The acronym naming and recognition times and error rates reported in Chapter 2 were significantly affected by stimulus type. Responses to acronyms took longer than to mainstream words for recognition and naming. This was interpreted as a reflection of the relatively low proportion of acronyms in everyday English. The reading system might be less practiced at processing acronyms and therefore less efficient. There was also a significant interaction between frequency and type of word in the lexical decision and naming tasks, such that being high in frequency was of greater benefit to acronyms than to words. Thus it appears clear that frequently occurring acronyms pose fewer problems for the reader.

Two particularly interesting findings were described in Chapter 2. One was the significant interaction between frequency and type of stimulus (mainstream word versus acronym) in lexical decision performance. The frequency effect was larger for acronyms than for words. This was interpreted as evidence that the unusual way in which letters are combined to form acronyms make them look orthographically non-words. However, acronyms have meaning, just like any other word. This ambivalence (i.e., looking like non-words but being words) caused a conflict at the decision stage that was absent during the recognition of mainstream words. Definitive recognition responses can only be made once a lexical entry has been sufficiently activated to reach a criterion level. According to Perea and Rosa (2005), high frequency words have a higher resting activation than low frequency words, and as such high frequency words are closer to the criterion level. The same would be true for high versus low frequency acronyms. Thus, relatively little activation is required to recognise high frequency acronyms without interferences from the unusual orthography or phonology. Dual route models (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart et al., 2001) propose that processing in the sublexical route is slow to be completed. The lexical route is able to access high frequency words and acronyms quickly enough that the sublexical route has not

completed processing the stimulus. Thus sublexical information is only involved in the processing of items which the lexical route is slow to process, like low frequency words.

The second relevant finding from the experiments reported in Chapter 2 was the high accuracy rates (93%) on the naming responses for low frequency acronyms (when compared with the accuracy rates (51%) on the identification of the same acronyms. Some authors have presumed that the unusual relationship between orthography and phonology of acronyms would require a previous knowledge of the acronym and its pronunciation (i.e., lexical reading) in order to name them correctly (Laszlo & Federmeier, 2007a; 2007b; 2008). However, this might not be necessarily the case. Lexical reading involves access to a previously stored representation of the presented word (or acronym) in order to retrieve its phonology. The results from the lexical decision task (i.e., chance level of identification of low frequency acronyms) suggest that those low frequency acronyms might not have been known by the participants. Nevertheless the same set of acronyms was correctly named by the majority of individuals in Experiment 2. If the acronyms were unknown correct reading could not have been achieved via the lexical route. Thus, it was concluded that an alternative reading mechanism might have been available for acronyms.

It was noted that there were some differences in the pronunciation of the high and low frequency acronyms used in Chapter 2. Specifically, all 25 of the high frequency acronyms required that each constituent letter was named in turn. In the low frequency acronyms, 4 items were pronounced in a word-like manner (AWOL, BAFTA, NASA, and SIDS). It is plausible that these four items had an impact on the mean RT for the low frequency acronym condition. This led to the discussion of the print to pronunciation characteristics of acronyms in Chapter 3. Acronyms were split into three categories based on their orthography and phonology. Acronyms which comprise only consonants can only be pronounced by naming each of the letters in turn. Therefore they were described as orthographically *unambiguous*. Their spelling immediately determines the appropriate pronunciation. Acronyms which include vowels and consonants can either be pronounced by naming each constituent letter (HIV) or in a word-like manner (NASA). In these cases, the spelling is not helpful when choosing the correct pronunciation. Thus acronyms containing vowels were considered *ambiguous*. The majority of acronyms are read by pronouncing each letter name in turn. This is the *typical* pronunciation for acronyms. The *atypical* pronunciation method is to produce a single whole response. This classification system creates three types;

unambiguous and typically pronounced, ambiguous and typically pronounced and ambiguous and atypically pronounced.

Studies which use mainstream word stimuli usually manipulate one factor (e.g. frequency) while holding other factors (imageability, age of acquisition etc.) constant. This level of control was not exercised for the acronyms in Chapter 2 because no normative values were available. Chapter 3 therefore comprised a normative study of acronyms and an assessment of the most influential factors in acronym naming and recognition times and accuracy. It began with a description of the lexico-semantic characteristics of 146 acronyms. This was the first collection of normative information for acronyms and provided values for rated and printed frequency, imageability, age of acquisition, orthographic neighbourhood, bigram and trigram frequency and length. The collection of norms on a large scale for mainstream words has allowed the design of strictly controlled studies. The values reported in Chapter 3 will allow a similar level of control to be exercised in acronym studies. This database also highlights important differences between acronyms and mainstream words. For example, in contrast to what is normally found with mainstream words, printed frequency did not show a significant correlation with age of acquisition suggesting that acronym frequency might not be related to the order in which they are learned. This lack of correlation is unusual in studies using common words (see Zevin & Seidenberg 2002; 2004). Further, the number of orthographic neighbours for an acronym correlated positively with number of letters but negatively with number of phonemes. The more letters and fewer phonemes an acronym has, the greater the number of neighbours. This correlation departs from the correlations reported with mainstream words (see Adelman & Brown, 2007; Balota et al., 2004). The dissociations between acronym characteristics which are related in mainstream words can be of use in future studies of reading.

Chapter 3 also collected naming and recognition data for the acronyms. In the analysis of acronym naming times, number of letters, printed and rated word frequency, age of acquisition and letter frequencies (bigram and trigram) emerged as significant predictors. Frequency and age of acquisition have typically been considered as lexical variables (i.e. they have an influence on lexical processes). In contrast, number of letters has been argued to reflect the serial nature of sublexical processes. Therefore, the processing of acronyms seems to be a complex task. Further, the influence of both lexical and sublexical factors hints that not all acronyms are processed in the same way. This interpretation was further supported by

the significance of a number of interaction terms in the regression analyses. Frequency showed a significant interaction with ambiguous typical and ambiguous atypical acronym types. For ambiguous typical acronyms (HIV), faster responses were recorded for high than low frequency items. The pattern was reversed for ambiguous atypical acronyms, with low frequency items being pronounced more quickly. A similar interaction was shown between age of acquisition and the print to pronunciation characteristics of acronyms. Early acquired ambiguous typical acronyms were read at shorter latencies than late-acquired acronyms while the advantage was for late versus early acquired ambiguous atypical acronyms. These findings were interpreted as a consequence of the predominance of typically pronounced (letter by letter) acronyms in the task. When ambiguous atypical acronyms were presented, therefore, the response was slowed down because this pronunciation mechanism conflicts with a 'letter-by-letter naming' mechanism more frequently used. The higher the frequency or the earlier the acquisition of those acronyms pronounced following grapheme-to-phoneme correspondences the greatest the conflict and the time needed to resolve it. It was suggested, therefore, that some acronyms might be named 'sub-lexically' using a letter naming rule system, while others require lexical reading.

An analysis of the predictor factors in lexical decision for acronyms was also performed as part of Chapter 3. A significant difference in the response latencies for ambiguous atypical and ambiguous typical acronyms was observed. This was particularly interesting because spelling to sound correspondences rarely have an impact on the lexical decision latencies in mainstream word studies, unless the task is designed in such way as to emphasise phonological information (Hino & Lupker, 1996; 2000; Seidenberg et al., 1984; Waters & Seidenberg, 1985). It was argued that orthography alone was perhaps not sufficient to differentiate acronyms from non-words and therefore an influence of phonology was exhibited. For ambiguous atypical acronyms (NASA, NATO) the phonology is similar to that of mainstream words. As a consequence the reading system is able to offer the phonology quickly. Phonological activation can therefore aid the retrieval of the lexical representation, and hence the recognition of the acronym. The pronunciation for ambiguous but typically pronounced acronyms (HIV, IBS) might be more difficult to assemble because the system is not so used to naming individual letters. The phonological activation does not add much (or not as quickly) to the activation of the lexical representation and responses are made more slowly. The interpretation of the influence of phonology in lexical decision for acronyms was supported by the significant interaction terms in the regression analyses. The

number of influential variables was far fewer than for naming performance. Indeed, the only significant predictors were imageability and age of acquisition. Early acquired and highly imageable acronyms were recognised more quickly than later acquired or less imageable counterparts. This mirrors the findings typically reported in mainstream word recognition studies (e.g. Balota et al. 2004). Both imageability and age of acquisition were shown to interact with the print to pronunciation characteristics of acronyms. A greater advantage was observed for high versus low imageability ambiguous atypical acronyms than for ambiguous typical acronyms. The influence of age of acquisition was greater for ambiguous typical acronyms than for ambiguous atypical acronyms. These interactions were interpreted as evidence that acronym recognition times might be influenced by phonology. That is, as the orthographic forms of acronyms are insufficient to determine that they are meaningful, phonology is used to assist in the lexical decision process. The phonology for an ambiguous atypical acronym can be assembled using grapheme phoneme correspondences. This process is relatively quick compared to naming each letter in turn. Thus when ambiguous atypical acronyms are presented their recognition is being assisted by both their phonology and their meaning, generating the fastest reaction times and given rise to the interaction since the recognition of ambiguous but typical acronyms is not as quickly assisted by their phonological characteristics. In relation to age of acquisition, Ellis and Lambon Ralph (2000) argued that an influence of age of acquisition will emerge only when there is an arbitrary relationship between the input (e.g. orthography) and the required output (e.g. phonology). It was suggested in Chapter 3 that the pronunciations for ambiguous typical acronyms may be particularly arbitrary. This is because a pronunciation following grapheme-phoneme correspondences is plausible, but the correct pronunciation requires that each letter is named in turn. In contrast, the assembly of phonology for ambiguous atypical acronyms follows the commonly used GPC rules, and could therefore be argued to be relatively consistent with the English language. This accounts for the finding that age of acquisition effects were only observed for the arbitrary ambiguous typical acronyms. Further, no effect of age of acquisition was observed in unambiguous acronyms. The pronunciation of this type of acronym, although unusual in the language, is clearly signalled by the orthography. A string of consonants can only reasonably be pronounced one letter at a time. Therefore the mapping between spelling and sound is consistent and predictable, and no age of acquisition effects are observed.

In sum two relevant findings can be extracted from the results reported in Chapter 3. First, it may be possible, at least for some acronyms, to be read without lexical access through the application of a specific letter naming rule, and the pronunciation of these may be influenced by sublexical factors like length. Secondly, recognising acronyms is particularly influenced by phonology and semantics. These findings were further examined in the Chapters 5, 6 and 7.

Chapter 4 used the discrete word association task to examine the role of acronym characteristics in a semantic task. In a discrete association task, the participant is presented with a single word and required to produce the first word that comes to his/her mind. In order to achieve this, the participant is forced to activate a second lexical representation which is connected semantically or lexically to the target word. Semantic network models posit that words in the lexicon are stored as interconnected nodes (e.g. Collins & Quillian, 1969; Collins & Loftus, 1975). Each node has a number of other nodes linked to it. The strength of the links between associations determines the ease with which an association between the two concepts is made. Stronger links are easier to retrieve and result in faster responses. It has been argued that a link between two nodes is strengthened every time it is activated. Frequency, imageability and age of acquisition are among the factors which seem to influence the strength of the lexico-semantic connections between representations, and are therefore important in word association behaviour (Altarriba, Bauer & Benvenuto, 1999; Brysbaert, Van Wijnendaele & De Deyne, 2000; de Groot, 1989; Hall & Ugelow, 1957; Postman, 1964; 1970). The importance of these variables was examined in an acronym association task. Analyses concerning word association RT, the distribution of word association responses and the qualitative types of association elicited were computed using regression techniques. Findings regarding word association RT mirrored those previously reported in word association tasks (Altarriba et al., 1999; Brysbaert et al., 2000; de Groot, 1989). Specifically, responses were given at shorter latencies when the cue acronym was high in imageability or acquired early in life. No significant effect of frequency was observed. In the analysis concerning associative strength (the proportion of participants who gave the most popular response to a given cue) imageability emerged as the only significant predictor of word association behaviour. De Groot (1989) had also reported an effect of imageability on associative strength in a study using mainstream word cues, and interpreted her findings as evidence that the strength of links between nodes in semantic networks is increased only when they are explicitly retrieved, and not when they are merely activated.

That is, the automatic and unconditional activation of related words in the lexicon (which is evidenced by semantic priming effects e.g. Brysbaert et al., 2009; Meyer & Schvaneveldt, 1975), does not increase the strength of the link between two words, otherwise high frequency words would have particularly strong links. Instead, the linked-to concept must become "conscious." The lack of a significant effect of frequency on the associations generated in response to acronym cues supported this position. Chapter 4 was novel in that it was the first word association study to examine the factors which influenced the type of response that was given to acronyms. Responses were categorised as being based on the meaning, form or position in sentences of the cue. Imageability was the only significant predictor of response type. Highly imageable acronyms elicited a greater proportion of meaning based associates, and fewer responses which co-occurred with the cue in the language than abstract acronyms. It was argued that the connections between a high imageability acronym and its related concepts might be strong and salient, and thus meaning based responses are easily generated. In contrast, the links stemming from abstract acronyms might be relatively weak. As a result they are harder to retrieve, and there is more competition between prospective associates. Under these circumstances it is possible that the first associate to be generated is based on something other than semantics. The findings reported in Chapter 4 indicate that the meaning of acronyms is processed in a similar way to that of mainstream words. Further, the findings have implications for semantic network models, suggesting that both the linked-from and linked-to concepts must be consciously processed in order to increase the strength of the connection. It was concluded that a clear picture of the structure of the semantic system is yet to be achieved, and that a continued assessment of the characteristics of the cue which have an impact on association behaviour has the potential to illuminate the nature of semantic networks and inform models of the lexicon.

Chapter 5 analysed data from a patient with semantic dementia, JD. Her performance on a number of tasks repeated across a 15 month period was assessed. Semantic dementia is a disorder which is characterized by deficits in single word comprehension and word recognition, as well as a difficulty in reading aloud irregular words (Hodges et al., 1992). Thus JD was expected to perform poorly in semantic categorisation of the acronyms. Her performance was indeed found to be significantly poorer than that of healthy age-matched controls. There is usually an association between semantic deficits and a decrease in

performance in lexical tasks in reported cases of semantic dementia (Patterson, Lambon Ralph, Jefferies, Woollams, Jones, & Hodges, 2006; Woollams, Lambon Ralph, Plaut, & Patterson, 2007 though see Blazely, Coltheart, & Casey, 2005; Cipolloti & Warrington, 1995; Schwartz, Saffran, & Marin, 1980). In connectionist models this is an inevitable consequence of the damage to the semantic system. The architecture of the connectionist models dictates that all reading is achieved via a single system. This system uses semantic information to mediate the conversion from orthography to phonology in irregular words. According to this model, damage to the semantic system affects the ability to perform semantic and lexical tasks at the same time. The DRC model (Coltheart et al., 2001), on the other hand, allows for the possibility that lexical task performance is preserved once the semantic system is damaged. This model proposes a lexical-nonsemantic pathway which may remain undamaged by the progression of the semantic dementia. Thus activation of entries in the orthographic and phonological lexicons can still be achieved, and words can be recognised, without reference to semantics. JD remained capable of accurate lexical decision even as her dementia progressed. This is more readily reconciled with dual route accounts of reading.

The specific pattern of deficits in semantic dementia and surface dyslexia provided an opportunity to investigate the processes involved in reading acronyms aloud. As acronyms have orthography to phonology mappings which are unusual in the English language, previous researchers have assumed that they must be read via the lexical route (or with mediation from the semantic system from a connectionist perspective, Laszlo & Federmeier, 2007a; 2007b; 2008). According to this assumption, acronym reading by JD would have had to be largely inaccurate, because surface dyslexics are particularly prone to error in reading irregular words which must be processed by the lexical route. However, as some data in Chapter 2 suggested reading might be achieved sub-lexically for some acronyms. Findings reported in Chapter 3 (Izura & Playfoot, under review) also indicated that some sublexical processing may be involved. Therefore, if acronym reading can be accomplished avoiding lexical access, JD would have been able to pronounce them accurately in spite of her semantic dementia. JD was able to maintain a high level of accuracy in reading typically pronounced (letter by letter) acronyms through the course of the three testing sessions (spanning a total time of 15 months). However, her performance in reading irregular words, ambiguous atypical acronyms and regular words decreased over time. Further, it was noticed

that JD applied a letter naming strategy to items in all conditions. This was argued to be a kind of regularisation error based on an acronym naming rule. The data therefore suggest that reading acronyms does not always necessitate lexical access. It was thought that there were two potential mechanisms by which this pattern of performance could be explained. The first was that a second set of sublexical processes, either as a third route or achieved by a reconfiguration of the GPC route, was needed. The second possibility was that acronym reading was achieved by a completely separate system different from mainstream word reading. These interpretations were assessed with reference to the pathway control hypothesis in Chapter 6.

The pathway control hypothesis states that skilled readers are able to emphasise one processing route in order to suit the material to be read. For example, when a reading task contains a large proportion of non-words, the sublexical pathway is predominantly used. The sublexical path is the only route available for non-word reading as no lexical representation can be stored for a novel stimulus. The use of the sublexical pathway is necessary and efficient in processing the majority of the items, but the correct pronunciation of an irregular word requires access to its lexical representation. The reading response to the irregular word is made more slowly in the context of non-words. A similar increase in response latency is also observed when reading a non-word in a context made largely of irregular words. It is argued that this is a consequence of a switch in processing routes. Support for the pathway control hypothesis has been offered by Baluch and Besner (1991), Reynolds and Besner (2005a; 2005b; 2008) and Zevin and Balota (2000). In Chapter 6 the influence of context when reading ambiguous (HIV, NASA) acronyms was examined.. Ambiguous typically pronounced acronyms (HIV) and ambiguous atypically pronounced acronyms (NASA) were presented in a task containing a large proportion of unambiguous acronyms (BBC, DVD). Thus, the correct pronunciations for the majority of the stimuli were achieved by naming each letter in turn. Only the ambiguous atypical acronyms required a different method of pronunciation. Therefore it was predicted that reaction times for this set of items would be slower than for ambiguous typical acronyms. This prediction was supported by the data. In a second experiment, ambiguous typically pronounced acronyms (HIV) and ambiguous atypically pronounced acronyms (NASA) were presented in the context of regular words. In this experiment, no significant difference was exhibited in the RT for either type of ambiguous acronyms. It was argued that this was because all items were being read via the

lexical route. The same system was capable of reading ambiguous typical and ambiguous atypical acronyms. It was acknowledged that the lack of any significant difference between reaction times in ambiguous typical (HIV) and ambiguous atypical (NATO) acronym trials could reflect an alternation between entirely separate word and acronym reading systems. The regular words presented were inevitably processed by the word reading system. If acronyms are not accommodated by mainstream word reading processes, then it would be necessary to change to the reading system tailored to acronyms. The switch from word to acronym reading would result in an increase in naming time. Importantly, the same change of processing would be required by all acronyms. The presentation of NATO would extend response latency in just the same way as presenting HIV. Although ambiguous typical and ambiguous atypical acronyms were read with similar speed, the interpretation that acronym reading and word reading are achieved by distinct systems was argued to be inappropriate. This referred to the finding that the responses in the regular word context were significantly faster than in the unambiguous acronym context. Dual route models contend that the lexical route is particularly quick to process common words, and that the GPC route is slower to complete processing. It would be reasonable to assume that common acronyms would also be accessed quickly in the lexical route. If a sublexical letter naming route was also integrated into the reading system it would be likely to process slowly and serially like the GPC pathway does. Thus, when the sublexical processes were emphasised by the predominance of unambiguous acronyms the overall response times were slower than when the items were processed by the quicker lexical route. Thus it was concluded that acronyms were not only integrated in the mental lexicon alongside mainstream words, but also that they were processed within the same reading system.

Data collected in Chapter 3 indicated that the peculiar relationship between orthography, phonology and meaning in acronyms might create greater conflict at the time of recognition than for mainstream words. In addition, Chapter 6 found evidence to support the suggestion that the same reading system is employed when reading acronyms and mainstream words. Chapter 7 aimed to examine these findings further. The first section of this Chapter described a naming task which presented 5 types of stimulus to undergraduate participants. Stimuli included regular and irregular mainstream words, as well as the ambiguous typical, ambiguous atypical and unambiguous acronyms. The same stimuli were presented in 4 consecutive blocks. This allowed for the examination of the relative processing speeds of the

different stimulus types, and to assess the effects of practicing the responses. A significant effect of stimulus type was shown in the RT data. Mainstream words were read aloud quickly while acronyms were read at longer latencies. Further differences in RT were observed between types of acronym. Specifically, unambiguous acronyms were read more quickly than ambiguous acronyms (whether pronounced in the typical or atypical way). This was interpreted as evidence of a difference in the ease of retrieving the lexical representations for acronyms and mainstream words. Mainstream words are more common in any text than acronyms. It was argued that although stored representations for acronyms are available for lexical reading, the reading system is more used to processing mainstream words. Thus mainstream word representations are accessed quickly while acronyms take longer to retrieve. The observed differences between acronym named were interpreted as follows: The retrieval of lexical representations for acronyms was slow enough (due to low frequency of access) that sublexically assembled information was available at the same time. For unambiguous acronyms, the information from a letter naming rule system and the lexically addressed pronunciation were congruent. The orthography of the unambiguous acronym meant that no pronunciation based on grapheme to phoneme correspondences was possible. Thus there was little conflict between lexical and sublexical routines and the responses were relatively quick compared to ambiguous acronyms. In the case of ambiguous acronyms there were potentially three pronunciations; the lexical reading, the grapheme to phoneme correspondence pronunciation and the letter naming output. The additional time taken to respond to ambiguous acronyms was interpreted as a result of the need to decide between the conflicting pronunciations. There was also a significant effect of presentation block, such that response latencies decreased throughout the experiment. Visser and Besner (2001) reported a similar effect of practice on word naming latencies. This has been argued to reflect an increase in the speed of lexical retrieval. The presentation of a word temporarily increases its level of resting activation. It is therefore accessed more quickly in subsequent presentations. The same interpretation was offered as an explanation for the naming findings in Chapter 6. The final important finding reported in the naming experiment was that there was no interaction between the type of stimulus and the effect of presentation block. Visser and Besner (2001) reported a frequency by regularity by repetition interaction in word naming. In their experiment, low frequency irregular words were read aloud at longer latencies than low frequency regular words when they were initially presented. When the presentation of the stimuli was repeated, the difference between low frequency regular and irregular words was smaller. They argued that the retrieval of the lexical representations

were sufficiently facilitated by the first presentation that the sublexical system provided less interference when items appeared a second time. The same was not true in the naming task in Chapter 6. Thus it appeared that the reading of any of the stimuli was benefitted by repetition, and that no single type of stimulus was helped more than any other. It may be, therefore, that acronyms are unusual enough in text that a large amount of practice is required before their representations are activated quickly enough to avoid interference from sublexical processes.

The suggestion that the lexical representations for acronyms are retrieved slowly was also assessed in a lexical decision task. This task explicitly requires that a lexical representation is identified before an item can be accepted as familiar. Again, regular words, irregular words, ambiguous typical acronyms, ambiguous atypical acronyms and unambiguous acronyms were presented in each of four blocks. A similar pattern of results was reported as had been observed in the naming task, with one notable exception. As before, responses to each type of stimulus were given more quickly with repeated presentations. The effect of stimulus type was also significant. Mainstream words were recognised quickly, as were ambiguous atypical acronyms (NASA). Typically pronounced acronyms, however, took longer to be identified. The interpretation offered for this was that the recognition of acronyms is helped by phonological information. Ambiguous atypical acronyms have letter patterns which resemble mainstream words. They are also pronounced in similar ways. Thus both orthographic information and phonological information assembled using grapheme to phoneme correspondences can be used to increase the activation of the lexical representation until it reaches the criterion for recognition. This makes responses relatively quick. The phonology of typically pronounced (letter by letter) acronyms is likely to take longer to assemble because the system is less efficient at dealing with this method of pronunciation and because the acronym is phonologically longer. Thus the activation of the lexical representation is reliant on orthography and therefore the recognition threshold takes longer to reach. The assembly of the phonology for acronyms is not affected by repeated presentations. Hence the recognition of ambiguous atypical acronyms receives more assistance from phonological activation than typically pronounced acronyms irrespective of the number of repetitions. This accounts for the lack of a significant interaction between type of stimulus and presentation block.

Electrophysiological activity was recorded for the lexical decision task described in Chapter 7. The use of EEG was used to examine two components that have been reported to be sensitive to lexicality (word or non-word). These components were the N170 and the N250 or Recognition Potential. The N170 is a negative peak seen between 150 and 200 milliseconds after stimulus onset which has a greater amplitude following a non-word than a word (Compton et al., 1991; McCandliss et al., 1997). Some authors (Bentin et al., 1999; Dehaene et al., 2002; McCandliss et al., 1997; Vigneau et al., 2005) have interpreted this difference as an indication of orthographic typicality (as assessed by bigram frequency measures). Dien (2009), in a review of the literature, suggested that the N170 could equally indicate early lexical access. Acronyms have orthographies which are generally low in bigram frequency. Therefore an orthographic typicality interpretation would predict that acronyms would show N170 amplitudes which are similar to those elicited by non-words. However, as has been indicated by previous researchers (Besner et al., 1984; Brysbaert et al., 2009; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984) and in the data collected in this thesis, acronyms appear to be integrated into the mental lexicon alongside mainstream words. Thus if lexical access underpins the lexicality effect in the N170 window, acronyms would be expected to elicit amplitudes similar to words. Chapter 7 reported a significant lexicality effect, such that non-words elicited greater negative amplitudes than words replicating the findings of (Compton et al., 1991; McCandliss et al., 1997). The N170 in acronym trials resembled that recorded in word trials, and were statistically smaller than in non-word trials. This suggested that the N170 effect may be a reflection of early lexical access. The second component, the Recognition Potential, is a negative deflection typically reported between 220 and 300 milliseconds after stimulus onset. Amplitudes in this window are significantly more negative for words than for non-words. This component has been shown to be sensitive to semantic information and is widely considered as a reflection of lexical access (Mari-Beffa et al., 2005; Martin-Loeches et al., 2001a; 2001b). Two findings are of note in relation to the RP for acronyms. First, the Recognition Potential is usually shown as a distinct peak in amplitude. In Chapter 7, the peak was not sharp and obvious. As the ERP wave is an average of the electrophysiological activity of all the participants when presented with all the items in a given condition, there is considerable scope for variability, particularly in relation to a stimulus that is likely to differ in familiarity from one person to the next. The averaging techniques used to create ERPs is designed to increase the strength of the signal generated in response to the stimulus relative to the noise that is caused by constant neural activity unrelated to the task. This assumes that the signal is at roughly the

same point in time for every trial and every participant. If the potentials evoked by two stimuli are recorded at different latencies, the averaging techniques will have the effect of lowering the peak amplitude and flattening the waveform. There was a considerable span of recognition latencies recorded in the lexical decision task. It has been shown that the Recognition Potential latency is a predictor of the behavioural response time. That is to say, the electrophysiological response precedes the motor response by a reasonably constant duration (Rudell, 1992; Rudell & Hua, 1997). As the behavioural reaction times were widely dispersed it is likely that the RP latencies also varied, and this may have contributed to the failure to observe an obvious Recognition Potential peak. In spite of the lack of a single RP peak, the amplitude of the ERP for the various types of stimuli diverged considerably shortly after 250ms. The amplitudes recorded between 240 and 300ms were therefore considered analogous to the RP. The finding that the ERP amplitudes for mainstream words (both regular and irregular) were significantly more negative than amplitudes in non-word trials during this time window parallels the amplitude differences in RP reported by Martin-Loeches et al (1999) and Rudell (1991). The second important finding is that acronym amplitudes in this time window fell between those of words and non-words. If the Recognition Potential is indeed an index of lexical access, acronym-related and word-related potentials ought to have been statistically similar. This was not the case in the data collected in Chapter 7. Martin-Loeches et al (1999) suggested that the RP component was sensitive to both orthographic and semantic information, because amplitudes increase from orthographically illegal non-words to orthographically legal non-words to words. This interpretation, assuming equal weighting of orthographic and semantic information, would predict that unambiguous acronyms show amplitudes similar to pseudowords (because the acronym has an illegal orthography but specific semantic content). This prediction was supported in Chapter 7. Ambiguous acronyms (HIV, NATO) have word-like orthography and phonology, and would therefore be equivalent to mainstream words in RP amplitude. This prediction was not supported. The amplitudes reported in Chapter 7 differed between typical and atypical acronyms, and between regular and irregular words. This was argued to reflect the sensitivity of the RP to phonological information as well as the orthography and semantic influences previously proposed. Irregular words elicited the greatest negativities in the RP window, significantly greater than regular words. This was taken as evidence that the resolution of conflict between orthography and phonology might be represented in the RP. According to the DRC model (Coltheart et al., 2001) the difference between regular and irregular words, all else being equal, is the method of pronunciation. Considering that lexical

and sublexical routes will offer disparate pronunciations of an irregular word, the integration of phonology might be particularly effortful, contributing to large RP amplitudes. A similar conflict resolution interpretation was applied to the finding that ambiguous and typically pronounced acronyms (HIV) elicited greater negative amplitudes than ambiguous atypical acronyms (NASA). It could be expected that the letter by letter method of pronunciation is more effortful because it is used infrequently in general English, and because it is phonologically longer. The sensitivity of the RP to phonology adds to the similarity between this ERP component and the visual word form area which was highlighted by Martin-Loeches (2007).

8.2. Addressing the research questions.

This thesis set out to address two specific research questions. The first question considered how similar acronym processing is to that which is proposed to occur in mainstream word reading and recognition. The level of similarity between acronyms and mainstream words is not only important in the understanding of acronyms themselves, but also has potential implications for models of word reading, and for theories of the mental lexicon. The second central question for this thesis was whether acronyms can be considered as irregular words. This has been the assumption in previous studies including acronyms, but has not been explicitly tested until now. The following sections will examine the evidence in relation to both of these questions.

8.2.1. Are acronyms processed like mainstream words?

The evidence collected in this thesis has indicated that the answer to this question is relatively complex. In the early stages of processing, the activity in the brain appears to be very similar whether the string of letters presented form an acronym or a mainstream word. Indeed, the electrophysiological response to the presentation of an acronym is not significantly different in amplitude from the amplitudes elicited by seeing a mainstream word in the N170. At first glance, then, acronyms appear to be processed like mainstream words.

Prior to this thesis there were only a handful of experiments in the literature which concerned acronym processing. The predominant conclusion among these studies was that acronyms were integrated into the mental lexicon (Besner et al., 1984; Brysbaert et al., 2009; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984). The data collected here reaffirm this

conclusion. Following this interpretation, it could be expected that acronyms and mainstream words can be read and recognised in a somewhat similar manner. Throughout the current research, high frequency acronyms, those that are early-acquired or those that are highly imageable elicited faster responses than their low-frequency, late-acquired or abstract counterparts. These findings mirror the commonly reported effects in mainstream word reading and recognition studies, and could be taken as evidence that acronyms are processed like mainstream words.

However, the conclusion is not as obvious as it might first appear. Although acronym trials were shown to be affected by variables which are known to affect mainstream word reading and recognition, the extent of this influence has often been strikingly different from that observed in mainstream words. The findings of this thesis, therefore, indicate important differences between acronyms and mainstream words.

Another important difference between acronyms and mainstream words has been consistently observed throughout this thesis. In every experiment, responses in acronym trials were observed at significantly longer latencies than for mainstream words. This is immediate evidence that acronyms and mainstream words differ in the efficiency with which they are processed. It has been argued in several places that this may reflect a degree of difficulty in decoding acronym stimuli, because their orthography and phonology are so unusual in the English language. If the source of the difference in reaction times between acronyms and mainstream words is a result of a lack of experience with their particular written form, then it could be suggested that sufficient practice with acronyms should close the gap. Unfortunately, the attempt to demonstrate that acronyms could be read and recognised as quickly as words given practice was not successful. It remains unclear whether this reflects that a fundamentally different process is involved in reading acronyms or because the number of repetitions was not sufficient for acronym responses to gain parity with mainstream words. In either case, the evidence collected here shows that acronyms are not equal to words in the majority of cases.

The findings described in this thesis also provided evidence of the importance of phonology in acronym processing. Phonology tends not to be particularly important for mainstream word processing unless the task explicitly demands it. Here, too, a fundamental difference was observed between acronyms and mainstream words.

8.2.2. Do acronyms require processing similar to that required by irregular words?

Previous studies have assumed that the unusual spelling and sound characteristics of acronyms would necessarily require that acronyms were read aloud via the lexical route. However, this had not been substantiated prior to this thesis. The answer to this research question is considerably more clear cut on the basis of the evidence collected here. While acronyms may be inconsistent in their spelling to sound configurations and idiosyncratic in their written form it is almost certainly not the case that reading them necessitates the lexical system. There are three important pieces of evidence described in this thesis that indicate that acronyms (at least not all acronyms) can be considered as irregular words.

The first finding to highlight is that there were interactions between the spelling to sound pattern of acronyms and lexical variables. This parallels common effects in the mainstream word reading literature. Among mainstream words, the regularity of the pronunciation of a word like MINT means that important information can be abstracted and applied to the processing of lower frequency or later acquired words with similar characteristics (e.g. LINT). Regular words show little to no effect of lexical variables. Irregular words, on the other hand, rely on lexical processes and cannot benefit from knowledge of words with similar spellings. Thus frequency, age of acquisition and imageability effects are particularly pronounced in irregular words. In the acronym data collected here, there is a similar pattern. Responses to unambiguous acronyms are particularly stable in the face of varying values on lexical variables. This seems to suggest that they are more similar to regular than irregular words. In contrast, the written representations of ambiguous acronyms do not signal their pronunciation to the reader. In this type of acronym, as in irregular words, significant influences of frequency, AoA and imageability are observed. This indicates that there is a kind of regularity which is peculiar to acronyms – those which are obviously pronounced a letter at a time do not require lexical access, but acronyms with multiple possible pronunciations do.

The second finding which indicates that not all acronyms are processed via the lexical route (the route specifically tailored to irregular word reading) is that the responses to ambiguous acronyms are altered by the context in which they are presented. When the context is such that the majority of the stimuli are read lexically, the responses to ambiguous typical and ambiguous atypical do not differ significantly. However, when majority of the stimuli are pronounced a letter at a time, typical acronyms are pronounced faster than atypical acronyms.

If all acronyms required lexical reading, then this would not be the case. Some acronyms have a degree of predictability in their pronunciation which is conferred on them by a letter naming strategy. This is not the case in irregular words and represents an important difference between the two types of stimulus.

The third, and most compelling, finding is that there are acronyms which can be read accurately when lexical representations do not exist for them in the participant's lexicon. Participants pronounce the majority of letter by letter acronyms correctly even when they do not report that they know the meaning of it. Under these circumstances, the lexical route cannot be providing the correct pronunciation. By definition, irregular words can only be named correctly via lexical processes. This means that typically pronounced acronyms are not the same as irregular words. This interpretation is further supported by the continued success of JD in reading aloud typically pronounced acronyms even after her lexico-semantic processes had been adversely affected by semantic dementia. It also has considerable implications in relation to the work by Laszlo and Federmeier (2007). They used consonant-only acronyms (unambiguous typical acronyms as described in this thesis) as a stimulus which was supposed to be familiar but illegal, and require lexical reading – that they were irregular. It has been demonstrated here that unambiguous typical acronyms are probably the least irregular subtype of acronyms. This calls in to question both their assumptions and their conclusions regarding the source of the N400 repetition effect.

In sum, then, the findings of this thesis indicate that acronyms cannot all be considered in the same way, and that their characteristics may necessitate different processes. It is also argued that acronyms cannot be considered the same as irregular words.

8.3. Acronyms and models of reading

Having gone some way to answering the research questions above, it becomes pertinent to discuss the success of currently influential models of word reading to accommodate acronym performance. It is acknowledged that to date no model of word reading has actually attempted to account for acronym reading as well. Nevertheless, human readers are able to decode and use acronyms in everyday life, and thus it could be argued that theoretical models ought to provide explanations for these processes.

Throughout this thesis it has been suggested that the peculiar characteristics of acronyms may provide a useful tool to examine the function of the reading system. Previous researchers have also made this assertion, and acronyms have been used to evaluate currently influential word reading models (Laszlo & Federmeier, 2007b; 2008). These authors considered that acronyms would necessarily involve lexical reading (or a semantically mediated processing), because of their unusual orthography and phonology. Following this assumption they examined acronyms in relation to the differential N400 repetition effect found for words (HAT) and pseudowords (e.g., DAWK) but not for orthographically illegal nonwords (MDTP). They argued that according to the dual route model, the sensitivity of the N400 component to the repetition of legal letter strings, for both words and pseudowords (Deacon, Dynowska, Ritter, & Gorse-Fifer, 2004; Rugg, 1990) could only reflect the performance of the non-lexical pathway since this is the only route available to read novel items. In consequence, no repetition effects in the N400 should be observed when reading consonant-only acronyms since their unusual pronunciation precludes the use of the non-lexical route. Connectionist models, alternatively, would predict repetition effects in the N400 for words, pseudowords and acronyms since the same process underpins the recognition of any type of letter string. Laszlo and Federmeier (2007b) found N400 repetition effects for words, pseudowords and acronyms and not for illegal non-words. They concluded that this outcome could only be accommodated by the connectionist account for oral reading. However, the data in this thesis (particularly Chapter 5) indicate that lexical processing is not always necessary for acronym processing, especially in the case of unambiguous (i.e. consonant only) acronyms. Further Laszlo and Federmeier (2007b) failed to acknowledge that pseudowords created from high frequency base words can cause lexical activation (Coltheart, 2007) and therefore give rise to their results via a lexical route for reading. Thus Laszlo and Federmeier's conclusion that their findings were not reconcilable with a dual route perspective was based on some flawed assumptions.

That said, neither the dual route model nor the connectionist model of reading, as they currently stand, can adequately account for all of the findings detailed in this thesis. With a few minor alterations, acronym processing could be accommodated in a dual route framework. The addition of a second set of sublexical processing rules to the dual route model would be sufficient to cope with acronyms. These may require a third pathway, or a mechanism for altering the GPC rules when acronyms are encountered. A letter naming route from print to pronunciation would allow for the successful reading of the majority of

acronyms without the need for lexical access. Such a model would also be able to account for the disparity in the speed of processing observed between different types of acronyms with reference to the potential conflicts between the pronunciations offered by each route.

Accommodating acronym reading in connectionist models is more complex. Connectionist models (e.g. Harm & Seidenberg, 2004; Plaut et al., 1996) propose that all written stimuli are processed using a single system for converting orthography to phonology. The system assembles a pronunciation based on the phonemes most commonly associated with the word body. In cases where the correct pronunciation for the word does not rhyme with other words with a similar spelling, the orthography to phonology pathway is mediated by input from the semantic system. The majority of acronyms (i.e. those which are typically pronounced) would be incorrectly read if the pronunciation was based on mainstream word neighbours. Thus typical acronym pronunciation would have to be semantically mediated in current connectionist models. However, this is not by the findings reported in this thesis. If the reading of typically pronounced acronyms requires some input from the semantic system, accuracy in reading these items would suffer in semantic dementia. However, JD was most accurate in reading typically pronounced acronyms, even when she had progressively poorer performances in semantic tasks. Unambiguous typical acronyms have peculiar orthographies, containing strings of consonants together in combinations which seldom occur in mainstream English words. Unambiguous acronyms are also likely to have few neighbours for comparison. It is possible to suggest that this peculiarity would be enough to set them apart from the majority of the English language words, and that a connectionist model with enough training would therefore be able to learn to pronounce each letter in turn when a stimulus with these characteristics was presented. This would enable the model to adequately account for JD's success in unambiguous acronyms. However, the results showed with ambiguous acronyms are difficult to explain with connectionist models. Ambiguous atypical acronyms like NASA often follow word-like orthography to phonology conversions and would likely use the orthography to phonology connections proposed by the model. Throughout the thesis, ambiguous atypical acronyms were consistently read slower than either unambiguous or ambiguous typical acronyms, while regular words were read more quickly. According to connectionist models, the orthography to phonology pathway should be equally efficient at reading ambiguous atypical acronyms and regular words (everything else being equal). However, this was not the case, in fact ambiguous typical acronyms (HIV) were processed

more quickly. These acronyms would be pronounced as regular words if the orthography to phonology pathway was left unconstrained by semantic input. Again, the data in Chapter 5 showed that JD remained able to successfully read ambiguous typical acronyms once her semantic system had been damaged. Thus, in order to name ambiguous typical acronyms successfully, the intervention of the semantic system is not necessary.

8.4. Future directions

Throughout this thesis it has been suggested that the characteristics of acronyms may make them a valuable resource for investigating the factors involved in word reading. One avenue of research which may yield particularly interesting and informative results is using acronyms to examine the age of acquisition effect. The arbitrary mapping hypothesis (Ellis & Lambon Ralph, 2000) states that age of acquisition effects should be observable only when the mapping between the input and the output is arbitrary, such as in reading words with unpredictable spelling to sound correspondences. The argument is that words which are acquired early in life are well represented in the mental lexicon irrespective of their regularity. Late acquired words with predictable spelling to sound correspondences are able to draw on the knowledge of similarly spelled words which have already been learned, and hence they are read quickly and accurately. Those irregular words which are acquired later in life have no previous knowledge to build upon. Thus late acquired irregular words are read more slowly than early acquired words and late acquired regular words. The three types of acronym discussed here vary in their print to pronunciation characteristics. Typically pronounced acronyms follow a letter naming rule. Atypical acronyms are, on occasions, GPC regular. Thus unambiguous acronyms follow a rule system which is clearly signalled by their orthography. As such no age of acquisition effects would be predicted. Ambiguous acronyms, by definition, have less obvious pronunciations. Thus age of acquisition would be expected to play a part in their reading. Some evidence of this was provided in Chapter 3, where a significant interaction was shown between AOA and acronym type. By integrating one type of ambiguous acronym into a mainstream word naming experiment, it may be possible to explore the nature of the relationship between orthography to phonology correspondences and age of acquisition effects.

One finding reported in this thesis, specifically in Chapter 3, warrants further exploration. Naming responses to ambiguous atypical acronyms showed effects of age of acquisition and frequency in the opposite direction to other acronyms, and to those reported in mainstream word reading studies. Late acquired or low frequency atypical acronyms were read more quickly than their early acquired or high frequency counterparts. Ambiguous atypical acronyms are pronounced in the same way as regular words (i.e. by grapheme to phoneme correspondences). However, their pronunciation does not follow the same pattern as the majority of acronyms. In Chapter 3, most of the stimuli presented required a letter by letter pronunciation. The reversed frequency and age of acquisition effects observed for atypical acronyms was attributed to the fact that their pronunciation required a different mechanism to the majority of the items. This created a conflict in the system which was greater for high frequency or early acquired at atypical acronyms. If this is the case, then it could be expected that changing the context of the experiment altered the direction of the frequency and age of acquisition effects for ambiguous atypical acronyms. In a list of items which contained mainstream words, but not acronyms, the pronunciation of ambiguous atypical acronyms would be similar to the other stimuli. In this case there would be little conflict between pronunciation mechanisms, and it might be expected that the advantage was observed for high frequency acronyms. In relation to age of acquisition effects, it may be that in a context where grapheme-phoneme correspondences were commonly employed as a method of assembling phonology, the pronunciation of ambiguous atypical acronyms was predictable. Thus it could be expected that the predictability of the pronunciation of ambiguous atypical acronyms meant that no age of acquisition effect was exhibited. The predicted result would be that late acquired ambiguous atypical acronyms were read at similar latencies to early acquired ambiguous atypical acronyms, early acquired irregular words, and all regular words. The fact that irregular words acquired later in life cannot draw on previous reading experience and spelling to sound knowledge would make the reaction times longer in this condition.

The characteristics of acronyms could also be used to investigate the development of age of acquisition effects. The arbitrary mapping hypothesis posits that the advantage at reading late acquired regular versus late acquired irregular words stems from the fact that learning new regular words builds on existing spelling to sound knowledge. If this was true, then it could be expected that it would take fewer encounters to learn a new word with predictable spelling

to sound correspondences. This could be tested. An assessment of this could be undertaken using acronyms. Unambiguous acronyms have a particularly transparent orthography to phonology translation. In this case, it would be possible to predict a very rapid learning process. Little learning of the pronunciation would be required which may allow for quicker acquisition of meaning. Ambiguous acronyms are not consistent and predictable in their pronunciation, so a greater amount of practice may be required before the item is fully learned. Therefore, acronyms might be useful material to be used in studies of artificial learning for two reasons. The first is that they are constantly being coined, and that many come from specialist fields. Thus it is possible to select acronyms which are unfamiliar to the participant. Furthermore, the form of an acronym is such that they could be invented for the specific purposes of the experiment at hand if the need arose. As acronyms have unusual orthographies in any case, there would be less opportunity for spelling to be a factor in the creation of the items. The second advantage that acronyms have in laboratory learning experiments is that they are a part of the English language. In the majority of cases, simulating age or order of acquisition effects in the laboratory (as well as other types of learning experiment) rely on learning words in a foreign language. This presents its own challenges to the participant as well as adding to the task of designing an adequately controlled experiment. An examination of the role of print to pronunciation characteristics in acquiring new words could be of use in language teaching methods and inform theories concerning age of acquisition effects.

Another strand of research stemming from a better understanding of acronym processing could focus on acronym usage. Acronyms are ostensibly created to abbreviate long or cumbersome phrases and make the concepts easier to discuss. As evidenced in this thesis, participants are often slower to recognise and understand acronyms than they are to comprehend mainstream words. The American Psychological Association style manual dictates that acronyms should be used if they will be easy for the reader to remember and understand. "I'm going to put on the DVD" is easy to understand. DVD is a common acronym and is used frequently, but what if the acronym is less familiar to the reader? "I'm going to put on the GPR" is probably more difficult to decipher. One question that arises is as to whether using an unfamiliar acronym in place of its full term is easier or more difficult to read and process a sentence. To examine this, participants could be asked to assess the appropriateness of a sentence. In order to determine whether the sentence is meaningful it

would be necessary to understand the acronym. By comparing the time taken to respond to "I'm going to put on the GPR" with the latency in responding to "I'm going to put on the ground penetrating radar" it would be possible to determine whether using the acronym was having the desired effect. It may also be able to extend this paradigm to assess how many presentations of the acronyms are required before they are sufficiently well known to provide no obstacle to the comprehension of the sentence.

In sum, this thesis has added to the study of word reading by describing the characteristics of a type of stimulus which has not been widely used, by examining the factors which influence acronym processing, and by highlighting the shortfalls of currently influential models to account for the performance of participants in acronym reading. The full potential of acronyms as an experimental stimulus is yet to be realised, and future research could benefit from the inclusion of acronyms.

REFERENCES

Abboud, H. A. (1999). *Superlab pro 1.75: The experimental lab software.* Phoenix, AZ: Cedrus Corporation.

Adelman, J., & Brown, G. (2007). Phonographic neighbors, not orthographic neighbors, determine word naming latencies. *Psychonomic Bulletin and Review, 24,* 455-459.

Aderman, D., & Smith, E., (1971). Expectancy as a determinant of functional units in perceptual recognition. *Cognitive Psychology, 2,* 117-129.

Aitchison, J. (2003). *Words in the mind: An introduction to the mental lexicon.* Blackwell: Oxford, UK.

Alameda, J., & Cuetos, F. (2000). Incidencia de la vecidad ortografica en el reconocimiento de palabras. *Revista de Psicologica General y Aplicada, 53 (1),* 85-107.

Alija, M., & Cuetos, F. (2006). Effects of the lexical-semantic variables in visual word recognition. *Psicothema, 18 (3),* 485-491.

Altarriba, J., Bauer, L., & Benvenuto, C., (1999). Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behaviour Research Methods, Instruments and Computers,* 31(4), 578-602.

Andrews, S. (1989). Frequency and neighbourhood effects on lexical access: activation or search? *Journal of Experimental Psychology: Learning, Memory and Cognition, 15 (5),* 802-814.

Andrews, S. (1992). Frequency and neighbourhood effects on lexical access: lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory and Cognition, 18 (2),* 234-254.

Anisfeld, E. (1964). *A comparison of the cognitive function of monolinguals and bilinguals.* Unpublished doctoral thesis. McGill University.

Assadollahi, R. & Pulvermüller, F. (2001). Neuromagnetic evidence for early access to cognitive representations. *Neuroreport, 12,* 207-213.

Atwood, H., & MacKay, W. (1989). *Essentials of neurophysiology*, B.C. Decker, Hamilton, Canada.

Azuma, T., & Van Orden, G. C. (1997). Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. *Journal of Memory and Language, 36 (4),* 484-504.

Baayen, H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database*, Linguistic Data Consortium, University of Pennsylvania, Philadelphia.

Baayen, R.H., Piepenbrock, R. and Gulikers, L. (1995). *The CELEX Lexical Database (Version 2) (CD-ROM),* Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Baayen, R. H., Feldman, L. B., & Schreuder, R. (2006). Morphological influences on the recognition of monosyllabic monomorphemic words. *Journal of Memory and Language, 55 (2),* 290-313.

Balota, D. A., Cortese, M. J., Hutchison, K. A., Neely, J. H., Nelson, D., Simpson, G. B., et al. (2000). *The English Lexicon Project: A Web-based repository of descriptive and behavioral measures for 40,481 English words and nonwords.*

Balota, D.A. & Ferraro, F., (1996). Lexical, sublexical, and implicit memory processes in healthy young and healthy older adults and in individuals with dementia of the Alzheimer type. *Neuropsychology, 10(1),* 82-95.

Balota, D. A., & Spieler, D. H. (1998). The utility of item-level analyses in model evaluation: A reply to Seidenberg and Plaut. *Psychological Science, 9,* 238-240.

Balota, D.A., Law, M., & Zevin, J., (2000). The attentional control of lexical processing pathways: Reversing the word frequency effect. *Memory & Cognition, 28(7),* 1081-1089.

Balota, D. A, Yap, M. J., & Cortese, M. J. (2006). Visual word recognition: The journey from features to meaning (a travel update). In: M. Traxler & M. A. Gernsbacher (Eds.). *Handbook of Psycholinguistics* (pp. 285-375). Amsterdam: Academic Press.

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. J. (2004). Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General, 133,* 283-316.

Balota, D.A., Yap, M., Cortese, M., Hutchison, K., Kessler, B., Loftis, B., Neely, J., Nelson, D., Simpson, G., & Treiman, R. (2007). The English lexicon project. *Behavior Research Methods, 39(3),* 445-459.

Baluch, B., & Besner, D. (1991). Visual Word Recognition: Evidence for Strategic Control of Lexical and Nonlexical Routines in Oral Reading. *Journal of Experimental Psychology, Learning, Memory and Cognition, 17(4)*, 644-651.

Barca, L., Burani, C., & Arduino, L. S. (2002). Word naming times and psycholinguistic norms for Italian nouns. *Behavior Research Methods, 34,* 424-434

Baron, J., & Strawson, C. (1976). Use of orthographic and word-specific knowledge in reading aloud. *Journal of Experimental Psychology; Human Perception and Performance, 2 (3),* 386-393.

Barry, C., Morrison, C., & Ellis, A.W. (1997). Naming the Snodgrass and Vanderwart pictures: Effects of age of acquisition, frequency and name agreement, *Quarterly Journal of Experimental Psychology, 50,* 565-560.

Barry, C., Johnston, R. A., & Wood, R. F. (2006). Effects of age of acquisition, age and repetition priming on object naming, *Visual Cognition, 13,* 911-927.

Becker, C. (1976). Allocation of attention during visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance,* 2, 658-672.

Behrmann, M., & Bub, D. (1992). Surface dyslexia and dysgraphia: Dual routes, a single lexicon. *Cognitive Neuropsychology, 9,* 209 –258.

Bentin, S., McCarthy, G., Perez, E., Puce, A., Allison, T. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*, 551-565.

Bentin, S., Mouchetant-Rostaing, Y., Giard, M., Echallier, J., & Pernier, J., (1999). ERP manifestations of processing printed words at different psycholinguistic levels: time course and scalp distribution. *Journal of Cognitive Neuroscience, 11 (3)*, 235–260.

Besner, D., and Davelaar, E. (1983) Suedohomofoan effects in visual word recognition: evidence for phonological processing. *Canadian Journal of Psychology, 37*, 300–305.

Besner, D., Davelaar, E., Alcott, D., & Parry, P. (1984). Wholistic reading of alphabetic print: Evidence from the FDM and the FBI. In L. Henderson (Ed.), *Orthographies and reading: Perspectives from cognitive psychology, neuropsychology and linguistics* (pp. 121–135) Hillsdale, NJ: Erlbaum.

Biedermann, G., (1966). Supplementary report: the recognition of tachistoscopically presented five-letter-words as a function of digram frequency. *Journal of Verbal Learning and Behavior, 5,* 208-209.

Bijeljac-Babic, R., Millogo, V., Farioli, F., & Grainger, J. (2004). A developmental investigation of word length effects in reading using a new on-line word identification paradigm. *Reading and Writing, 17 (4),* 411-431.

Binder, J. R, Medler, D. A., Westbury, C. F., Liebenthal, E., & Buchanan, L. (2006). Tuning of the human left fusiform gyrus to sublexical orthographic structure. *NeuroImage, 33 (2),* 739-748.

Bird, H., Franklin, S., & Howard, D., (2001). Age of acquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments and Computers, 33(1),* 73-79.

Blair, I. V., Urland, G. R., & Ma, J. E. (2002). Using Internet search engines to estimate word frequency. *Behavior Research Methods, 34,* 286-290.

Blazely, A., Coltheart, M., & Casey, B. (2005). Semantic impairment with and without surface dyslexia: Implications for models of reading. *Cognitive Neuropsychology, 22,* 695–717.

Bonin, P. (2005). Comment accè-t-on à un mot en production verbale écrite? [Lexical access in written word production]. *Psychologie Française, 50,* 323-338.

Bonin, P., Barry, C., Meot, A., & Chalard, M. (2004). The influence of age of acquisition in word reading and other tasks: A never ending story? *Journal of Memory and Language, 50,* 456-476.

Bonner, M., Vesely, L., Price, C., Anderson, C., Richmond, L., Farag, C., Avants, B., Grossman, M. (2009) Reversal of the concreteness effect in semantic dementia. *Cognitive Neuropsychology, 26(6),* 568-579

Bowey, J. A. (1990). Orthographic onsets and rimes as functional units of reading. *Memory and Cognition, 18 (4),* 419-427.

Broadbent, D., & Gregory, M., (1968). Visual perception of words differing in letter ddigram frequency. *Journal of Verbal Learning and Verbal Behavior, 7,* 569-571.

Brysbaert, M., Ghyselilnck, M. (2006). The effect of age of acquisition: Partly frequency-related, partly frequency-independent. *Visual Cognition, 13*, 992-1011.

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods, 41,* 977-990.

Brysbaert, M., Speybroeck, S., & Vanderelst, D. (2009). Is there room for the BBC in the mental lexicon? On the recognition of acronyms. *Quarterly Journal of Experimental Psychology, 62 (9),* 1832-1842.

Brysbaert, M., Van Wijnendaele, I., & De Deyne, S. (2000). Age of acquisition effects in semantic tasks. *Acta Psychologica, 104,* 215-226.

Bub, D., Cancelliere, A., & Kertesz, A. (1985). Whole-word and analytic translation of spelling to sound in a non-semantic reader. In K. Patterson, M. Coltheart, & J. C. Marshall (Eds.), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading* (pp. 3–34). London: Erlbaum.

Burgess, C., & Livesay, K. (1998). The effect of corpus size in predicting reaction time in a basic word recognition task: Moving on from Kucera & Francis. *Behavior Research Methods, Instruments and Computers, 30 (2),* 272-277.

Butler, B., & Hains, S. (1979). Individual differences in word recognition latency. *Memory and Cognition, 7*, 68-76.

Canas, J. J. (1990). Associative strength effects in the lexical decision task. *Quarterly Journal of Experimental Psychology,* 42A, 121-145.

Cannon, G., (1989). Abbreviations and acronyms in Englsih word formation. *American Speech, 64(2),* 99-127.

Carroll, J. B., & White, M. N. (1973). Word frequency and age of acquisition as determiners of picture naming latency, *Quarterly Journal of Experimental Psychology, 25,* 85-95.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition, 47 (2)*, 149–180.

Catling, J. C., Dent, K., & Williamson, S. (2008). Age of acquisition, not word frequency affects object recognition: Evidence from the effects of visual degradation. *Acta Psychologica, 129 (1),* 130-137.

Chan, D., Fox, N., Scahill, R., Crum, W., Whitwell, J., Leschziner, G., Rossor, A., Stevens, J., Cipolotti, L., & Rossor, M., (2001). Patterns of temporal lobe atrophy in semantic dementia and Alzheimer's disease. *Annals of Neurology, 49,* 433-442.

Cheng, T. (1992). Acronyms of major cardiologic trials. *American Journal of Cardiology, 70(18),* 1512-1514.

Cheng, T. (1994a). Acronyms of clinical trials in cardiology. *American Journal of Cardiology, 74(1),* 79-94.

Cheng, T. (1994b). Use of unexplained acronyms in speciality journals. *International Journal of Cardiology, 46(2),* 185-188.

Cheng, T. (1994c). Acronymophilia. *British Medical Journal, 309,* 683.

Cipolotti, L., & Warrington, E. (1995). Semantic memory and reading abilities: A case report. *Journal of the International Neuropsychological Society, 1,* 104 –110.

Collins, A., & Quillian, M., (1969). Retrieval time from semantic memory. *Journal of verbal learning and verbal behaviour, 8 (2),* 240–248.

Collins, A., & Loftus, E., (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82 (6),* 407–428

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.) *Strategies of information processing.* New York: Academic Press.

Coltheart, M. (1981). The MRC Psycholinguistic Database. *Quarterly Journal of Experimental Psychology, 33A,* 497-505.

Coltheart, M. (2001). Assumptions and methods in cognitive neuropsychology. In Rapp, B. (Ed.), *Handbook of Cognitive Neuropsychology.* Philadelphia: Psychology Press.

Coltheart, M. (2007). Modelling reading: The dual-route approach. In M. J. Snowling & C. Hulme (Eds.) *The science of reading: A handbook.* Malden, MA: Blackwell.

Coltheart, M., & Rastle, K. (1994). Serial processing in reading aloud: Evidence for dual-route models of reading. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1197-1211.

Coltheart, M., Saunders, S., & Tree, J. (2010). Computational modelling of the effects of semantic dementia on visual word recognition. *Cognitive Neuropsychology, 27(2),* 101-114.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and paralleldistributed-processing approaches. *Psychological Review, 100 (4),* 589-608.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535-555). Hillsdale, NJ: Erlbaum.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108,* 204-256.

Compton, P., Grossenbacher, P., Posner, M. I., & Tucker, D. M. (1991). A cognitive anatomical approach to attention in lexical access. *Journal of Cognitive Neuroscience, 3,* 304–312.

Connine, C. M., Mullenix, J., Shernoff, E. & Yelen, J. (1990). Word familiarity and frequency in visual and auditory word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 1084-1096.

Conrad, M., Carreiras, M., Tamm, S., & Jacobs, A. M. (2009). Syllables and bigrams: Orthographic redundancy and syllabic units affect visual word recognition at different processing levels. *Journal of Experimental Psychology: Human Perception and Performance, 35 (2),* 461-479.

Cortese, M. J., & Simpson, G. B. (2000). Regularity effects in word naming: What are they? *Memory and Cognition, 28 (8),* 1269-1276.

Cortese, M. J., Simpson, G.B., & Woolsey, S., (1997). Effects of association and imageability on phonological mapping. *Psychonomic Bulletin and Review, 4(2),* 226-231.

Cramer, P. (1968). *Word association.* New York: Academic Press.

Cuetos, F., Barbón, A., Urrutia, M., & Dominguez, A. (2009). Determining the time course of lexical frequency and age of acquisition using ERP. *Clinical Neurophysiology, 120 (2),* 285-294.

Davis, C. J. (2006). Orthographic input coding: A review of behavioural data and current models. In S. Andrews (Ed.), *From inkmarks to ideas: Current issues in lexical processing* (pp. 180–206). Psychology Press.

Davis, C.J. (2010). The spatial coding model of visual word identification. *Psychological Review, 117 (3),* 713-758.

Deacon, D., Dynowska, A., Ritter, W., & Grose-Fifer, J. (2004). Repetition and semantic priming of nonwords: Implications for theories of N400 and word recognition. *Psychophysiology, 41,* 60–74.

De Groot, A., (1989). Representational aspects of word imageability and word frequency as assessed through word association. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15(5),* 824-845.

Dehaene, S., Le, C., Poline, J., Le Bihan, D., & Cohen, L., (2002). The visual word form area: a prelexical representation of visual words in the fusiform gyrus. *Neuroreport, 13 (3),* 321–325.

Dien, J., (2009). The neurocognitive basis of reading single words as seen through early latency ERPs: A model of converging pathways. *Biological Psychology, 80,* 10-22.

Dien, J., Frishkoff, G., Cerbone, A., & Tucker, D., (2003). Parametric analysis of event-related potentials in semantic comprehension: evidence for parallel brain mechanisms. *Cognitive Brain Research, 15,* 137–153.

Dilkina, K., McClelland, J., & Plaut, D. (2008). A single-system account of semantic and lexical deficits in five semantic dementia patients. *Cognitive Neuropsychology, 25,* 136-164

Drieghe, D., & Brysbaert, M. (2002). Strategic effects in associative priming with words, homophones and pseudohomophones. *Journal of Experimental Psychology: Learning, Memory and Cognition,* 28(5), 951-961.

Dubois, S., Rossion, B., Schiltz, C., Bodart, J. M., Michel, C., Bruyer, R & Crommelinck, M. (1999). Effect of familiarity on the processing human faces, *NeuroImage, 9,* 278-289.

Ellis, A. W., & Lambon-Ralph, M.A., (2000). Age of acquisition effects in adult lexical processing reflect loss of plasticity in maturing systems: Insights from connectionist networks. *Journal of Experimental Psychology: Learning, Memory and Cognition, 26(5),* 1103-1123.

Ellis, A., & Monaghan, J., (2002). Reply to Strain, Patterson and Seidenberg (2002). *Journal of Experimental Psychology: Learning, Memory and Cognition, 28(1),* 215-220.

Ellis, A. W., Burani, C., Izura, C., Bromiley, A., & Venneri, A. (2006). Traces of vocabulary acquisition in the brain: evidence from covert object naming. *NeuroImage, 33*, 958-968.

Ferrand, L. (2000). Reading aloud polysyllabic words and nonwords: the syllabic length effect reexamined. *Psychonomic Bulletin and Review, 7 (1),* 142-148.

Ferrand, L., & New, B. (2003). Associative and semantic priming in the mental lexicon. In P. Bonin (Ed.), *The mental lexicon: Some words to talk about words* (pp. 25-43). New York: Nova Science Publishers.

Ferraro, F.R., & Hansen, C.L. (2002) Orthographic neighborhood size, number of word meanings, and number of higher frequency neighbors, *Brain and Language,* 82, 200–205.

Fiebach, C., Ricker, B., Friederici, A., & Jacobs, A., (2007). Inhibition and facilitation in visual word recognition: Prefrontal contribution to the orthographic neighbourhood size effect. *NeuroImage, 36,* 901-911.

Fitzpatrick, T. (2006). Habits and rabbits: word associations and the L2 lexicon. *EUROSLA Yearbook 6*, 121-145.

Fitzpatrick, T. (2007). Word association patterns: unpacking the assumptions. *International Journal of Applied Linguistics* 17, 3, 319-331.

Fitzpatrick, T. (2009). Word association profiles in a first and second language: Puzzles and problems. In Fitzpatrick, T. and Barfield, A. (eds) *Lexical Processing in Second Language Learners.* Bristol: Multilingual Matters.

Fodor, J. A. (1983). *Modularity of mind.* Cambridge, MA: MIT Press.

Forster, K.I., (1976). Accessing the mental lexicon. In R. J. Wales and E. W. Walker (Eds.) *New approaches to language mechanisms* (pp. 257-287). Amsterdam: North-Holland.

Forster, K.I., (1998). Pros and cons of masked priming. *Journal of Psycholinguistic Research, 27(2),* 203-233.

Forster, K. I., & Chambers, S. M. (1973). Lexical access and naming. *Journal of Verbal Learning and Verbal Behavior, 12 (6),* 627-635.

Forster, K.I., & Shen, D, (1996). No enemies in the neighbourhood: Absence of inhibitory neighbourhood effects in lexical decision and semantic categorization. *Journal of Experimental Psychology: Learning, Memory and Cognition, 22(3),* 696-713.

Fox, P., (1970). Patterns of stability and change in behaviors of free association. *Journal of Verbal Learning and Verbal Behavior*, 9 (1), 30-36

Frederiksen, J. R., & Kroll, J. F. (1976). Spelling and sound: Approaches to the internal lexicon. *Journal of Experimental Psychology: Human Perception and Performance, 2 (3),* 361-379.

Gaskell, G. (2009). *The Oxford handbook of psycholinguistics.* Oxford, UK: Oxford University Press

Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models.* Cambridge: Cambridge University Press.

Gerhand, S. (1998). *Age of acquisition effects in normal reading and in deep dyslexia.* Unpublished doctoral dissertation, University of Cardiff, Cardiff, Wales.

Gerhand, S., & Barry, C. (1999). Age-of-acquisition and frequency effects in speeded naming. *Cognition, 73 (2),* B27-B36.

Gernsbacher, M. A., (1984) Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology: General, 113*, 254–281.

Gevins, A., & Rémond, A. (1987). *Handbook of electroencephalography and clinical neurophysiology, Methods of analysis of brain electrical and magnetic signals*, Elsevier, Amsterdam.

Ghyselinck, M., De Moor, W., & Brysbaert M. (2000). Age-of-acquisition ratings on 2816 Dutch four- and five-letter nouns, *Psychologica Belgica, 40 (2),* 77-98.

Ghyselinck, M., Lewis, M. B., & Brysbaert, M., (2004). Age of acquisition and the cumulative frequency hypothesis: A review of the literature and a new multitask investigation. *Acta Psychologica, 115,* 43-67.

Gibson, E. J., Bishop, C. H., Schiff, W., & Smith, J. (1964). Comparisons of meaningfulness and pronunciability as grouping principles in the perception and retention of verbal material. *Journal of Experimental Psychology, 67 (2),* 173-182.

Gilhooly, K., & Gilhooly, M. (1980). The validity of age-of-acquisition ratings. *British Journal of Psychology, 71*, 105-110

Gilhooly, K. J., & Logie, R. H. (1982). Word age-of-acquisition and lexical decision making. *Acta Psychologica, 50 (1),* 21-34.

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 674-691.

Gough, P., & Cosky, M. (1977). One second of reading again. In N. Castellan, D. Pisoni, & G. Potts (Eds.), *Cognitive theory (Vol. 2).* Hillsdale, New Jersey: Erlbaum.

Graduate Record Examinations Board. (1992). *Practicing to take the official GRE General Test (No. 9).* Princeton, NJ: Educational Testing Service.

Graham, N., Patterson, K., & Hodges, J. (2000). The impact of semantic memory impairment on spelling: Evidence from semantic dementia. *Neuropsychologia, 38,* 143–163.

Grainger, J, & Jacobs, A., (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review, 103(3),* 518-565.

Graves, W., Desai, R., Humpries, C., Seidenberg, M.S., Binder, J.R. (2010). Neural systems for reading aloud: A multiparametric approach. *Cerebral Cortex, 20 (8),* 1799-1815.

Hall, J., & Ugelow, A., (1957). Free association time as a function of word frequency. Canadian Journal of Psychology, 11 (1), 29-32.

Harm, M. W., & Seidenberg, M. S. (1999). Reading acquisition, phonology, and dyslexia: Insights from a connectionist model. *Psychological Review, 106*, 491-528.

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review, 111*, 662-720.

Hauk, O., & Pulvermuller, F., (2004). Effects of word length and frequency on the human event-related potential. *Clinical Neurophysiology 115 (5),* 1090–1103.

Hauk, O., Davis, M. H., Ford, M., Pulvermuller, F. & Marslen-Wilson, W. D. (2006). The time course of visual word recognition as revealed by linear regression analysis of ERP data. *NeuroImage, 30,* 1383-1400.

Hauk, O., Patterson, K., Woollams, A., Watling, L., Pulvermuller, F., & Rogers, T. T. (2006). [Q:] When would you prefer a SOSSAGE to a SAUSAGE? [A:] At about 100 msec. ERP correlates of orthographic typicality and lexicality in written word recognition. *Journal of Cognitive Neuroscience, 18 (5),* 818-832.

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review, 111,* 662–720.

Henderson, L. (1974). A word superiority effect without orthographic assistance. *Quarterly Journal of Experimental Psychology, 20,* 301–311.

Hino, Y., & Lupker, S. J., (1996). Effects of polysemy in lexical decision and naming - an alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance,* **22,** 1331–1356

Hino, Y., & Lupker, S. J., (2000). Effects of word frequency and spelling-to-sound regularity in naming with and without preceding lexical decision. *Journal of Experimental Psychology: Human Perception and Performance,* **26(1),** 166–183.

Hirsh, K. W. & Ellis, A. W. (1994). Age of acquisition and aphasia: A case study. *Cognitive Neuropsychology, 11,* 435-458.

Hodges, J., Graham, N., & Patterson, K. (1995). Charting the progression in semantic dementia: Implications for the organisation of semantic memory. *Memory, 3,* 463–495.

Hodges, J., Patterson, K., Oxbury, S., & Funnell, E. (1992). Semantic dementia. Progressive fluent aphasia with temporal lobe atrophy. *Brain, 115,* 1783–1806.

Holmes, S., Fitch, J., & Ellis, A. W., (2006). Age of acquisition affects object recognition and naming in patients with Alzheimer's Disease. *Journal of Clinical and Experimental Neuropsychology, 28 (6),* 1010-1022.

Howard, D. (1991). Letter by letter readers: Evidence for parallel processing. In D. Besner & G. W. Humphreys (Eds.) *Basic Processes in Reading: Visual Word Recognition.* Hillsdale, New Jersey: Erlbaum.

Howard, D., & Patterson, K. (1992). *Pyramids and palm trees: A test of semantic access from pictures and words.* Bury St. Edmunds, England: Thames Valley Test Company.

Howes, D. H., & Solomon, R. L. (1951) Visual threshold as a function of word-probability. *Journal of Experimental Psychology, 41,* 401-410.

Hudson, P. T. W., & Bergman, M. W. (1985). Lexical knowledge in word recognition: Word length and word frequency in naming and lexical decision tasks. *Journal of Memory and Language, 24 (1),* 46-58.

Izura, C., & Ellis, A. W., (2002). Age of acquisition effects in word recognition and production in first and second languages. *Psicologica, 23,* 245-281.

Izura, C., Hernandez-Muñoz, N., & Ellis, A. W. (2005). Category norms for 500 Spanish words in five semantic categories. *Behavior Research Methods, 37,* 385-397.

Izura, C., & Playfoot, D., (under review). A normative study of acronyms and acronym naming.

James, C. (1975). The role of semantic information in lexical decisions. *Journal of Experimental Psychology: Human Perception and Performance, 104,* 130-136.

Jamieson, E. (1968). Acronymania-A Modern Contagion. *New Scientist,* 37: 473-74.

Jared, D., (1997). Spelling-sound consistency affects the naming of high frequency words. *Journal of Memory and Language, 36,* 505-529.

Jared, D. (2002). Spelling-sound consistency and regularity effects in word naming. *Journal of Memory and Language, 46,* 723-750.

Jared, D., & Seidenberg, M. S. (1990). Naming multisyllabic words. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 92–105.

Jared, D., McRae, K., & Seidenberg, M., (1990). The basis of consistency effects in word naming. *Journal of Memory and Language, 29(6),* 687-715.

Jefferies, E., Lambon Ralph, M. A., Jones, R., Bateman, D., & Patterson, K. (2004). Surface dyslexia in semantic dementia: A comparison of the influence of consistency and regularity. *Neurocase, 10,* 290 –299.

Jenkins, J., & Russell, W. (1960). Systematic changes in word association norms: 1910-1952. *Journal of Abnormal and Social Psychology*, 60(3), 293-304

Johnston, R. A., & Barry, C., (2006). Age of acquisition and lexical processing. *Visual Cognition, 13,* 789-845.

Juhasz, B. J., (2005). Age of acquisition effects in word and picture identification. *Psychological Bulletin, 131,* 684-712.

Juhasz, B. J., & Rayner, K. (2006). The role of age of acquisition and word frequency in reading: Evidence from eye fixation durations. *Visual Cognition, 13 (7-8),* 846-863.

Kaplan, E., Goodglass, H., & Weintraub, S (1983). *The Boston Naming Test.* Lea & Febiger: Philadelphia.

Kay, J., & Bishop, D. (1987). Anatomical differences between nose, palm, and foot, or, the body in question: Further dissection of the processes of sub-lexical spelling-sound translation. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 449-469). Hillsdale, NJ: Erlbaum

Kay, J. & Ellis, A. (1987) A cognitive neuropsychological case study of anomia: implications for psychological models of word retrieval. Brain, 110, 613-629.

Kay, J., Lesser, R., & Coltheart, M. (1992) *PALPA: Psycholinguistic Assessments of Language Processing in Aphasia.* Hove: Lawrence Erlbaum Associates.

Kennet, J., McGuire, L., Willis, S. L., & Schaie, K. W. (2000). Memorability functions in verbal memory: A longitudinal approach. *Experimental Ageing Research, 26 (2),* 121-137.

Kent, G., & Rosanoff, A. (1910). A study of associations in insanity. *American Journal of Insanity*, 67,317-90.

Kessler, B., Treiman, R., & Mullenix, J (2002). Phonetic biases in voice key response time measurements. *Journal of Memory and Language, 47 (1),* 145-171

Klepousniotou, E., & Baum, S. R. (2007). Disambiguating the ambiguity advantage effect in word recognition: An advantage for polysemous but not homonymous words. *Journal of Neurolinguistics, 20 (1),* 1-24.

Kiss, G.R., Armstrong, C., Milroy, R., and Piper, J. (1973) An associative thesaurus of English and its computer analysis. In Aitken, A.J., Bailey, R.W. and Hamilton-Smith, N. (Eds.), *The Computer and Literary Studies*. Edinburgh: University Press.

Kučera, H., & Francis, W. (1967). *Computational analysis of present day American-English.* Providence: Brown University Press.

Kutas, M., & Hillyard, S. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203-208.

Kutas, M. & Federmeier, K. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Science, 4,* 463-470.

Laisney, M., Giffard, B., Belliard, S., de la Sayette, V., Desgranges, B., & Eustache, F., (2011). When the zebra loses its stripes: Semantic priming in early Alzheimer's disease and semantic dementia. *Cortex, 47,* 35-46.

Lambon Ralph M., & Howard D. (2000). Gogi aphasia or semantic dementia? Simulating and assessing poor verbal comprehension in a case of progressive fluent aphasia. *Cognitive Neuropsychology, 17 (5),* 437-465.

Lambon Ralph, M., Graham, K., Ellis, A., & Hodges, J., (1998). Naming in semantic dementia – what matters? *Neuropsychologia, 36(8),* 775-784.

Laszlo, S. & Federmeier, K. D. (2007a). The acronym superiority effect. *Psychonomic Bulletin and Review, 14 (6),* 1158-1163.

Laszlo, S. & Federmeier, K. D. (2007b). Better the DVL you know: acronyms reveal the contribution of familiarity to single-word reading. *Psychological Science, 18 (2),* 122-126.

Laszlo, S. & Federmeier, K. D. (2008). Minding the PS, queues and PXQs: Uniformity of semantic processing across multiple stimulus types. *Psychophysiology, 45,* 458-466.

Liu Y.Y., Hao, M.L., Hua, S., Tan L-H. & Weekes, B.S. (2008). Age of acquisition effects on oral reading in Chinese. *Psychonomic Bulletin and Review, 15 (2),* 344-350.

Lukatela, G. & Turvey, M. T. (1994). Visual lexical access is initially phonological: 1. Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General*, 123(2), 107-128.

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods, Instruments, & Computers, 28*, 203–208.

Lupker, S. J. (1984). Semantic priming without association: a second look. *Journal of Verbal Learning and Verbal Behavior, 23*, 709–733.

Marí-Beffa, P., Valdés, B., Cullen, D., Catena, A., & Houghton, G., (2005). ERP analyses of task effects on semantic processing from words. *Cognitive Brain Research, 23,* 293–305.

Martín-Loeches, M., Hinojosa, J., Gómez-Jarabo, G., & Rubia, F., (1999). The recognition potential: an ERP index of lexical access. *Brain and Language, 70,* 364–384.

Martín-Loeches, M., Hinojosa, J., Fernández-Frías, C., & Rubia, F., (2001a). Functional differences in the semantic processing of concrete and abstract words. *Neuropsychologia, 39,* 1086–1096.

Martín-Loeches, M., Hinojosa, J., Gómez-Jarabo, G., & Rubia, F., (2001b). An early electrophysiological sign of semantic processing in basal extrastriate areas. *Psychophysiology 38,* 114–124

Martin-Loeches, M., (2007). The gate for reading: Reflections on the Recognition Potential. *Brain Research Reviews, 53,* 89-97.

Maurer, U., Brandeis, D., & McCandliss, B., (2005). Fast, visual specialization for reading in English revealed by the topography of the N170 ERP response. *Behavioural and Brain Functions, 1,* 13.

Massaro, D., & Cohen, M., (1994). Visual, orthographic, phonological, and lexical influences in reading. *Journal of Experimental Psychology: Human Perception and Performance, 20(6),* 1107-1128.

Marshall, J., & Newcombe, F. (1973). Patterns of paralexia: A psycholinguistic approach. *Journal of Psycholinguistic Research,* 2, 175–199.

Mathey, S. (2001). L'influence du voisinage orthographique lors de la reconnaisance des mots écrits [The influence of orthographic neighbourhood on visual word recognition]. *Revue Canadienne de Psychologie Expérimentale/Canadian Journal of Experimental Psychology, 55*, 1-23.

McCandliss, B., Posner, M., & Givon, T., (1997). Brain plasticity in learning visual words. *Cognitive Psychology, 33,* 88-110.

McCarthy, R., & Warrington, E. (1986). Phonological reading: Phenomena and paradoxes. *Cortex, 22,* 359 –380.

McClelland, J., (1976). Preliminary letter perception in the perception of words and nonwords. *Journal of Experimental Psychology: Human Perception and Performance, 2,* 80-91.

McClelland, J., & Johnston, J., (1977). The role of familiar units in perception of words and nonwords. *Perception & Psychophysics, 22(3),* 249-261.

McClelland, J., & Rumelhart, D., (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review, 88(5),* 375-407.

McRae, K., de Sa, V., & Seidenberg, M. S. (1997). On the nature and scope of featural representations of word meaning. *Journal of Experimental Psychology: General, 126*, 99–130.

McKoon, G. M., & Ratcliff, R. (1992). Spreading activation versus compound cue accountsof priming: mediated priming revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 1155–1172

Medler, D.A., & Binder, J.R. (2005). MCWord: An On-Line Orthographic Database of the English Language. http://www.neuro.mcw.edu/mcword/

Menenti, L., & Burani, C., (2007). What causes the effect of age of acquisition in lexical processing? *Quarterly Journal of Experimental Psychology, 60,* 652- 660.

Meuter, R., & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language, 40,* 25-40.

Meyer, D., & Schvaneveldt, R. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology,* 90, 227-234.

Meyer, D. & Schvaneveldt, R. (1975). Loci of contextual effects on visual word recognition. In Rabbitt, P. & Dornic, S. (Eds.), *Attention and performance*, Academic Press.

Miles, J., & Shevlin, M. (2001). *Applying regression & correlation: A guide for students and researchers.* London: Sage.

Monaghan, J., & Ellis A. W. (2002). What exactly interacts with spelling-sound consistency in word naming? *Journal of Experimental Psychology: Learning, Memory, & Cognition, 28,* 183-206.

Monaghan, P., & Ellis, A. W. (2010). Modeling reading development: Cumulative, incremental learning in a computational model of word naming. *Journal of Memory and Language, 63,* 506-525.

Monsell, S. (1991). The nature and locus of word frequency effects in reading. In D. Besner & G. W. Humphreys (Eds), *Basic Processes in Reading: Visual Word Recognition*, pp. 148-197. Hillsdale, NJ: Erlbaum.

Monsell, S., Patterson, K., Graham, A., Hughes, C., & Milroy, R. (1992). Lexical and sublexical translation of spelling to sound: Strategic anticipation of lexical status. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18(3),* 452-467.

Morrison, C. M., Chappell, T. D., & Ellis, A. W., (1997). Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. *Quarterly Journal of Experimental Psychology,50A,* 528-559.

Morrison, C. M., & Ellis, A. W., (1995). The roles of word frequency and age of acquisition in word naming and lexical decision. *Journal of Experimental Psychology: Learning, Memory and Cognition, 21,* 116-133.

Morrison, C. M., & Ellis, A. W., (2000). Real age of acquisition effects in word naming and lexical decision. *British Journal of Psychology, 91,* 167-180.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review*, 76, 165-178.

Moss, H., & Older, L., (1996). *Birkbeck Word Association Norms.* Hove: Psychology Press.

Mossman, J. (Ed.) (1994). *Acronyms Initialisms and Abbreviations Dictionary.* Detroit Michigan: Gale Cengage.

Nagy, W., & Anderson, R. (1984). How many words are there in printed school English? *Reading Research Quarterly, 19*, 304-330.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. http://www.usf.edu/FreeAssociation/.

Nelson, D. L., & Schreiber, T. A. (1992). Word concreteness and word structure as independent determinants of recall. *Journal of Memory & Language*, 31, 237-260.

Nelson, D. L., Schreiber, T A., & McEvoy, C. L. (1992). Processing implicit and explicit representations. *Psychological Review, 99,* 322-348.

New, B., Ferrand, L., Pallier, C., & Brysbaert, M., (2006). Re-examining the word length effect in visual word recognition: new evidence from the English Lexicon Project. *Psychonomic Bulletin and Review, 13(1),* 45-52.

Noice, H., & Hock, H. S. (1987). A word superiority effect with nonorthographic acronyms: Testing for unitized visual codes. *Perception & Psychophysics, 42*, 485–490.

O'Regan, J., & Jacobs, A. (1992). Optimal viewing position effect in word recognition: A challenge to current theory. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 990-1001.

Oldfield, R. (1966). Things, Words and the Brain. *Quarterly Journal of Experimental Psychology*, 18, 240-253.

Oldfield, R. C., & Wingfield, A. (1965). Response latencies in naming objects. *Quarterly Journal of Experimental Psychology, 17 (4),* 273-281.

Osipow, S., & Grooms, R. (1965). Comparisons between cultural and individual associative response hierarchies. *Journal of Verbal Learning and Verbal Behavior*, 4(2), 94-97

Owsowitz, S. E. (1953) *The effect of word familiarity and letter structure familiarity on the perception of words.* Rand Corporation Publications, No. P-2820, 1963.

Oxford English Dictionary (2009). Oxford: Oxford University Press.

Paap, K., & Noel, R. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research, 53*, 13-24.

Paap, K., Newsome, S., McDonald, J., & Schvaneveldt, R., (1982). An activation-verification model for letter and word recognition: The word superiority effect. *Psychological Review, 89,* 573-594.

Paivio, A. (1965). Abstractness, imagery, and meaningfulness in paired-associate learning. *Journal of Verbal Learning and Verbal Behavior, 4,* 32-38.

Paivio, A. (1971). *Imagery and verbal processes.* New York: Holt, Rinehart, and Winston.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45,* 255-287.

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology, 76 (1, Pt.2),* 1-25.

Palermo, D., & Jenkins, J. (1964). *Word association norms: Grade school through college.* Minneapolis: University of Minnesota Press.

Parkin, A. J. (1982). Phonogical recoding in lexical decision: Effects of spelling-to-sound regularity depend on how regularity is defined. *Memory & Cognition, 10 (1),* 43-53.

Parkin, A. J., & Underwood, G. (1983). Orthographic versus phonological irregularity in lexical decision. *Memory and Cognition, 11,* 351-355.

Patterson, K., & Hodges, J. R. (1992). Deterioration of word meaning: Implications for reading. *Neuropsychologia, 30,* 1025–1040.

Patterson, K., & Kay, J. (1982). Letter-by-letter reading: Psychological descriptions of a neurological syndrome. *Quarterly Journal of Experimental Psychology, 34A,* 411-441.

Patterson, K., Lambon Ralph, M., Jefferies, E., Woollams, A., Jones, R., Hodges, J., & Rogers, T. (2006). "Presemantic" cognition in semantic dementia: Six deficits in search of an explanation. *Journal of Cognitive Neuroscience, 18,* 169 –183.

Pechmann, T., Reetz, H., & Zerbst, D. (1989). Kritik einer Meßmethode: Zur Ungenauigkeit von Voice-key Messungen. [Critique of a method of measurement: On the unreliability of voice-key measurements.] *Sprache & Kognition, 8,* 65–71.

Peereman, R., & Content, A. (1995). Neighborhood size effect in naming: Lexical activation or sublexical correspondences? *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21*, 409-421

Perea, M., & Lupker, S. J. (2003). Transposed-letter confusability effects in masked form priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art.* Philadelphia, PA: Psychology Press.

Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language, 51,* 231–246.

Perea, M., & Rosa, E., (2002). Does "whole-word shape" play a role in visual word recognition? *Perception and Psychophysics, 64(5),* 785-794.

Perea, M., Acha, J., & Fraga, I. (2008). Lexical competition is enhanced in the left hemisphere: Evidence from different types of orthographic neighbors. *Brain and Language, 105*, 199-210.

Perea, M., Rosa, E., & Gómez, C. (2002). Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? *Memory and Cognition, 30*, 34-45.

Perea, M., Rosa, E., & Gómez, C. (2005). The frequency effect for pseudowords in the lexical decision task. *Perception and Psychophysics, 67*, 301-314.

Pérez, M. A., (2007). Age of acquisition persists as the main factor in picture naming when cumulative word frequency and frequency trajectory are controlled. *Quarterly Journal of Experimental Psychology, 60,* 32-42.

Plaut, D., & Shallice, T., (1993). Perseverative and semantic influences on visual object naming errors in optic aphasia: A connectionist account. *Journal of Cognitive Neuroscience, 5(1),* 89-117.

Posnansky, C. J. et al. (1973). *The Colorado concreteness and imagery norms* (Program on Cognitive Factors in Human Learning and Memory Report No. 10). Boulder, CO: University of Colorado, Institute for the Study of Intellectual Behavior

Postman, L. (1964). Short term memory and incidental learning. In W.A. Melton (Ed.) *Categories of Human Learning,* New York: Academic Press (pp. 145-201).

Postman, L. (1970). The California norms: Association as a function of word frequency. In L. Postman & G. Keppel (Eds.). *Norms of word association* (pp. 241-320). New York: Academic Press.

Postman, L & G Keppel (1970). *Norms of Word Association*. New York: Academic Press.

Price, C., & Devlin, J., (2003). The myth of the visual word form area. *NeuroImage 19,* 473–481.

Prinzmetal, W., & Millis-Wright, M. (1984). Cognitive and linguistic factors affect visual feature integration. *Cognitive Psychology, 16,* 305-340.

Pind, J., & Tryggvadottir, H. B. (2002). Determinants of picture naming times in Icelandic. *Scandinavian Journal of Psychology, 43 (3),* 221-226.

Raman, I. (2006). On the age-of-acquisition effects in word naming and orthographic transparency: Mapping specific or universal? *Visual Cognition,* **13**, 1044–1053.

Rastle, K., & Coltheart, M. (1999). Serial and strategic effects in reading aloud. *Journal of Experimental Psychology: Human Perception & Performance, 25,* 482-503.

Rayner, K., McConkie, G., & Zola, D., (1980). Integrating information across eye movements. *Cognitive Psychology, 12,* 206-226.

Reicher, G. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81 (2),* 275–280.

Reynolds, M., & Besner, D. (2005a). Basic processes in reading: A critical review of pseudohomophone effects in naming and a new implemented computational account. *Psychonomic Bulletin & Review, 12,* 622– 646.

Reynolds, M., & Besner, D. (2005b). Contextual control over lexical and sublexical routines when read English aloud. *Psychonomic Bulletin & Review, 12,* 113–118.

Reynolds, M., & Besner, D., (2008). Contextual effects on reading aloud: Evidence for pathway control. *Journal of Experimental Psychology: Learning, Memory and Cognition, 34(1),* 50-64.

Rice, G. A., & Robinson, D. O. (1975). The role of bigram frequency in the perception of words and nonwords. *Memory & Cognition, 3 (5),* 513-518.

Richards, R. M., & Ellis, A. W (2008). Mechanisms of identity and gender decisions to faces: Who rocked in 1986? *Perception, 37,* 1700-1719.

Richardson, J., (1976). The effects of stimulus attributes upon latency of word recognition. *British Journal of Psychology, 67(3),* 315-325.

Riddoch, M., & Humphreys, G. (1993). *The Birmingham Object Recognition Battery (BORB).* London: Erlbaum.

Rogers R.D., Monsell S. (1995). The cost of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*, 207–231

Rogers, T., Lambon Ralph, M., Hodges, J., & Patterson, K. (2004). Natural selection: The impact of semantic impairment on lexical and object decision. *Cognitive Neuropsychology, 21*, 331–352.

Rubenstein, H., Garfield, L., & Millikan, J.A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior, 9(5),* 487-494.

Rubenstein, H., Lewis, S., & Rubenstein, M. (1971). Homographic entries in the internal lexicon: Effects of systematicity and relative frequency of meanings. *Journalof Verbal Learning & Verbal Behavior,* 10, 57-62

Rudell, A., (1990). The recognition potential: a visual response evoked by recognizable images. *Abstracts – Neuroscience, 16*, 106.

Rudell, A., (1992). Rapid stream stimulation and the recognition potential. *Electroencephalography and Clinical Neurophysiology, 83,* 77–82.

Rudell, A., & Hua, J., (1995). Recognition potential latency and word image degradation. *Brain and Language, 51,* 229–241.

Rudell, A., & Hua, J., (1997). The recognition potential, word difficulty, and individual reading ability: on using event-related potentials to study perception. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 1170–1195.

Rugg, M. D. (1990) Event-related brain potentials dissociate repetition effects of high- and low-frequency words, *Memory and Cognition,* **18**, 367–379.

Rumelhart, D., & Siple, P., (1974). The process of recognizing tachistoscopically presented words. *Psychological Review, 81,* 99-118.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime 1.0.* Pittsburgh, PA: Psychological Software Tools.

Schwartz, M., Saffran, E., & Marin, O. (1980). Fractionating the reading process in dementia: Evidence for word-specific print-to-sound associations. In M. Coltheart, K. Patterson, & J. C. Marshall (Eds.), *Deep dyslexia* (pp. 259 –269). London: Routledge.

Sears, C., Hino, Y., & Lupker, S. (1995). Neighbourhood size and neighbourhood frequency effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21(4),* 876-900.

Seidenberg, M. (1985). The time course of phonological activation in two writing systems. *Cognition, 19,* 1–30.

Seidenberg, M., & McClelland, J. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96,* 523-568.

Seidenberg, M., & Waters, G. (1989). Word recognition and naming: A mega study. *Bulletin of the Psychonomic Society, 27,* 489.

Seidenberg, M., Waters, G., Barnes, M., & Tanenhaus, M., (1984). When does irregular spelling or pronunciation influence word recognition. *Journal of Verbal Learning and Verbal Behavior, 23(3),* 383-404.

Sereno, S., Rayner, K., & Posner, M., (1998). Establishing a time-line in word recognition: evidence from eye movements and event-related potentials. *NeuroReport 9,* 2195–2200.

Shallice, T., Warrington, E., & McCarthy, R. (1983). Reading without semantics. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 35(A),* 111–138.

Sheehan, E. A., Namy, L. L., & Mills, D. L. (2007). Developmental changes in neural activity to familiar words and gestures. *Brain & Language, 101 (3),* 246-259.

Snodgrass, J., & Jarvella, R. (1972). Some linguistic determinants of word classification times. *Psychonomic Science, 27,* 220-222.

Snodgrass, J., & Vanderwart, M., (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6 (2), 174-215.

Snowden, J., Goulding, P., & Neary, D. (1989). Semantic dementia: A form of circumscribed cerebral atrophy. *Behavioural Neurology, 2,* 167–182.

Spoehr, K., & Smith, E., (1975). The role of orthographic and phonotactic rules in perceiving letter patterns. *Journal of Experimental Psychology: Human Perception and Performance, 104,* 21-34.

Stadthagen-Gonzalez, H., & Davis, C. J. (2006). The Bristol norms for age of acquisition, imageability and familiarity. *Behavior Research Methods, 38,* 598–605.

Stolz, W., & Tiffany, J., (1972). The production of "child-like" word associations by adults to unfamiliar adjectives. *Journal of Verbal Learning and Verbal Behavior,* 11, 38-46.

Spieler, D. H., & Balota, D. A. (1997). Bringing computational models of word naming down to the item level. *Psychological Science*, *8*, 411-416.

Stadthagen-Gonzalez, H., & Davis, C. J. (2006). The Bristol norms for age of acquisition, imageability, and familiarity. *Behavior Research Methods, 38*, 598-605.

Staller, J. D., & Lappin, J. S. (1981). Visual detection of multi-letter patterns. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 1258–1272.

Stanovich, K. E., & Bauer, D. W. (1978). Experiments on the spelling-to-sound regularity effect in word recognition. *Memory & Cognition, 6 (4),* 410-415.

Steyvers, M., & Tenenbaum, J., (2005). The large-scale structure of semantic networks: statistical analyses and a model of semantic growth. *Cognitive Science, 29 (1),* 41-78.

Strain, E., & Herdman, C. M. (1999). Imageability effects in word naming: An individual differences analysis. *Canadian Journal of Experimental Psychology, 53 (4),* 347-359.

Strain, E., Patterson, K. E. & Seidenberg, M. S. (1995). Semantic effects in single-word naming. *Journal of Experimental Psychology: Learning, Memory and Cognition, 21,* 1140-1154.

Strain, E., Patterson, K. E., & Seidenberg, M. S. (2002). Theories of word naming interact with spelling-sound consistency. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 28*, 207-214.

Teplan, M., (2002). Fundamentals of EEG measurement. *Measurement Science Review, 2*, 1-11.

Tree J.J., Perfect T. J., Hirsh K. W. & Copstick S. (2001) Deep dysphasic performance in non-fluent progressive aphasia: A case study, *Neurocase: Case Studies in Neuropsychology, Neuropsychiatry, and Behavioural Neurology*, 7 *(6),* 473-488.

Turner, J., Valentine, T., & Ellis, A.W., (1998). Contrasting effects of age of acquisition and word frequency on auditory and visual lexical decision. *Memory and Cognition, 26(6),* 1282-1291.

van Elk, M., van Schie, H. T., & Bekkering, H. (2010). The N400-concreteness effect reflects the retrieval of semantic information during the preparation of meaningful actions. *Biological Psychology, 85 (1),* 134-142.

van Loon-Vervoorn, W. A. (1989). Eigenschappen van basiswoorden. Lisse: Swets and Zeitlinger.

Van Petten, C., Coulson, S., Rubin, S., Plante, E., & Parks, M. (1999). Time course of word identification and semantic integration in spoken language. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25(2),* 394-417.

Venezky, R. (1970). *The structure of English orthography.* The Hague: Mouton.

Vigneau, M., Jobard, G., Mazoyer, B., & Tzourio-Mazoyer, N. (2005). Word and non-word reading: What role for the visual word form area? *Neuroimage, 27*, 694–705.

Vinckier, F., Dehaene, S., Jobert, A., Dubus, J. P., Sigman, M., & Cohen, L. (2007). Hierarchical coding of letter strings in the ventral stream: Dissecting the inner organization of the visual word-form system. *Neuron, 55 (1),* 143-156.

Visser, T., & Besner, D. (2001). On the dominance of whole word knowledge in reading aloud. *Psychonomic Bulletin & Review, 8(3),* 560-567.

Warrington, E. K., & Shallice, T., (1980). Word-form dyslexia. *Brain, 103,* 99-112.

Waters, G. S., & Seidenberg, M. S. (1985). Spelling-sound effects in reading: Time course and decision criteria. *Memory and Cognition, 13,* 557-572.

Weekes, B.S. (1997). Differential effects of number of letters on word and nonword naming latency. *Quarterly Journal of Experimental Psychology, 50A (2)*, 439-456.

Weekes, B. S., & Raman, I. (2008). Bilingual deep dysphasia. *Cognitive Neuropsychology, 25 (3),* 411-436.

Weekes, B. S., Castles, A. E., & Davies, R. A. (2006). Effects of Consistency and Age of Acquisition on Reading and Spelling among Developing Readers. *Reading and Writing, 19 (2),* 133-169.

Weekes, B. S., Chan, A. H. D., & Tan, L. H. (2008). Effects of age of acquisition on brain activation during Chinese character recognition. *Neuropsychologia, 46 (7),* 2086-2090.

Whaley, C. P. (1978). Word-nonword classification time. *Journal of Verbal Learning and Verbal Behavior, 17 (2),* 143-154.

Woollams, A., Lambon Ralph, M., D., Plaut & Patterson, K. (2007). SD squared: On the association between semantic dementia and surface dyslexia. *Psychological Review, 114(2),* 316-339.

Woollams, A., Cooper-Pye, E., Hodges, J., & Patterson, K. (2008). Anomia: A doubly typical signature of semantic dementia. *Neuropsychologia, 46*, 2503-2514

Yang, L., & Givón, T. (1993). *Tracking the acquisition of L2 vocabulary: The Keki language experiment* (Tech. Rep. No. 93-11). Eugene: University of Oregon, Institute of Cognitive and Decision Sciences.

Yarkoni, T., Balota, D., & Yap, M. (2008). Moving beyond Coltheart's N: A new measure of orthographic similarity. *Psychonomic Bulletin and Review, 15,* 971-979.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: a review of 30 years of research. *Journal of Memory and Language, 46*, 441-517

Zeno, S., Ivens, S., Millard, R., & Duvvuri, R. (1995). *The educator's word frequency guide.* Brewster, NY: Touchstone Applied Science Associates.

Zevin, J., & Balota, D., (2000). Priming and attentional control of lexical and sublexical pathways during naming. *Journal of Experimental Psychology: Learning, Memory and Cognition, 26(1),* 121-135.

Appendix 2.1

High frequency acronyms	Low frequency acronyms	High frequency irregular words	Low frequency irregular words	High frequency regular words	Low frequency regular words	Illegal non-words	Legal non-words
ADHD	ABV	CAUSE	ALL	ART	BAWL	ACG	BERN
ASAP	AVI	DEATH	BEING	FACT	BEND	ANL	BRIET
ATM	AWOL	FOOT	BLEW	FAR	BORN	AQB	CLENG
BBC	BAFTA	GREAT	BRIEF	FEW	CLANG	CNZ	CRALT
BLT	BNP	GROUP	BROAD	JOB	CLOSE	CRN	FROAD
BMI	BPM	LEARN	BURY	KILL	DENT	DTF	LAVE
BMW	BSE	LOSE	CRAFT	LEAST	FAIL	FCL	MAV
CCTV	BSL	LOW	CURE	LIFE	FAINT	FIFP	MEEN
CIA	BST	MIND	EARN	LIVE	GUIDE	GIFA	MINTH
CSI	DHL	MONTH	FAST	MADE	LOUD	HPB	MOCT
DNA	DOA	MOST	GRIND	MAIN	MOAN	IVC	MOOL
DVD	EEG	MOVE	LAST	MAY	MOOD	JVT	MUND
FAQ	HMS	OLD	LAUGH	MEAN	NEAR	LDA	OND
GCSE	LBW	RAISE	NONE	MEET	NINE	LPL	PAG
HIV	LSD	REAL	PAST	MUCH	PAT	MCI	PALT
HMV	MGM	RISE	PURE	SEND	PEACE	MRQ	ROAL
HSBC	NASA	SHOW	QUIET	SENSE	REAR	MVF	SEP
ITV	OBE	SURE	RULE	SHORT	RIDE	PNC	SHEW
KFC	PTSD	THEM	SEW	SIDE	SAD	PVT	SODE
LCD	RNIB	THREW	WALK	THINK	SWELL	RDO	SUND
MTV	RNLI	THUS	WARN	TOWN	TALE	RKA	SWALL
NHS	RSPB	WAR	WASH	TURN	TREAT	RQP	THAM
NSPCC	SIDS	WHOM	WISE	WAIT	TRUST	RRC	TOIN
QVC	WWF	WORLD	WON	WHILE	WHY	TNN	WOSE
YMCA	YTS	YOUNG	WORSE	WROTE	WISH	VRI	WUSH

Appendix 3.1

Acronyms and norms in alphabetical order

Acronym	Definition	Ass Sem Rel (%)	V Ved: 0 Vless: 1	Pronun Un:1 Am Typ:2 Am Atyp:3	No. Lett	No. Syll	No. Phon	N	Imag	Rated Freq	Freq Log Google	Freq Log Bing	Freq Log AltaVista	AoA	Log (x+1) Big Freq	Log (x+1) Trig Freq
ABBA	Anni-Frid, Bjorn, Benny and Agnetha (Music group)	95	0	3	4	2	3	0	6.10	2.20	7.04	7.21	7.53	8.42	3.67	1.91
ACDC	Alternating Current Direct Current (Music group)	94	0	2	4	4	7	0	5.3	2.60	6.61	7.06	7.40	14.24	3.66	0.00
ADHD	Attention Deficit Hyperactivity Disorder	100	0	2	4	4	8	0	5.75	3.30	7.23	7.02	7.94	15.31	3.73	1.00
AGM	Annual General Meeting	69	0	2	3	3	5	4	3.6	1.80	6.82	6.71	7.65	16.33	3.52	1.68
AOL	America Online	94	0	2	3	3	4	5	5.25	2.70	8.20	8.25	8.70	18.19	3.71	0.00
APR	Annual Percentage Rate	67	0	2	3	3	4	3	3.6	2.50	8.87	8.53	9.17	16.44	3.93	1.84
ASAP	As Soon As Possible	100	0	2	4	2	6	0	5.3	4.25	7.84	7.11	6.12	10.49	4.20	2.16
ASBO	Anti-Social Behaviour Order	100	0	3	4	2	4	0	5.5	2.65	5.95	5.15	6.55	20.25	4.13	0.87
ATM	Automated Teller Machine	87	0	2	3	3	5	3	6.3	3.85	7.66	7.16	8.12	15.84	4.36	2.13

AWOL	*Absent Without Leave*	62	0	3	4	2	4	0	4.6	2.20	6.24	6.36	7.03	13.62	3.87
BAFTA	British Academy of Film and Television Arts	100	0	3	5	5	5	0	6.4	2.10	6.34	5.73	7.09	14.67	3.82
BBC	British Broadcasting Corporation	100	0	1	3	3	6	0	6.2	5.85	8.29	7.63	8.72	6.74	2.45
BHS	British Home Stores	94	0	1	3	3	7	1	5.9	2.70	6.61	6.37	7.12	11.68	2.42
BLT	Bacon Lettuce and Tomato	100	0	1	3	3	6	4	6.25	3.40	6.51	6.34	7.29	13.45	3.75
BMI	Body Mass Index	56	0	1	3	3	5	0	4.95	3.02	7.21	6.98	7.79	17.65	3.67
BMW	Bavarian Motor Works	94	0	1	3	3	9	1	6.45	3.90	8.23	7.90	8.63	9.83	1.54
BNP	British National Party	83	0	1	3	3	6	1	4.9	2.20	6.85	6.36	7.50	18.10	1.79
BOGOF	Buy One Get One Free	83	0	3	5	2	5	0	5.3	3.30	5.18	5.09	6.21	16.55	4.09
BPM	Beats Per Minute	80	0	1	3	3	6	1	3.65	1.90	7.11	6.97	7.68	15.21	2.18
BPS	British Psychological Society	58	0	1	3	3	6	1	3.95	2.75	7.12	6.57	7.42	18.26	3.00
BRB	Be Right Back	50	0	1	3	3	6	5	6.75	4.15	6.51	5.80	6.82	11.93	3.36
BSE	Bovine Spongiform Encephalography	62	0	1	3	3	5	3	4.15	1.90	6.75	6.62	7.58	16.07	4.16
BST	British Summer Time	81	0	1	3	3	6	4	3.1	2.10	7.92	6.78	8.04	15.16	4.24
BTW	By The Way	65	0	1	3	3	9	1	6.45	3.95	8.09	7.26	8.24	12.67	3.19
BYOB	Bring Your Own Bottle	50	0	2	4	4	7	2	3.6	1.75	6.16	5.63	7.06	18.36	3.76

CBT	Cognitive Behavioural Therapy	63	1	1	3	3	6	3	4.65	2.65	6.78	7.08	7.20	19.38	2.31	0.00
CCTV	Closed Circuit Television	100	1	1	4	4	8	0	6.4	4.15	7.76	6.70	8.00	14.44	3.61	0.00
CEO	Chief Executive Officer	79	1	2	3	3	4	1	4.7	2.30	8.26	7.67	8.82	17.74	4.01	0.32
CIA	Criminal Intelligence Agency	88	1	2	3	3	4	1	5.65	2.65	7.63	7.26	8.12	13.43	3.81	3.26
CJD	Creutzfeld-Jakob Disease	80	1	1	3	3	6	3	3.05	1.45	6.00	5.79	6.44	16.89	0.00	0.00
CNN	Cable News Network	100	1	1	3	3	6	3	5.35	3.20	7.97	7.49	8.54	15.23	3.06	0.00
CPU	Central Processing Unit	80	1	1	3	3	5	0	4.55	2.80	8.10	7.68	8.35	16.42	3.21	0.00
CSI	Crime Scene Investigation	100	1	1	3	3	5	1	5.3	3.40	7.68	6.96	8.12	18.11	3.90	0.47
DHL	Dalsey, Hillblom and Lynn (Delivery Company)	63	0	1	3	3	7	0	4.7	2.65	6.97	6.75	7.64	16.59	2.34	0.00
DIY	Do It Yourself	100	0	2	3	3	5	9	6.55	3.80	8.24	7.20	8.69	10.44	3.79	0.13
DNA	Deoxyribonucleic Acid	100	0	1	3	3	5	0	6	3.10	8.08	7.48	8.44	13.83	3.60	1.34
DOA	Dead On Arrival	58	0	2	3	3	4	0	4.25	2.35	6.98	6.40	8.21	14.55	3.68	0.00
DOB	Date Of Birth	100	0	2	3	3	5	23	6.15	3.50	6.90	6.60	7.35	10.15	3.72	0.34
DUI	Driving Under the Influence	69	0	2	3	3	4	6	3.4	2.05	7.33	6.63	8.00	17.51	3.52	0.74
DVD	Digital Versatile Disc	100	0	1	3	3	6	3	6.6	5.45	8.96	8.73	9.29	17.30	2.45	0.00
DVLA	Driver and Vehicle Licensing Authority	100	0	1	4	4	7	0	6.25	3.00	5.98	5.22	6.71	17.89	3.70	0.00
DVT	Deep Vein Thrombosis	46	0	1	3	3	6	1	4.25	1.90	6.63	6.15	6.83	16.54	2.45	0.00

ECG	*Electrocardiogram (Heart* Monitor)	85	0	1	3	3	5	5	4.60	2.10	7.05	6.48	7.22	15.08	3.8(
EEG	Electroencephalogram	73	0	2	3	3	4	8	4.95	2.90	6.86	6.26	8.61	18.09	3.97
ENT	Ear, Nose and Throat	27	0	2	3	3	5	4	3.45	2.50	7.75	7.28	8.05	17.24	4.57
ESP	Extra Sensory perception	50	0	2	3	3	5	1	4.3	1.95	7.65	6.89	8.02	14.52	4.32
ESRC	Economic and Social Research Council	50	0	1	4	4	7	0	3.5	2.35	5.80	6.03	6.65	23.14	4.12
ETA	Estimated Time of Arrival	45	0	2	3	3	4	1	4.75	2.45	7.87	7.09	7.72	16.43	4.16
FAO	For the Attention Of	50	1	2	3	3	4	8	4	3.00	7.37	6.49	7.49	15.38	3.47
FAQ	Frequently Asked Question	94	1	2	3	3	5	7	5.65	4.00	9.08	8.84	9.67	14.21	3.47
FBI	Federal Bureau of Investigation	94	1	1	3	3	5	1	6.1	2.80	7.72	7.52	8.15	11.93	3.19
FIFA	Federation of Internation Football Associations	94	1	3	4	2	4	1	5.85	3.25	8.07	7.21	8.29	11.80	3.84
FYI	For Your Information	78	1	1	3	3	5	0	4.7	3.80	7.23	6.91	7.90	16.24	2.90
GBH	Grievous Bodily Harm	100	0	1	3	3	7	0	5.15	2.25	6.06	5.84	6.57	14.31	1.22
GCSE	General Certificate of Secondary Education	100	0	1	4	4	7	0	5.6	3.15	6.68	6.53	7.54	13.23	3.98
GMT	Greenwich Mean Time	88	0	1	3	3	6	4	4.65	3.20	8.55	8.05	8.99	13.83	1.81
GPA	Grade Point Average	50	0	1	3	3	5	1	1.85	1.40	7.19	6.67	7.60	16.97	3.66

GPS	Global Positioning Satellite	82	0	1	3	3	6	1	4.85	3.70	8.41	7.65	8.84	20.30	3.00	0.00
HDTV	High Definition Television	85	0	1	4	4	9	0	5.95	3.45	8.03	7.23	8.34	14.50	1.75	0.00
HGV	Heavy Goods Vehicle	83	0	1	3	3	7	0	5.3	2.75	6.16	5.73	6.75	15.62	0.32	0.00
HIV	Human Immunodeficiency Virus	100	0	2	3	3	6	6	5.55	2.95	7.76	7.58	8.36	13.34	4.27	1.62
HMO	Health Management Organisation	50	0	1	3	3	6	0	3.95	1.95	7.09	6.59	7.39	18.46	3.77	0.40
HMS	His/Her Majesty's Ship	53	0	1	3	3	7	2	5.25	2.70	6.89	6.65	7.41	12.58	3.18	0.88
HMV	His Master's Voice (Trademark in the music business)	100	0	1	3	3	7	0	6.6	3.60	6.86	6.46	7.35	12.20	2.09	0.00
HRT	Hormone Replacement Therapy	56	0	1	3	3	7	5	4.5	2.20	6.76	6.32	7.19	18.06	3.82	0.00
HSBC	Hong Kong and Shanghai Banking Corporation	89	0	1	4	4	9	0	5.95	3.60	7.18	6.48	7.83	18.70	2.41	0.00
IBM	International Business Machines Corporation	79	0	2	3	3	5	0	4.5	2.50	8.03	7.94	8.47	15.28	3.10	0.00
IBS	Irritable Bowel Syndrome	85	0	2	3	3	5	1	4.85	2.20	6.67	6.48	7.53	13.80	3.26	1.22
ICT	Information and Communication Technology	65	0	2	3	3	5	4	6.50	3.05	7.61	6.93	8.04	8.67	4.15	2.93
IMDB	Internet Movie Database	81	0	2	4	4	7	0	3.75	2.50	8.36	6.72	8.55	20.56	3.57	0.00
IRA	Irish Republican Army	100	0	2	3	3	4	7	5.75	2.05	7.60	7.24	7.96	12.73	4.14	2.40

ISP	*Internet Service Provider*	*72*	*0*	*2*	*3*	*3*	*5*	*0*	3.8	2.90	7.44	7.55	8.10	19.81	4.30
ITN	Independent Television News	83	0	2	3	3	5	3	5.85	3.85	6.75	5.84	7.21	10.47	4.29
ITV	Independent Television	79	0	2	3	3	5	1	5.95	4.75	7.15	6.57	7.72	8.42	4.28
IVF	In Vitro Fertilisation	100	0	2	3	3	5	1	5.2	2.95	6.58	6.23	7.20	16.08	3.58
KFC	Kentucky Fried Chicken	100	0	1	3	3	6	0	6.4	3.05	6.90	6.30	7.61	11.17	1.65
LBW	Leg before Wicket	63	0	1	3	3	10	2	3.15	2.05	6.06	5.82	6.69	13.03	1.77
LCD	Liquid Crystal Display	78	0	1	3	3	6	3	4.9	2.70	8.31	7.72	8.71	16.45	2.08
LMAO	Laughing My Ass Off	75	0	1	4	4	6	0	6.45	4.95	7.45	6.48	7.71	13.61	3.76
LSD	Lysergic Acid Diethylamide (Psychedelic Drug)	95	0	1	3	3	6	3	5.4	2.35	6.98	6.89	7.40	13.98	3.32
MBA	Masters in Business Administration	58	0	1	3	3	5	1	3.1	2.05	7.69	7.33	8.18	20.19	3.61
MDMA	Methylenedioxymethamphetamine (Ecstasy, Psychedelic Drug)	60	0	1	4	4	7	1	4.25	2.15	6.21	5.98	6.67	17.92	3.74
MGM	Metro Goldwyn Mayer	58	0	1	3	3	6	2	4.2	2.25	7.25	7.03	7.73	14.62	1.70
MMR	Measles Mumps Rubella	44	0	1	3	3	6	1	4.95	2.45	6.62	6.15	7.09	15.31	3.25
MRI	Magnetic Resonance Imaging	100	0	1	3	3	5	0	5.2	2.70	7.28	6.75	7.82	17.88	4.02
MRSA	Methicillin Resistant Staphylococcus Aureus	100	0	1	4	4	7	1	5	2.70	6.55	5.59	7.25	22.38	3.89

MSN	Microsoft Network	90	0	1	3	3	6	5	6.90	4.70	8.55	8.17	8.70	11.26	3.20	0.00
MTV	Music television	95	0	1	3	3	6	0	6.2	3.20	8.06	7.51	8.34	12.67	1.58	0.00
NASA	North American Space Agency	100	0	3	4	2	4	0	5.9	2.60	8.51	7.35	8.37	10.66	4.22	1.98
NASCAR	National Association for Stock Car Auto Racing	75	0	3	6	2	5	1	4.65	1.80	7.94	7.56	8.57	14.00	4.27	2.79
NATO	North American Trade Organisation	79	0	3	4	2	4	0	5.05	2.45	7.56	7.16	7.99	15.56	4.49	3.14
NBA	National Basketball Association	86	0	1	3	3	5	0	4.4	1.80	8.30	7.80	8.78	15.92	3.44	0.92
NCIS	Naval Criminal Intelligence Service	50	0	1	4	4	7	0	3.5	2.25	7.16	5.59	7.50	20.57	4.24	2.85
NHS	National Health Service	94	0	1	3	3	7	0	6.35	4.30	8.04	6.94	8.05	10.68	2.57	0.82
NSPCC	National Society for the Prevention of Cruelty to Children	100	0	1	5	5	10	0	5.95	2.75	5.76	5.42	6.49	13.26	3.69	1.97
NYPD	New York Police Department	95	0	1	4	4	8	0	5.90	2.20	6.40	6.33	7.33	12.40	3.16	0.17
OAP	Old Age Pensioner	100	0	2	3	3	4	16	6.35	3.20	6.15	6.59	6.67	11.40	3.60	1.44
OBE	Officer of the Order of the British Empire (British title)	71	0	2	3	3	4	4	4.95	2.20	6.76	6.78	7.07	14.89	4.08	2.28
OCD	Obsessive Compulsive Disorder	88	0	2	3	3	5	2	5.45	3.35	6.67	6.36	7.42	16.48	3.32	0.00

OCR	*Oxford Cambridge and RSA Examinations*	62	0	2	3	3	5	2	3.25	2.00	7.40	7.07	7.58	16.81	3.64
OHP	Over Head Projector	75	0	2	3	3	6	3	3.80	1.75	6.11	5.79	6.85	10.08	2.52
PAYE	Pay As You Earn	92	1	2	4	4	6	8	4.85	2.60	6.28	5.78	6.88	17.28	3.88
PDA	Personal Digital Assistant	41	1	2	3	3	5	1	3.2	2.25	8.09	7.66	8.45	20.77	3.38
PDF	Portable Document Format	93	1	1	3	3	6	0	6.15	5.35	9.03	8.34	9.22	19.50	1.74
PGCE	Post Graduate Certificate in Education	73	1	1	4	4	7	2	5.3	3.00	5.83	5.43	6.55	19.00	3.79
PSP	Playstation Personal	72	1	1	3	3	6	6	4.15	2.25	8.25	6.88	8.67	21.61	3.58
PTA	Parent Teacher Association	83	1	1	3	3	5	1	4.7	2.15	6.92	6.61	7.55	14.38	3.94
PTO	Please Turn Over	80	1	1	3	3	5	2	6.20	2.60	6.82	6.56	7.34	9.56	4.32
PTSD	Post Traumatic Stress Disorder	63	1	1	4	4	8	0	3.7	2.45	6.51	6.23	7.41	17.73	3.61
PVC	Polyvinyl Chloride (Thermoplastic material)	65	1	1	3	3	6	0	6.2	2.65	7.66	7.35	8.18	12.40	0.46
QVC	Quality, Value, Convenience (Multinacional Corporation)	69	1	1	3	3	6	0	4.9	1.90	6.54	6.36	7.24	17.36	0.41
RAF	Royal Air Force	100	0	2	3	3	5	9	6.25	2.90	7.28	6.91	7.67	9.53	3.99
RBS	Royal Bank of Scotland	27	0	1	3	3	6	0	4.45	2.20	6.72	6.25	7.55	15.86	2.95
REM	Rapid Eye Movement (Music		0	3				8	5.25	2.55	7.54	7.06	7.62	14.59	4.54

	group)	100			3	3	3								
RNIB	Royal National Institute for the Blind	56	0	2	4	4	7	0	4.05	1.90	5.57	5.71	6.26	14.74	3.74	2.63
RNLI	Royal National Lifeboat Institute	67	0	1	4	4	7	0	4.1	1.85	5.77	5.50	6.68	14.86	3.96	1.95
RPG	Role Playing Game	78	0	1	3	3	6	3	3.55	1.75	7.86	7.37	8.26	17.76	2.71	0.00
RRP	Recommended Retail Price	63	0	1	3	3	6	3	3.65	3.15	7.26	6.80	7.94	15.51	3.38	0.00
RSPB	Royal Society for the Protection of Birds	87	0	1	4	4	8	0	5.3	2.40	6.12	6.32	6.85	14.16	3.80	1.33
RSPCA	Royal Society for the Protection of Cruelty to Animals	100	0	1	5	5	9	0	5.9	2.80	6.20	5.82	6.89	10.66	3.94	1.13
RSVP	Repondez S'ill Vous Plait	100	0	1	4	4	8	0	6.75	2.80	7.25	6.77	8.12	10.16	3.65	0.09
SAE	Stamped Addressed Envelope	87	0	2	3	3	4	11	4.8	2.35	7.06	6.58	7.53	12.42	3.66	0.00
SAS	Special Air Services	71	0	2	3	3	5	13	5.65	2.30	7.62	7.17	8.01	13.15	4.32	1.92
SCUBA	Self Contained Underwater Breathing Apparatus	90	1	3	5	2	5	0	5.05	1.50	7.41	7.31	8.03	10.27	3.60	2.22
SMS	Short Messaging Service	100	0	1	3	3	6	1	5.1	4.95	8.46	8.19	8.63	18.17	3.40	1.64
SPSS	Statistical Package for the Social Sciences	87	0	1	4	4	8	2	4.8	3.40	7.10	6.88	7.32	19.66	3.81	0.83
STD	Sexually Transmitted Disease	89	0	1	3	3	6	3	5.3	2.60	7.63	7.33	8.10	14.59	4.23	0.13

TBA	*To Be Announced*	*64*	*1*	*1*	*3*	*3*	*5*	*1*	4.45	2.90	7.18	6.97	7.83	15.77	3.45
TBC	To Be Confirmed	73	1	1	3	3	6	2	4.3	2.80	6.71	6.28	7.36	15.76	1.86
TCP	Trichiorophenymlmethyliodosalicyl (Antiseptic)	71	1	1	3	3	6	4	4.6	2.00	7.42	7.36	7.79	12.03	2.84
TFT	Thin Film Transistor	57	1	1	3	3	6	7	2.9	2.10	7.42	7.30	7.89	20.82	3.25
TLC	Tender Loving Care	95	1	1	3	3	6	4	6.40	2.30	7.31	6.90	7.81	10.12	3.32
TNT	Trinitrotoluene (Explosive)	67	1	1	3	3	6	5	5.85	2.05	7.39	7.07	7.83	13.99	4.17
UCAS	University and College Admission System	100	0	3	4	2	4	0	6	2.85	6.15	5.84	6.79	17.30	4.25
UEFA	Union of European Football Associations	94	0	3	4	3	4	0	5.7	3.00	7.91	7.14	7.95	13.88	3.67
UFC	Ultimate Fighting Championship	24	0	2	3	3	5	0	3.25	2.00	7.78	6.11	8.17	14.64	2.46
UFO	Unidentified Flying Object	100	0	2	3	3	4	0	6.45	2.35	7.37	7.18	7.92	9.72	3.90
UHF	Ultra High Frequency	50	0	2	3	3	6	0	3.65	2.10	6.73	6.55	7.34	17.20	1.61
USA	United States of America	100	0	2	3	3	4	2	6.80	4.45	9.11	8.84	9.45	6.10	4.10
USB	Universal Serial Bus	100	0	2	3	3	5	1	6.6	5.40	8.44	7.90	8.76	20.18	3.91
USSR	Union of Soviet Socialist Republics	100	0	2	4	4	7	1	5.15	1.80	7.26	6.95	7.64	11.73	3.97
VCR	Video Cassette Recorder	95	0	1	3	3	6	1	6.40	2.85	6.74	7.55	7.77	7.20	3.35

VHS	Video Home System	80	0	1	3	3	7	2	6.15	2.05	8.64	8.05	8.13	9.93	2.41	0.00
VIP	Very Important Person	84	0	2	3	3	5	14	5.75	3.20	8.34	7.64	8.53	10.96	3.67	0.44
WWF	World Wrestling Federation	63	0	1	3	3	14	0	6	2.35	6.93	7.32	7.47	11.63	1.59	0.00
YMCA	Young Man's Christian Association	65	0	1	4	4	7	0	6	2.70	7.11	6.84	7.69	11.66	3.73	0.11

Note: Ass. Sem. Rel (%) = Percentage of associative responses semantically related to the acronym definition. V = voicing. Ved = voiced. Vless = voiceless. Pronun = pronunciation. Un = Unambiguous. Am Typ = Ambiguous typical. Am Atypical = ambiguous atypical. No lett = Number of letters. No Syll = Number of syllables. No Phon = Number of phonemes. N = Number of orthographic neighbours. Imag = Imageability. Freq = Frequency. Log = Logarithm transformation. AoA = Age of acquisition. Big = Bigram. Trig = Trigram.

ACDC	Frequency of response	Associative strength
band	16	0.36
music	10	0.22
rock	5	0.11
rock band	3	0.07
rock and roll	2	0.04
alternating current direct current	1	0.02
alternating current dual current	1	0.02
electricity	1	0.02
metal	1	0.02
plug	1	0.02
rock on	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.36
DIFFERENT RESPONSES	11
UNIQUE RESPONSES	6

ADHD	Frequency of response	Associative strength
disorder	7	0.16
attention deficit hyperactivity disorder	6	0.14
attention	4	0.09
hyper	4	0.09
crazy	3	0.07
	3	
attention deficit disorder	2	0.05
active children	1	0.02
advantage	1	0.02
ahead	1	0.02
antisocial	1	0.02
attention deficiency hyperactivity disorder	1	0.02
attention deficit hyperactive disorder	1	0.02
attention disorder	1	0.02
attention problems	1	0.02
brain	1	0.02
children	1	0.02
condition	1	0.02
difficulty	1	0.02
disease	1	0.02
excitable	1	0.02
hyperactive	1	0.02
hyperactivity	1	0.02
illness	1	0.02
problem	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.16
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	18

Appendix 4.1

AGM	Frequency of response	Associative strength
	16	
meeting	15	0.48
age	2	0.06
annual general meeting	2	0.06
ageism	1	0.03
aggressive goat man	1	0.03
argumental	1	0.03
cash	1	0.03
exam	1	0.03
machine	1	0.03
messaging	1	0.03
morning	1	0.03
organisation	1	0.03
sport	1	0.03
studio	1	0.03
TV	1	0.03

NUMBER OF RESPONSES	31
PRIMARY RESPONSE STRENGTH	0.48
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	12

AOL	Frequency of response	Associative strength
internet	26	0.55
computer	4	0.09
broadband	3	0.06
America on line	2	0.04
alcohol	1	0.02
also	1	0.02
America	1	0.02
American online messenger	1	0.02
anti Oliver Lyon	1	0.02
chat	1	0.02
internet provider	1	0.02
internet service provider	1	0.02
messaging	1	0.02
messaging system	1	0.02
organisation	1	0.02
search engine	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.55
DIFFERENT RESPONSES	16
UNIQUE RESPONSES	12

Appendix 4.1

APR	Frequency of response	Associative strength
April	9	0.23
	8	
tax	3	0.08
bank	2	0.05
credit	2	0.05
finance	2	0.05
interest	2	0.05
money	2	0.05
rate	2	0.05
allowed	1	0.03
alpha protocol recon	1	0.03
American	1	0.03
annual payment rate	1	0.03
apparent	1	0.03
apparently	1	0.03
appear	1	0.03
appreciate	1	0.03
blood	1	0.03
earnings	1	0.03
insurance	1	0.03
later	1	0.03
percentage	1	0.03
price	1	0.03
QPR	1	0.03
repetition	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	16

ASAP	Frequency of response	Associative strength
as soon as possible	16	0.35
soon	10	0.22
quickly	4	0.09
quick	4	0.09
now	2	0.04
fast	2	0.04
	2	
speed	1	0.02
soon as poss.	1	0.02
reply	1	0.02
possible	1	0.02
invitation	1	0.02
as soon as	1	0.02
as	1	0.02

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.35
DIFFERENT RESPONSES	13
UNIQUE RESPONSES	6

ASBO	Frequency of response	Associative strength
anti social behaviour order	7	0.16
chav	5	0.11
crime	4	0.09
criminal	4	0.09
anti social	2	0.04
naughty	2	0.04
young	2	0.04
	2	
anti social behaviour	1	0.02
anti social behavioural disorder	1	0.02
antisocial behavioural order	1	0.02
bad behaviour	1	0.02
Bully	1	0.02
children	1	0.02
constraint	1	0.02
crazy person	1	0.02
drunk	1	0.02
hassle	1	0.02
hobo	1	0.02
hoodies	1	0.02
law	1	0.02
mistake gun	1	0.02
offender	1	0.02
teen	1	0.02
test	1	0.02
yob	1	0.02
Youth	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.16
DIFFERENT RESPONSES	26
UNIQUE RESPONSES	19

Appendix 4.1

ATM	Frequency of response	Associative strength
cash	11	0.25
money	6	0.14
at the moment	4	0.09
	3	
bank	3	0.07
cash machine	3	0.07
now	3	0.07
cash point	2	0.05
hole in the wall	2	0.05
machine	2	0.05
at	1	0.02
attention	1	0.02
automated	1	0.02
cash withdrawals	1	0.02
internet	1	0.02
moment	1	0.02
music	1	0.02
Time	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.25
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	8

AWOL	Frequency of response	Associative strength
owl	8	0.19
absent without leave	7	0.17
	5	
absent	3	0.07
Army	3	0.07
crazy	3	0.07
missing	3	0.07
away	2	0.05
gone	2	0.05
a wookie or lion	1	0.02
a world of laughs	1	0.02
away without leave	1	0.02
flee	1	0.02
harry potter	1	0.02
jean claude	1	0.02
lost	1	0.02
runaway	1	0.02
services	1	0.02
Wales	1	0.02
wolf	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.19
DIFFERENT RESPONSES	19
UNIQUE RESPONSES	11

Appendix 4.1

BAFTA	Frequency of response	Associative strength
award	32	0.71
film	2	0.04
	2	
acting	1	0.02
actor	1	0.02
award ceremony	1	0.02
British academy film television awards	1	0.02
British academy for film and television	1	0.02
British acting awards	1	0.02
film and television	1	0.02
movies	1	0.02
television	1	0.02
test	1	0.02
TV actor awards	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.71
DIFFERENT RESPONSES	13
UNIQUE RESPONSES	11

Appendix 4.1

BBC	Frequency of response	Associative strength
television	26	0.55
British broadcasting corporation	4	0.09
British broadcasting	2	0.04
broadcast	2	0.04
news	2	0.04
television channel	2	0.04
telly	2	0.04
British broadcasting channel	1	0.02
British broadcasting company	1	0.02
channel	1	0.02
Eastenders	1	0.02
kids	1	0.02
news channel	1	0.02
player	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.55
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	7

BHS	Frequency of response	Associative strength
shop	16	0.36
British home stores	9	0.20
clothes	5	0.11
store	4	0.09
	3	
back	1	0.02
Britain	1	0.02
British home secretary	1	0.02
charity	1	0.02
fat	1	0.02
furniture	1	0.02
healthcare	1	0.02
hospital	1	0.02
money	1	0.02
sad	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.36
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	10

BLT	Frequency of response	Associative strength
sandwich	20	0.44
bacon lettuce and tomato	12	0.27
bacon	6	0.13
food	3	0.07
tomato	2	0.04
	2	
bloat	1	0.02
yuck	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.44
DIFFERENT RESPONSES	7
UNIQUE RESPONSES	2

BMI	Frequency of response	Associative strength
body mass index	10	0.22
weight	10	0.22
body	4	0.09
baby	3	0.07
computer	2	0.04
fat	2	0.04
travel	2	0.04
	2	
airline	1	0.02
body mass	1	0.02
British medical interns	1	0.02
flight	1	0.02
health thing	1	0.02
healthy	1	0.02
index	1	0.02
it	1	0.02
obese	1	0.02
plane	1	0.02
recording industry	1	0.02
size	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.22
DIFFERENT RESPONSES	19
UNIQUE RESPONSES	12

BMW	Frequency of response	Associative strength
car	41	0.89
bens mostly weird	1	0.02
black mans willy	1	0.02
Bryn motor workshop	1	0.02
car brand	1	0.02
German car manufacturers	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.89
DIFFERENT RESPONSES	6
UNIQUE RESPONSES	5

BNP	Frequency of response	Associative strength

politics	9	0.23
British national party	7	0.18
racist	7	0.18
	7	
national	2	0.05
party	2	0.05
racism	2	0.05
break	1	0.03
British	1	0.03
British nationalist party	1	0.03
hate	1	0.03
Holidays	1	0.03
nick	1	0.03
political	1	0.03
political party	1	0.03
pulse	1	0.03
Scotland	1	0.03
vote	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	11

BOGOF	Frequency of response	Associative strength
buy one get one free	16	0.52
deal	4	0.13
buy	3	0.10
	3	
bog off	2	0.06
free	2	0.06
shop	2	0.06
away	1	0.03
bargain	1	0.03
bigfoot	1	0.03
buy one	1	0.03
buy one get one	1	0.03
cheap	1	0.03
false	1	0.03
insult	1	0.03
offer	1	0.03
piss off	1	0.03
study	1	0.03
Tesco	1	0.03
toilet	1	0.03
too much	1	0.03
windows	1	0.03

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.52
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	15

BPM	Frequency of response	Associative strength
	9	
beats per minute	8	0.21
heart	5	0.13
blood pressure	4	0.11
beats	3	0.08
politics	2	0.05
rate	2	0.05
Ball	1	0.03
bank	1	0.03
biscuit	1	0.03
bmp	1	0.03
British	1	0.03
British parliament	1	0.03
British post master	1	0.03
British prime minister	1	0.03
computer	1	0.03
important	1	0.03
party	1	0.03
psychology	1	0.03
pulse	1	0.03
thing	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.21
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	14

BPS	Frequency of response	Associative strength
psychology	12	0.34
	9	0.26
British psychological society	5	0.14
blood pressure	3	0.09
British	3	0.09
blood	2	0.06
British psychology society	2	0.06
baps	1	0.03
beats	1	0.03
BP	1	0.03
British package service	1	0.03
British parliamentary system	1	0.03
British postal service	1	0.03
BUPA	1	0.03
GPS	1	0.03
heart	1	0.03
music	1	0.03
Society	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.34
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	11

Appendix 4.1

BRB	Frequency of response	Associative strength
be right back	28	0.67
	5	0.12
back	4	0.10
away	1	0.02
back in a minute	1	0.02
bank	1	0.02
bring	1	0.02
internet	1	0.02
lol	1	0.02
msn	1	0.02
quick break	1	0.02
return	1	0.02
text thing	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.67
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	10

BSE	Frequency of response	Associative strength
	11	
cow	10	0.28
base	2	0.06
best	2	0.06
disease	2	0.06
education	2	0.06
mad cow	2	0.06
science	2	0.06
award	1	0.03
bachelor	1	0.03
bachelors degree	1	0.03
Becky sells eggs	1	0.03
bessies	1	0.03
British sex education	1	0.03
British standards	1	0.03
busy	1	0.03
cattle	1	0.03
college	1	0.03
degree	1	0.03
honour	1	0.03
qualification	1	0.03
queen	1	0.03

NUMBER OF RESPONSES	36
PRIMARY RESPONSE STRENGTH	0.28
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	14

BST	Frequency of response	Associative strength
	17	
best	9	0.30
British standard time	3	0.10
summer	3	0.10
beast	2	0.07
summer time	2	0.07
time	2	0.07
batchelor	1	0.03
Britain	1	0.03
British	1	0.03
British sandwich tomatoes	1	0.03
cows	1	0.03
film	1	0.03
music	1	0.03
sandwich	1	0.03
standard	1	0.03

NUMBER OF RESPONSES	30
PRIMARY RESPONSE STRENGTH	0.3
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	9

Appendix 4.1

BTW	Frequency of response	Associative strength
by the way	32	0.73
also	4	0.09
	3	0.07
TEXT	2	0.05
car	1	0.02
internet	1	0.02
quick reply	1	0.02
WTF	1	0.02
as well	1	0.02
by	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.73
DIFFERENT RESPONSES	9
UNIQUE RESPONSES	6

BYOB	Frequency of response	Associative strength
	10	
bring your own beer	4	0.11
beer	3	0.08
bring your own booze	3	0.08
party	3	0.08
band	2	0.05
boy	2	0.05
bring your own bottle	2	0.05
system	2	0.05
system of a down	2	0.05
alcohol	1	0.03
be your own boss	1	0.03
Bet	1	0.03
biorb	1	0.03
bomb	1	0.03
booze	1	0.03
boyfriend	1	0.03
bring	1	0.03
bring your own	1	0.03
Britain	1	0.03
bye	1	0.03
egg	1	0.03
music	1	0.03
name	1	0.03

NUMBER OF RESPONSES	37
PRIMARY RESPONSE STRENGTH	0.11
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	14

CBT	Frequency of response	Associative strength
	14	
cognitive behavioural therapy	7	0.21
therapy	7	0.21
scan	2	0.06
basic training	1	0.03
business	1	0.03
businessmen	1	0.03
call	1	0.03
can't be told	1	0.03
children	1	0.03
ciabatta	1	0.03
control	1	0.03
counselling	1	0.03
crime	1	0.03
hospital	1	0.03
lazy	1	0.03
moped	1	0.03
news	1	0.03
phone	1	0.03
psychology	1	0.03
to be certified	1	0.03

NUMBER OF RESPONSES	33
PRIMARY RESPONSE STRENGTH	0.21
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	17

CCCP	Frequency of response	Associative strength
	24	
camera	8	0.35
closed circuit television	3	0.13
Russia	3	0.13
catalogue	1	0.04
Chinese cultural centre porters	1	0.04
computer	1	0.04
copper	1	0.04
email	1	0.04
repression	1	0.04
school	1	0.04
surveillance	1	0.04
television	1	0.04

NUMBER OF RESPONSES	23
PRIMARY RESPONSE STRENGTH	0.35
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	9

Appendix 4.1

CEO	Frequency of response	Associative strength
	11	
company	6	0.17
chairman	4	0.11
boss	2	0.06
business	2	0.06
chief executive officer	2	0.06
police	2	0.06
award	1	0.03
big	1	0.03
cat	1	0.03
chairman every order	1	0.03
chairman executive of	1	0.03
chemo therapy	1	0.03
chief	1	0.03
chief executive	1	0.03
ciao	1	0.03
civil service	1	0.03
director	1	0.03
executive	1	0.03
high	1	0.03
important	1	0.03
manager	1	0.03
officer	1	0.03
top	1	0.03
volunteer	1	0.03

NUMBER OF RESPONSES	36
PRIMARY RESPONSE STRENGTH	0.17
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	18

Appendix 4.1

CIA	Frequency of response	Associative strength
police	8	0.18
America	4	0.09
crime	4	0.09
Cardiff	3	0.07
intelligence	3	0.07
	3	
agent	2	0.05
investigation	2	0.05
agency	1	0.02
alias	1	0.02
American police	1	0.02
central intelligence agency	1	0.02
central intelligence association	1	0.02
central investigation academy	1	0.02
cops	1	0.02
criminal	1	0.02
criminal investigative agency	1	0.02
detectives	1	0.02
federal	1	0.02
intelligence agency	1	0.02
intelligence agent	1	0.02
intelligence American	1	0.02
Miami	1	0.02
secret	1	0.02
shop	1	0.02
Spy	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.18
DIFFERENT RESPONSES	25
UNIQUE RESPONSES	18

Appendix 4.1

CJD	Frequency of response	Associative strength
	21	
cow	5	0.19
court	3	0.12
disease	2	0.08
mad cow	2	0.08
mad cow disease	2	0.08
brain	1	0.04
cable	1	0.04
central	1	0.04
character	1	0.04
cow jelly disease	1	0.04
cream jam doughnuts	1	0.04
criminal	1	0.04
cujo	1	0.04
music	1	0.04
none	1	0.04
police check	1	0.04
sport	1	0.04
NUMBER OF RESPONSES	26	
PRIMARY RESPONSE STRENGTH	0.19	
DIFFERENT RESPONSES	17	
UNIQUE RESPONSES	12	

CNN	Frequency of response	Associative strength
television	16	0.38
news	14	0.33
	5	
American news	2	0.05
news channel	2	0.05
America	1	0.02
American	1	0.02
cartoon network	1	0.02
channel	1	0.02
CNN news broadcasting TV	1	0.02
corporate news network	1	0.02
network	1	0.02
sports channel	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.38
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	8

CPU	Frequency of response	Associative strength
computer	28	0.70
	7	
central processing unit	2	0.05
blood	1	0.03
central unit	1	0.03
computer hard drive computer processing unit	1	0.03
computer packaging unit	1	0.03
computer stuff	1	0.03
cup	1	0.03
drive	1	0.03
law	1	0.03
processor	1	0.03
security	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.7
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	10

CSI	Frequency of response	Associative strength
television	12	0.26

crime	6	0.13
crime scene investigation	6	0.13
police	6	0.13
Miami	3	0.07
American police	1	0.02
crime scene	1	0.02
crime scene investigators	1	0.02
crime show	1	0.02
crime support intelligence	1	0.02
detective	1	0.02
Grissom	1	0.02
investigation	1	0.02
money	1	0.02
murder	1	0.02
New York	1	0.02
programme	1	0.02
TV programme	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.26
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	13

Appendix 4.1

DHL	Frequency of response	Associative strength
	16	
parcel	6	0.19
delivery	4	0.13
darling	2	0.06
character	1	0.03
computer	1	0.03
courier service	1	0.03
deliver home less	1	0.03
delivery lorries	1	0.03
delivery service	1	0.03
digital	1	0.03
down her leg	1	0.03
downloading	1	0.03
driving	1	0.03
drugs	1	0.03
hand	1	0.03
laptop	1	0.03
letters	1	0.03
line	1	0.03
lovely	1	0.03
money	1	0.03
TV provider	1	0.03
vehicle	1	0.03

NUMBER OF RESPONSES	31
PRIMARY RESPONSE STRENGTH	0.19
DIFFERENT RESPONSES	22
UNIQUE RESPONSES	19

DIY	Frequency of response	Associative strength
do it yourself	19	0.41
hammer	3	0.07
fixing	2	0.04
home	2	0.04
shelf	2	0.04
tools	2	0.04
work	2	0.04
	1	
do it	1	0.02
do it myself	1	0.02
focus	1	0.02
furniture	1	0.02
handy Andy	1	0.02
Hardware	1	0.02
homebase	1	0.02
house	1	0.02
Jefferies	1	0.02
men	1	0.02
saw	1	0.02
shelves	1	0.02
shop	1	0.02
yourself	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.41
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	15

DNA	Frequency of response	Associative strength
genes	11	0.24
blood	6	0.13
deoxyribonucleic acid	4	0.09
genetics	4	0.09
cells	3	0.07
body	2	0.04
helix	2	0.04
test	2	0.04
acid	1	0.02
biological	1	0.02
biology	1	0.02
did not attend	1	0.02
dinonucleic acid	1	0.02
genetic cells	1	0.02
humans	1	0.02
not me	1	0.02
people	1	0.02
microbosomes	1	0.02
science	1	0.02
strand	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.24
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	12

Appendix 4.1

DOA	Frequency of response	Associative strength
dead	8	0.20
dead on arrival	8	0.20
death	6	
dead or alive	4	0.10
song	3	0.07
anniversary	3	0.07
birth	1	0.02
bodies	1	0.02
date of arrival	1	0.02
dodge	1	0.02
dog	1	0.02
doner	1	0.02
don't over act	1	0.02
dozing	1	0.02
drugs	1	0.02
dwad	1	0.02
film	1	0.02
genes	1	0.02
Goa	1	0.02
missing	1	0.02

NUMBER OF RESPONSES	41
PRIMARY RESPONSE STRENGTH	0.2
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	15

Appendix 4.1

DOB	Frequency of response	Associative strength
date of birth	22	0.52
birth	6	0.14
birthday	6	0.14
	5	0.12
date	3	0.07
age	1	0.02
birth dates	1	0.02
dobbing someone in	1	0.02
double	1	0.02
may	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.52
DIFFERENT RESPONSES	9
UNIQUE RESPONSES	5

Appendix 4.1

DUI	Frequency of response	Associative strength
	12	
drunk	6	0.17
driving under influence	5	0.14
drinking	3	0.09
driving	2	0.06
alcohol	1	0.03
charge	1	0.03
crime	1	0.03
dead	1	0.03
department	1	0.03
do it yourself	1	0.03
don't underestimate intelligence	1	0.03
drink driving	1	0.03
droid	1	0.03
druid	1	0.03
drunken	1	0.03
Dubai	1	0.03
duck	1	0.03
dummy	1	0.03
French	1	0.03
game	1	0.03
infection	1	0.03
police	1	0.03
two	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.17
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	19

Appendix 4.1

DVD	Frequency of response	Associative strength
film	23	0.49
digital video disc	4	0.09
disc	4	0.09
digital versatile disc	3	0.06
video	3	0.06
movie	2	0.04
digital	1	0.02
digital visual disc	1	0.02
disk	1	0.02
player	1	0.02
records	1	0.02
television	1	0.02
telly	1	0.02
watch	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.49
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	8

DVLA	Frequency of response	Associative strength
driving	20	0.45
car	10	0.23
	3	
driving licence	2	0.05
Swansea	2	0.05
drivers vans local aspects	1	0.02
driving company	1	0.02
driving licensing agency UK	1	0.02
driving Swansea	1	0.02
driving vehicle licensing association	1	0.02
driving vehicles licensing authority	1	0.02
license	1	0.02
money	1	0.02
motoring	1	0.02
tax	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.45
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	10

Appendix 4.1

DVT	Frequency of response	Associative strength
	15	
deep vein thrombosis	4	0.13
planes	3	0.09
digital versatile disc	2	0.06
legs	2	0.06
bad leg	1	0.03
cars	1	0.03
date	1	0.03
development	1	0.03
devil	1	0.03
devote	1	0.03
digital TV	1	0.03
divert	1	0.03
divided	1	0.03
DMV	1	0.03
done	1	0.03
drive	1	0.03
driven	1	0.03
driving vehicle training	1	0.03
DVLA	1	0.03
dyke von tramp	1	0.03
film	1	0.03
organisation	1	0.03
thrombosis	1	0.03
Time	1	0.03
vein	1	0.03

NUMBER OF RESPONSES	32
PRIMARY RESPONSE STRENGTH	0.13
DIFFERENT RESPONSES	25
UNIQUE RESPONSES	21

ECG	Frequency of response	Associative strength
	8	
heart	5	0.13
brain	4	0.10
egg	4	0.10
hospital	4	0.10
scan	4	0.10
electro cardio gram	3	0.08
electro cardio graph	3	0.08
brain scan	1	0.03
device to measure heartbeat patterns	1	0.03
electroencephalogram	1	0.03
electric	1	0.03
electrode	1	0.03
heart rate	1	0.03
psychology	1	0.03
qualification	1	0.03
report	1	0.03
testing	1	0.03
treatment	1	0.03
wires	1	0.03

NUMBER OF RESPONSES	39
PRIMARY RESPONSE STRENGTH	0.13
DIFFERENT RESPONSES	19
UNIQUE RESPONSES	12

Appendix 4.1

EEG	Frequency of response	Associative strength
scan	9	0.21
brain	5	0.12
egg	5	0.12
	5	
electroencephalogram	2	0.05
electronic	2	0.05
psychology	2	0.05
test	2	0.05
brain scan	1	0.02
eed	1	0.02
elecroecenogenic gram	1	0.02
electric	1	0.02
electrode	1	0.02
electro echocardiogram	1	0.02
electroencephalographology	1	0.02
emission	1	0.02
experiment	1	0.02
head	1	0.02
heart	1	0.02
hospitals	1	0.02
measurement	1	0.02
scam	1	0.02
wires	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.21
DIFFERENT RESPONSES	22
UNIQUE RESPONSES	15

ENT	Frequency of response	Associative strength
entertainment	7	0.18
	7	
enter	4	0.10
tree	4	0.10
ear nose and throat	3	0.08
end	2	0.05
Swansea	2	0.05
university	2	0.05
ant	1	0.03
box office	1	0.03
camera	1	0.03
clinic	1	0.03
computer	1	0.03
ear	1	0.03
entry	1	0.03
ents	1	0.03
every nettle thistle	1	0.03
eyes	1	0.03
freshers	1	0.03
hospital	1	0.03
students	1	0.03
tent	1	0.03
tickets	1	0.03
tonsils	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.18
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	16

Appendix 4.1

ESP	Frequency of response	Associative strength
especially	10	0.24
	6	
psychic	5	0.12
Spain	4	0.10
extra sensory perception	3	0.07
Spanish	2	0.05
telepathy	2	0.05
birds	1	0.02
business	1	0.02
electro sensory perception	1	0.02
electronic	1	0.02
ESPN	1	0.02
extra special person	1	0.02
eyes	1	0.02
ghost	1	0.02
perception	1	0.02
Position	1	0.02
programme	1	0.02
six sense	1	0.02
SPAIM	1	0.02
sport	1	0.02
technology	1	0.02

NUMBER OF RESPONSES	41
PRIMARY RESPONSE STRENGTH	0.24
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	15

ESRC	Frequency of response	Associative strength
	26	
escape	3	0.14
funding	3	0.14
research	3	0.14
cricket	1	0.05
econo social research council	1	0.05
ecstatic	1	0.05
entertainment	1	0.05
environment	1	0.05
erratic	1	0.05
European funding agency	1	0.05
events recorded	1	0.05
grant	1	0.05
money	1	0.05
money grants	1	0.05
video games	1	0.05

NUMBER OF RESPONSES	21
PRIMARY RESPONSE STRENGTH	0.14
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	12

Appendix 4.1

ETA	Frequency of response	Associative strength
	9	
estimated time of arrival	7	0.18
time	5	0.13
arrival	4	0.11
eat	3	0.08
estimate	2	0.05
et	2	0.05
bomb	1	0.03
airplanes	1	0.03
arrival time	1	0.03
arrive	1	0.03
Basque	1	0.03
beta	1	0.03
doctor	1	0.03
Ethan	1	0.03
ever	1	0.03
expected time of arrival	1	0.03
money	1	0.03
parents club	1	0.03
terrorists	1	0.03
time of arrival	1	0.03
TV	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.18
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	15

FAO	Frequency of response	Associative strength
	18	
attention	5	0.17
for the attention of	5	0.17
fax	2	0.07
letter	2	0.07
question	2	0.07
du	1	0.03
facts	1	0.03
fail	1	0.03
far	1	0.03
far away	1	0.03
favour	1	0.03
foreigners	1	0.03
forever	1	0.03
frequently	1	0.03
frequently asked	1	0.03
frequently asked operatives	1	0.03
frequently associated objects	1	0.03
information	1	0.03

NUMBER OF RESPONSES	29
PRIMARY RESPONSE STRENGTH	0.17
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	13

FAQ	Frequency of response	Associative strength
question	25	0.54
frequently asked questions	13	0.28
facts	4	0.09
	1	
company	1	0.02
dumb questions	1	0.02
fak	1	0.02
frequent	1	0.02

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.54
DIFFERENT RESPONSES	7
UNIQUE RESPONSES	4

FBI	Frequency of response	Associative strength

police	14	0.31
federal bureau of investigation	5	0.11
America	4	0.09
agent	3	0.07
investigation	3	0.07
crime	2	0.04
detective	2	0.04
federal	2	0.04
	2	
American	1	0.02
American detectives	1	0.02
American police	1	0.02
American security	1	0.02
crime agents	1	0.02
files	1	0.02
law	1	0.02
Scully	1	0.02
unit	1	0.02
Watch	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.31
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	10

FIFA	Frequency of response	Associative strength
football	36	0.77
world cup	2	0.04
federal institute for the football association	1	0.02
football federation association	1	0.02
football international France association	1	0.02
football is flipping annoying	1	0.02
for information for analysis	1	0.02
international football association	1	0.02
money	1	0.02
soccer	1	0.02
sport	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.77
DIFFERENT RESPONSES	11
UNIQUE RESPONSES	9

FYI	Frequency of response	Associative strength
for your information	20	0.45
information	13	0.30
Americans	3	0.07
	3	
actually	1	0.02
also	1	0.02
chat	1	0.02
fibre	1	0.02
fly	1	0.02
for	1	0.02
internet	1	0.02
stereo	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.45
DIFFERENT RESPONSES	11
UNIQUE RESPONSES	8

GBH	Frequency of response	Associative strength
grievous bodily harm	9	0.24
harm	9	
	8	0.21
assault	4	0.11
attack	3	0.08
crime	2	0.05
drug	2	0.05
fight	2	0.05
bodily harm	1	0.03
Britain	1	0.03
general bodily harm	1	0.03
great Britain	1	0.03
police	1	0.03
prison	1	0.03
violence	1	0.03
violent	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.24
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	8

GCSE	Frequency of response	Associative strength
exams	22	0.49
general certificate of secondary education	5	0.11
school	5	0.11
qualification	4	0.09
	2	
award	1	0.02
college	1	0.02
high school	1	0.02
maths	1	0.02
results	1	0.02
school exam	1	0.02
test	1	0.02
work	1	0.02
year 11	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.49
DIFFERENT RESPONSES	13
UNIQUE RESPONSES	9

GMT	Frequency of response	Associative strength
time	18	0.40
Greenwich mean time	4	0.09
TV	3	0.07
GMTV	2	0.04
Greenwich	2	0.04
morning	2	0.04
	2	
big Ben	1	0.02
clock	1	0.02
college	1	0.02
computer	1	0.02
g meridian time	1	0.02
game	1	0.02
general mean time	1	0.02
good	1	0.02
good morning today	1	0.02
Greenwich median time	1	0.02
London	1	0.02
morning TV	1	0.02
programme	1	0.02
sun	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.4
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	14

GPA	Frequency of response	Associative strength
	17	
money	5	0.17
doctor	2	0.07
grade	2	0.07
gross	2	0.07
school	2	0.07
analysis	1	0.03
best	1	0.03
business	1	0.03
car	1	0.03
computer	1	0.03
general	1	0.03
general practitioners authority	1	0.03
geography	1	0.03
Global	1	0.03
global positioning analysis	1	0.03
going places	1	0.03
grade point average	1	0.03
guideline	1	0.03
hand held device	1	0.03
income	1	0.03
money value	1	0.03
product	1	0.03

NUMBER OF RESPONSES	30
PRIMARY RESPONSE STRENGTH	0.17
DIFFERENT RESPONSES	22
UNIQUE RESPONSES	17

Appendix 4.1

GPS	Frequency of response	Associative strength
	7	
map	6	0.15
sat nav	5	0.13
satellite	5	0.13
car	3	0.08
global positioning system	3	0.08
system	3	0.08
doctor	2	0.05
navigation	2	0.05
directions	1	0.03
GP	1	0.03
heart	1	0.03
location	1	0.03
Machine	1	0.03
measurement	1	0.03
road	1	0.03
signal	1	0.03
sterling	1	0.03
tom tom	1	0.03
travel	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.15
DIFFERENT RESPONSES	19
UNIQUE RESPONSES	11

HDTV	Frequency of response	Associative strength
high definition television	10	0.24
television	9	0.21
	5	
TV	4	0.10
hi def	3	0.07
high definition	2	0.05
high definition TV	2	0.05
blu-ray	1	0.02
freeview	1	0.02
good telly	1	0.02
highly descriptive television	1	0.02
movies	1	0.02
plasma screen	1	0.02
ready	1	0.02
Samsung	1	0.02
screen quality	1	0.02
tele	1	0.02
video	1	0.02
whale	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.24
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	12

HGV	Frequency of response	Associative strength
lorries	11	0.31
	11	
car	4	0.11
van	3	0.08
heavy goods vehicle	2	0.06
truck	2	0.06
bank	1	0.03
heavy	1	0.03
high	1	0.03
high five	1	0.03
HIV	1	0.03
hog	1	0.03
holiday	1	0.03
hospital	1	0.03
license	1	0.03
music	1	0.03
recording	1	0.03
TV	1	0.03
vehicle	1	0.03
virus	1	0.03

NUMBER OF RESPONSES	36
PRIMARY RESPONSE STRENGTH	0.31
DIFFERENT RESPONSES	19
UNIQUE RESPONSES	14

HIV	Frequency of response	Associative strength
aids	20	0.45
disease	12	0.27
	3	
illness	2	0.05
infection	2	0.05
virus	2	0.05
blood	1	0.02
gay	1	0.02
human immune deficiency	1	0.02
human immunity virus	1	0.02
music store	1	0.02
positive	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.45
DIFFERENT RESPONSES	11
UNIQUE RESPONSES	6

Appendix 4.1

HMO	Frequency of response	Associative strength
	16	
home	2	0.06
ship	2	0.06
the queen	2	0.06
America	1	0.03
bank	1	0.03
channel	1	0.03
government	1	0.03
health	1	0.03
health management organisation	1	0.03
healthcare	1	0.03
height mass order	1	0.03
her majesty's order	1	0.03
HMV	1	0.03
homeless	1	0.03
homo	1	0.03
homosexual	1	0.03
hospital	1	0.03
house	1	0.03
house multiple occupancy	1	0.03
housing	1	0.03
letter	1	0.03
majesty	1	0.03
Office	1	0.03
order	1	0.03
prison	1	0.03
queen	1	0.03
royalty	1	0.03
travel	1	0.03

NUMBER OF RESPONSES	31
PRIMARY RESPONSE STRENGTH	0.06
DIFFERENT RESPONSES	28
UNIQUE RESPONSES	25

Appendix 4.1

HMS	Frequency of response	Associative strength
ship	10	0.23
her majesty's service	5	0.12
bank	4	0.09
	4	
boat	3	0.07
queen	3	0.07
her majesty	2	0.05
home	1	0.02
government	1	0.02
hamper	1	0.02
health	1	0.02
her majesty's ship	1	0.02
high school	1	0.02
hospital	1	0.02
human m system	1	0.02
jewellery	1	0.02
msn	1	0.02
music	1	0.02
navy	1	0.02
revenue	1	0.02
Scotland	1	0.02
shop	1	0.02
stationery office	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	22
UNIQUE RESPONSES	16

Appendix 4.1

HMV	Frequency of response	Associative strength
music	14	0.31
CDs	8	0.18
shop	8	0.18
his masters voice	2	0.04
music store	2	0.04
records	2	0.04
	2	
band	1	0.02
caravan	1	0.02
DVD	1	0.02
DVD store	1	0.02
Harry's music video	1	0.02
her majesty's voice	1	0.02
his majesty's voice music store	1	0.02
music and videos	1	0.02
store	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.31
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	9

HRT	Frequency of response	Associative strength
heart	8	0.19
hormone replacement therapy	5	0.12
hormones	5	0.12
menopause	5	0.12
	4	
hurt	3	0.07
baby	1	0.02
bank	1	0.02
blood pressure	1	0.02
computer	1	0.02
DRUG	1	0.02
health	1	0.02
heart rate	1	0.02
heart resuscitation tramp	1	0.02
high reaction time	1	0.02
hospital	1	0.02
hurtz	1	0.02
illness	1	0.02
injection	1	0.02
medical treatment	1	0.02
old	1	0.02
the queen	1	0.02
women	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.19
DIFFERENT RESPONSES	22
UNIQUE RESPONSES	17

HSBC	Frequency of response	Associative strength
bank	36	0.80
banking	2	0.04
money	2	0.04
	2	
back	1	0.02
bank name	1	0.02
disaster	1	0.02
HBOS	1	0.02
Hong Kong shanghai banking corporation	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.8
DIFFERENT RESPONSES	8

UNIQUE RESPONSES	5	
IBM	**Frequency of response**	**Associative strength**
computer	19	0.50
	9	
bank	3	0.08
business	2	0.05
book	1	0.03
building	1	0.03
company	1	0.03
computer manufacturers	1	0.03
flight	1	0.03
ice	1	0.03
I'll be a minute	1	0.03
international	1	0.03
international business model	1	0.03
money	1	0.03
music	1	0.03
International Banking Management	1	0.03
studio	1	0.03
TV	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.5
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	14

IBS	**Frequency of response**	**Associative strength**
irritable bowel syndrome	12	0.34
	12	
stomach	3	0.09
bank	2	0.06
bowel	2	0.06
illness	2	0.06
branch	1	0.03
computers	1	0.03
curry bowels	1	0.03
Indian bird sanctuary	1	0.03
international bureau society	1	0.03
irritable	1	0.03
martin	1	0.03
pain	1	0.03
service	1	0.03
syndrome	1	0.03

technology	1	0.03
television	1	0.03
toilet	1	0.03
treatment	1	0.03
NUMBER OF RESPONSES	35	
PRIMARY RESPONSE STRENGTH	0.34	
DIFFERENT RESPONSES	19	
UNIQUE RESPONSES	14	

Appendix 4.1

ICT	Frequency of response	Associative strength
computers	18	0.46
	8	
information communication technology	6	0.15
it	3	0.08
technology	2	0.05
computing	1	0.03
GCSE	1	0.03
information	1	0.03
information computer technology	1	0.03
intensive care	1	0.03
International Chemical Testers	1	0.03
learning	1	0.03
school	1	0.03
university	1	0.03
useless	1	0.03

NUMBER OF RESPONSES	39
PRIMARY RESPONSE STRENGTH	0.46
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	10

IMDB	Frequency of response	Associative strength
	12	
movies	5	0.14
film	4	0.11
computers	3	0.09
internet movie data base	3	0.09
credit	1	0.03
debt	1	0.03
film raters	1	0.03
image	1	0.03
immobile	1	0.03
Imodium	1	0.03
in months December born	1	0.03
internal movie database	1	0.03
international movie database	1	0.03
international managing directors bureau	1	0.03
international media database	1	0.03
internet movie	1	0.03
IVF	1	0.03
mind	1	0.03
mobile	1	0.03
movie database	1	0.03
studio	1	0.03
television	1	0.03
video	1	0.03
website	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.14
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	20

Appendix 4.1

IRA	Frequency of response	Associative strength
Ireland	13	0.31
bomb	6	0.14
	5	
Irish republican army	4	0.10
terrorists	4	0.10
Irish	2	0.05
America	1	0.02
committee	1	0.02
fighting Irish	1	0.02
inland revenue	1	0.02
international rifle association	1	0.02
Iraq	1	0.02
Irene	1	0.02
Irish army	1	0.02
Irish royal army	1	0.02
military	1	0.02
money	1	0.02
planes	1	0.02
politics	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.31
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	13

Appendix 4.1

ISP	Frequency of response	Associative strength
	17	
internet	12	0.40
book	2	0.07
internet service provider	2	0.07
lisp	2	0.07
server	2	0.07
bank	1	0.03
computer	1	0.03
computer number address	1	0.03
individual service pack	1	0.03
injury	1	0.03
international sales person	1	0.03
Ireland	1	0.03
pc	1	0.03
sip	1	0.03
wasp	1	0.03

NUMBER OF RESPONSES	30
PRIMARY RESPONSE STRENGTH	0.4
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	10

Appendix 4.1

ITN	Frequency of response	Associative strength
news	19	0.44
TV	6	0.14
television	4	0.09
	4	
channel	3	0.07
international television network	3	0.07
ITV	2	0.05
CITV	1	0.02
Connection	1	0.02
in the night	1	0.02
international	1	0.02
internet	1	0.02
TV channel	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.44
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	6

Appendix 4.1

ITV	Frequency of response	Associative strength
channel	10	0.22
TV	10	0.22
television	7	0.15
international television	3	0.07
independent television	2	0.04
kids	2	0.04
three	2	0.04
channel three	1	0.02
company	1	0.02
crap	1	0.02
ITN	1	0.02
ITV TV channel	1	0.02
news	1	0.02
rubbish	1	0.02
television channel	1	0.02
telly	1	0.02
TV channel	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.22
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	10

IVF	Frequency of response	Associative strength
babies	11	0.26
treatment	7	0.16
pregnancy	4	0.09
	4	
fertility	2	0.05
five	2	0.05
in vitro fertilisation	2	0.05
Children	1	0.02
fertilisation	1	0.02
fertility treatment	1	0.02
fertilization treatment	1	0.02
hospital	1	0.02
in vivo fertility	1	0.02
infertility treatment	1	0.02
injection	1	0.02
international virus forum	1	0.02
intravenous fluid	1	0.02
I've	1	0.02
IVF treatment	1	0.02
scan	1	0.02
veins	1	0.02
women	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.26
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	15

KFC	Frequency of response	Associative strength
chicken	30	0.65
Kentucky fried chicken	9	0.20
food	6	0.13
	1	
restaurant	1	0.02

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.65
DIFFERENT RESPONSES	4
UNIQUE RESPONSES	1

LBW	Frequency of response	Associative strength

	18	
cricket	9	0.31
car	5	0.17
leg before wicket	4	0.14
law	2	0.07
low	2	0.07
lesbian black women	1	0.03
liberal	1	0.03
library	1	0.03
line	1	0.03
little blue wellies	1	0.03
look	1	0.03
wicket	1	0.03

NUMBER OF RESPONSES	29
PRIMARY RESPONSE STRENGTH	0.31
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	7

Appendix 4.1

LCD	Frequency of response	Associative strength
screen	9	0.20
light	8	0.17
DRUG	6	0.13
TV	6	0.13
acid	2	0.04
monitor	2	0.04
	1	
dug	1	0.02
equipment	1	0.02
laser c device	1	0.02
light causing diode	1	0.02
lights	1	0.02
liquid clear display	1	0.02
local council drama	1	0.02
lucid crazy disease	1	0.02
phonejacker	1	0.02
radar	1	0.02
tele	1	0.02
television	1	0.02
TV screen	1	0.02

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.2
DIFFERENT RESPONSES	19
UNIQUE RESPONSES	13

LMAO	Frequency of response	Associative strength
laughing	15	0.33
laughing my a off	9	0.20
laugh	8	0.18
laugh my ass off	4	0.09
funny	2	0.04
internet	2	0.04
	2	
facebook	1	0.02
geeks	1	0.02
laugh out loud	1	0.02
lol	1	0.02
text speak	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.33
DIFFERENT RESPONSES	11
UNIQUE RESPONSES	5

LSD	Frequency of response	Associative strength
drug	30	0.65
light	4	0.09
acid	3	0.07
Beatles	1	0.02
kind of drug	1	0.02
Lucy sky diamonds	1	0.02
lying seductive dance	1	0.02
phone	1	0.02
pounds shillings and pence	1	0.02
red	1	0.02
screen	1	0.02
TV	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.65
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	9

Appendix 4.1

MBA	Frequency of response	Associative strength
	13	
basketball	8	0.24
award	5	0.15
business	2	0.06
football	2	0.06
NBA	2	0.06
acting	1	0.03
business man	1	0.03
charity	1	0.03
college	1	0.03
credit cards	1	0.03
degree	1	0.03
mambo	1	0.03
management in business administration	1	0.03
masters	1	0.03
member British authority	1	0.03
mother	1	0.03
Music	1	0.03
qualification	1	0.03
queen	1	0.03
special	1	0.03

NUMBER OF RESPONSES	34
PRIMARY RESPONSE STRENGTH	0.24
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	15

Appendix 4.1

MDMA	Frequency of response	Associative strength
drug	14	0.40
	12	
ecstasy	4	0.11
illness	2	0.06
college	1	0.03
credit cards	1	0.03
doctor	1	0.03
Drive	1	0.03
fighting	1	0.03
finance	1	0.03
high	1	0.03
mad	1	0.03
medical	1	0.03
medicine	1	0.03
my dad misses America	1	0.03
qualification	1	0.03
Technology	1	0.03
television	1	0.03
TV	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.4
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	15

Appendix 4.1

MGM	Frequency of response	Associative strength
	12	
film	5	0.14
studios	3	0.09
band	2	0.06
cinema	2	0.06
lion	2	0.06
magnum	2	0.06
music	2	0.06
business	1	0.03
cars	1	0.03
Disney	1	0.03
grand	1	0.03
grant	1	0.03
Las Vegas	1	0.03
Magnetic	1	0.03
management	1	0.03
metro Goldwyn mayor	1	0.03
MGM recording studios	1	0.03
mgmt	1	0.03
midget	1	0.03
mother	1	0.03
movies	1	0.03
my dad	1	0.03
Vegas	1	0.03
work	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.14
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	17

MMR	Frequency of response	Associative strength
scan	8	0.19
injection	5	0.12
	5	
jab	3	0.07
measles mumps rubella	3	0.07
VACCINE	3	0.07
mumps	2	0.05
test	2	0.05
brain	1	0.02
doctor	1	0.02
fat in the bloodstream	1	0.02
football	1	0.02
health	1	0.02
job	1	0.02
magnetic resonance medical procedure	1	0.02
map	1	0.02
measles	1	0.02
messages	1	0.02
mirror	1	0.02
mmmmmrrrrr	1	0.02
pain	1	0.02
psychology	1	0.02
Microsoft manager resources	1	0.02
virus	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.19
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	16

Appendix 4.1

MRI	Frequency of response	Associative strength
scan	26	0.58
brain	4	0.09
magnetic resonance imaging	4	0.09
doctors	2	0.04
hospital	2	0.04
	2	
brain scan	1	0.02
illness	1	0.02
machine	1	0.02
magnetic resonance picture of the brain	1	0.02
multi resonance imaging	1	0.02
scam	1	0.02
virus	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.58
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	7

MRSA	Frequency of response	Associative strength
disease	14	0.35
	7	
hospital	5	0.13
illness	4	0.10
infection	4	0.10
virus	3	0.08
VACCINE	2	0.05
aids	1	0.03
bug	1	0.03
Disability	1	0.03
my rebel sisters army	1	0.03
scan	1	0.03
science	1	0.03
sick	1	0.03
treatment	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.35
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	8

Appendix 4.1

MSN	Frequency of response	Associative strength
messenger	10	0.22
chat	7	0.16
COMPUTER	5	0.11
Microsoft network	3	0.07
emails	2	0.04
internet	2	0.04
	2	
blackberry	1	0.02
hotmail	1	0.02
instant messaging	1	0.02
instant messenger	1	0.02
laptops	1	0.02
message	1	0.02
messaging	1	0.02
messenger hotmail	1	0.02
multisocial network	1	0.02
online chat	1	0.02
Microsoft special network	1	0.02
software	1	0.02
speaking	1	0.02
talking	1	0.02
txt	1	0.02
uni	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.22
DIFFERENT RESPONSES	22
UNIQUE RESPONSES	16

Appendix 4.1

MTV	Frequency of response	Associative strength
music	19	0.40
music television	7	0.15
television	4	0.09
channel	3	0.06
music channel	3	0.06
TV	3	0.06
America	1	0.02
American television	1	0.02
Awards	1	0.02
morning television	1	0.02
music TV	1	0.02
music video	1	0.02
rubbish	1	0.02
telly	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.4
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	8

Appendix 4.1

NASA	Frequency of response	Associative strength
space	29	0.64
space shuttle	3	0.07
rocket	2	0.04
	2	
America	1	0.02
astronaut	1	0.02
centre for space research	1	0.02
hello	1	0.02
moon	1	0.02
national American space agency	1	0.02
national association for space aircraft	1	0.02
north American	1	0.02
science	1	0.02
space rockets	1	0.02
space travel people	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.64
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	11

NASCAR	**Frequency of response**	**Associative strength**
racing	14	0.38
	10	
car	5	0.14
driving	2	0.05
NASA	2	0.05
America	1	0.03
Americans	1	0.03
army	1	0.03
car rally	1	0.03
drugs	1	0.03
lines	1	0.03
nature	1	0.03
North American Stock Car Association Racing	1	0.03
north Atlantic service cars and repairs	1	0.03
race	1	0.03
racecar	1	0.03
rocket	1	0.03
speed	1	0.03
transport	1	0.03

NUMBER OF RESPONSES	37
PRIMARY RESPONSE STRENGTH	0.38
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	14

Appendix 4.1

NATO	Frequency of response	Associative strength
	12	
space	4	0.11
bomb	3	0.09
rocket	3	0.09
army	2	0.06
force	2	0.06
north Atlantic treaty organisation	2	0.06
organisation	2	0.06
politics	2	0.06
Atlantic	1	0.03
European peacekeepers	1	0.03
government	1	0.03
important	1	0.03
international	1	0.03
NASA	1	0.03
nation	1	0.03
native	1	0.03
peace	1	0.03
peace keepers	1	0.03
response	1	0.03
science	1	0.03
shop	1	0.03
USA	1	0.03
war	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.11
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	15

Appendix 4.1

NBA	Frequency of response	Associative strength
basketball	26	0.63
	6	
national basketball association	5	0.12
national	2	0.05
sport	2	0.05
award	1	0.02
bank	1	0.02
credit cards	1	0.02
football	1	0.02
nasty	1	0.02
royal	1	0.02

NUMBER OF RESPONSES	41
PRIMARY RESPONSE STRENGTH	0.63
DIFFERENT RESPONSES	10
UNIQUE RESPONSES	6

Appendix 4.1

NCIS	Frequency of response	Associative strength
	12	
crime	5	0.14
national	3	0.09
TV	3	0.09
charity	2	0.06
navy	2	0.06
boat	1	0.03
children	1	0.03
company	1	0.03
computer	1	0.03
crime scene	1	0.03
military	1	0.03
national college Indian studies	1	0.03
naval crime investigation service	1	0.03
new case in strength	1	0.03
New York crime scene	1	0.03
nick	1	0.03
nits	1	0.03
police	1	0.03
programme	1	0.03
rubbish TV programme	1	0.03
space	1	0.03
television	1	0.03
TV programme	1	0.03
TV show	1	0.03
yawned	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.14
DIFFERENT RESPONSES	25
UNIQUE RESPONSES	20

Appendix 4.1

NHS	Frequency of response	Associative strength
hospital	13	0.28
national health service	9	0.19
health	6	0.13
nurse	3	0.06
doctor	2	0.04
health service	2	0.04
healthcare	2	0.04
medical	2	0.04
national	2	0.04
dental	1	0.02
employer	1	0.02
government	1	0.02
Help	1	0.02
Medicine	1	0.02
staff	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.28
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	6

NSPCC	Frequency of response	Associative strength
children	27	0.57
charity	5	0.11
animals	2	0.04
bank	1	0.02
bird protection	1	0.02
care	1	0.02
children's charity	1	0.02
cruelty	1	0.02
NAACP	1	0.02
nation society for prevention of cruelty to children	1	0.02
national society for the protection of children	1	0.02
national society prevention cruelty to children	1	0.02
national society protection children	1	0.02
new support per child care	1	0.02
prevention of cruelty to children	1	0.02
	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.57
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	13

NYPD	Frequency of response	Associative strength
police	23	0.50
New York police department	9	0.20
blue	5	0.11
New York	4	0.09
America	1	0.02
films	1	0.02
nasty	1	0.02
police force	1	0.02
TV programme	1	0.02
	1	0.02

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.5
DIFFERENT RESPONSES	9
UNIQUE RESPONSES	5

OAP	Frequency of response	Associative strength
old	20	0.45

old age pensioner	12	0.27
old person	3	0.07
pensioner	3	0.07
	3	0.07
old people	2	0.05
age	1	0.02
grey	1	0.02
Nan	1	0.02
person	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.45
DIFFERENT RESPONSES	9
UNIQUE RESPONSES	4

OBE	Frequency of response	Associative strength
award	14	0.35
	7	
queen	4	0.10
knighthood	2	0.05
obese	2	0.05
order of the British empire	2	0.05
Britain	1	0.03
celebs	1	0.03
exam	1	0.03
honour	1	0.03
knight	1	0.03
knighted	1	0.03
knighting	1	0.03
medals	1	0.03
medical	1	0.03
oboe	1	0.03
old person	1	0.03
orange balloons every	1	0.03
orbit	1	0.03
qualification	1	0.03
special	1	0.03
special award	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.35
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	16

Appendix 4.1

OCD	Frequency of response	Associative strength
obsessive compulsive disorder	13	0.30
disorder	10	0.23
obsessive	7	0.16
	4	
compulsive	2	0.05
obsession	2	0.05
clean	1	0.02
mad	1	0.02
mental	1	0.02
obsessed	1	0.02
obsessive compulsive	1	0.02
order crazed driven	1	0.02
organisation	1	0.02
pop group	1	0.02
psychology	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.3
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	9

OCR	Frequency of response	Associative strength
	14	
exam	6	0.18
exam board	5	0.15
exams	4	0.12
eye	2	0.06
computer	1	0.03
confusion	1	0.03
counter	1	0.03
disorder	1	0.03
examination body	1	0.03
ocre	1	0.03
only chase rabbits	1	0.03
optical	1	0.03
optical character recognition	1	0.03
overhead crime reduction	1	0.03
projector	1	0.03
qualification	1	0.03
result	1	0.03
ritual	1	0.03
room	1	0.03
school	1	0.03

NUMBER OF RESPONSES	33
PRIMARY RESPONSE STRENGTH	0.18
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	16

OHP	Frequency of response	Associative strength
overhead projector	11	0.28
projector	8	0.21
overhead	7	0.18
computer	4	0.10
OAP	2	0.05
slide	2	0.05
health	2	0.05
help	1	0.03
lecture	1	0.03
lecture slides	1	0.03
old	1	0.03
old person	1	0.03
out of date	1	0.03
photocopier	1	0.03
primary school	1	0.03
projection	1	0.03
school	1	0.03

NUMBER OF RESPONSES	39
PRIMARY RESPONSE STRENGTH	0.28
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	11

PAYE	Frequency of response	Associative strength
money	10	0.27
	10	
pay	4	0.11
payment	3	0.08
wages	3	0.08
cash	2	0.05
paid	2	0.05
pay slip	2	0.05
cheque	1	0.03
income tax	1	0.03
income tax agency payer a tax exempt	1	0.03
pain	1	0.03
pavement	1	0.03
pay as you earn	1	0.03
Payne	1	0.03
Pete and Yasmin's estate	1	0.03
reference number	1	0.03
salary	1	0.03
stock	1	0.03

NUMBER OF RESPONSES	37
PRIMARY RESPONSE STRENGTH	0.27
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	11

PDA	Frequency of response	Associative strength
	13	
phone	3	0.09
affection	2	0.06
file	2	0.06
love	2	0.06
panda	2	0.06
pets	2	0.06
amount	1	0.03
amplifier	1	0.03
assistant	1	0.03
association	1	0.03
computer	1	0.03
doctor	1	0.03
document	1	0.03
Format	1	0.03
handheld device	1	0.03
organiser	1	0.03
pad	1	0.03
pardon	1	0.03
parents	1	0.03
per down allowance	1	0.03
personal	1	0.03
personal diary	1	0.03
Pete's dating Abi	1	0.03
PTA	1	0.03
public display of affection	1	0.03
sick animals	1	0.03
spread sheet	1	0.03

NUMBER OF RESPONSES	34
PRIMARY RESPONSE STRENGTH	0.09
DIFFERENT RESPONSES	27
UNIQUE RESPONSES	21

Appendix 4.1

PDF	Frequency of response	Associative strength
file	8	0.19
document	7	0.17
	5	
computer	4	0.10
file format	2	0.05
journals	2	0.05
A date of birth	1	0.02
article	1	0.02
computer document	1	0.02
computer programme	1	0.02
excel	1	0.02
format	1	0.02
glue	1	0.02
map	1	0.02
paper	1	0.02
permanently	1	0.02
personal	1	0.02
personal data file	1	0.02
personal development folder	1	0.02
printed document file	1	0.02
program	1	0.02
programme	1	0.02
text	1	0.02
type of word processing document	1	0.02
writing	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.19
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	19

PGCE	Frequency of response	Associative strength
teaching	10	0.26
	9	
teacher	5	0.13
postgraduate certificate in education	4	0.11
page	3	0.08
qualification	3	0.08
school	2	0.05
doctor	1	0.03
education	1	0.03
Exam	1	0.03
further learning	1	0.03
kids	1	0.03
Page centre	1	0.03
parental guidance	1	0.03
tea	1	0.03
teach	1	0.03
teaching certificate	1	0.03
training	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.26
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	11

Appendix 4.1

PSP	Frequency of response	Associative strength
playstation	15	0.39
	9	
game	7	0.18
computer	2	0.05
playstation portable	2	0.05
post	2	0.05
computer game	1	0.03
console	1	0.03
drug	1	0.03
file	1	0.03
hand held playstation	1	0.03
play station pack	1	0.03
please	1	0.03
PMS	1	0.03
portable playstation	1	0.03
postage	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.39
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	10

Appendix 4.1

PTA	Frequency of response	Associative strength
	9	
parents	8	0.21
parent teacher association	7	0.18
teachers	3	0.08
animals	2	0.05
meeting	2	0.05
school	2	0.05
committee	1	0.03
game	1	0.03
mothers	1	0.03
page	1	0.03
parent teacher	1	0.03
PDA	1	0.03
pet	1	0.03
pet teaches alien	1	0.03
pets	1	0.03
please	1	0.03
teachers meeting	1	0.03
Test	1	0.03
turn over	1	0.03
turning	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.21
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	14

Appendix 4.1

PTO	Frequency of response	Associative strength
please turn over	17	0.38
page	5	0.11
turn over	5	0.11
turn	4	0.09
book	2	0.04
letters	2	0.04
paper	2	0.04
	2	
please	1	0.02
company	1	0.02
pet	1	0.02
post it note	1	0.02
pot	1	0.02
teacher	1	0.02
turn page	1	0.02
turn paper over	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.38
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	8

PTSD	Frequency of response	Associative strength
	17	
post traumatic stress disorder	7	0.23
stress	3	0.10
shock	2	0.07
animal	1	0.03
chance	1	0.03
computer	1	0.03
disorder	1	0.03
fake	1	0.03
letters	1	0.03
mental	1	0.03
mix	1	0.03
percentage	1	0.03
peter	1	0.03
pets	1	0.03
Physical	1	0.03
points	1	0.03
post traumatic	1	0.03
posted	1	0.03
thing	1	0.03
trauma	1	0.03
video	1	0.03
NUMBER OF RESPONSES	30	
PRIMARY RESPONSE STRENGTH	0.23	
DIFFERENT RESPONSES	21	
UNIQUE RESPONSES	18	

Appendix 4.1

PVC	Frequency of response	Associative strength
plastic	17	0.40
window	5	0.12
	4	
glue	3	0.07
leather	3	0.07
pc	2	0.05
bag	1	0.02
bondage	1	0.02
do it yourself	1	0.02
fabric	1	0.02
fake leather	1	0.02
latex	1	0.02
material	1	0.02
pipe	1	0.02
plastic macs	1	0.02
polystyrene	1	0.02
pro vice chancellor	1	0.02
suit	1	0.02
Work	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.4
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	13

Appendix 4.1

QVC	Frequency of response	Associative strength
shopping	10	0.24
	6	
shop	5	0.12
channel	4	0.10
shopping channel	3	0.07
TV	3	0.07
sherry	2	0.05
brand	1	0.02
company	1	0.02
covering	1	0.02
online shopping	1	0.02
qualification	1	0.02
qualified	1	0.02
quality	1	0.02
quality versus control	1	0.02
queen	1	0.02
queen Victoria	1	0.02
query vice card	1	0.02
store	1	0.02
TV channel	1	0.02
video	1	0.02

NUMBER OF RESPONSES	41
PRIMARY RESPONSE STRENGTH	0.24
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	14

Appendix 4.1

RAF	Frequency of response	Associative strength
royal air force	11	0.23
plane	9	0.19
air force	6	0.13
aeroplane	4	0.09
army	3	0.06
flight	3	0.06
airplane	2	0.04
flying	2	0.04
Air	1	0.02
Exercise	1	0.02
fighting	1	0.02
gun	1	0.02
navy	1	0.02
raft	1	0.02
royal	1	0.02

NUMBER OF RESPONSES	47
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	7

RBS	Frequency of response	Associative strength
bank	16	0.52
	10	
royal bank of Scotland	8	0.26
birds	3	0.10
money	2	0.06
banking	1	0.03
British	1	0.03
credit cards	1	0.03
health	1	0.03
post	1	0.03
really big show	1	0.03
red blue sunshine	1	0.03
ribs	1	0.03

NUMBER OF RESPONSES	37
PRIMARY RESPONSE STRENGTH	0.52
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	8

REM	Frequency of response	Associative strength
sleep	10	0.23
rapid eye movement	9	0.20
music	8	0.18
band	5	0.11
computer	3	0.07
	3	
Eye	2	0.05
corner	1	0.02
dream	1	0.02
losing my religion	1	0.02
rapid	1	0.02
remedy	1	0.02
remote	1	0.02
songs	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	13
UNIQUE RESPONSES	7

RNIB	Frequency of response	Associative strength

	17	
blind	6	0.20
birds	3	0.10
lifeboat	3	0.10
royal national institute for the blind	3	0.10
royal	2	0.07
running	2	0.07
bank	1	0.03
charity	1	0.03
clus	1	0.03
company	1	0.03
nib	1	0.03
rabies	1	0.03
reunited in battle	1	0.03
rib	1	0.03
right now I'm boiling	1	0.03
right now it's back	1	0.03
what the hell	1	0.03

NUMBER OF RESPONSES	30
PRIMARY RESPONSE STRENGTH	0.2
DIFFERENT RESPONSES	17
UNIQUE RESPONSES	11

RNLI	Frequency of response	Associative strength
	17	
lifeboat	15	0.50
lifesaving	2	0.07
royal national lifeboat institute	2	0.07
boat	1	0.03
navy	1	0.03
rail	1	0.03
real	1	0.03
really	1	0.03
Renault	1	0.03
run	1	0.03
running	1	0.03
Scotland	1	0.03
sea	1	0.03
unreal	1	0.03

NUMBER OF RESPONSES	30
PRIMARY RESPONSE STRENGTH	0.5
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	11

Appendix 4.1

RPG	Frequency of response	Associative strength
	16	
game	5	0.16
nerd	2	0.06
role playing game	2	0.06
colour	1	0.03
equipment	1	0.03
grenade	1	0.03
Lorry	1	0.03
petrol	1	0.03
pig	1	0.03
radio	1	0.03
rage	1	0.03
rates	1	0.03
recommended parental guidance	1	0.03
Registration	1	0.03
rifle	1	0.03
rip	1	0.03
rocket launcher	1	0.03
role	1	0.03
role play	1	0.03
royal	1	0.03
royal post graduates	1	0.03
vehicle	1	0.03
war	1	0.03
warcraft	1	0.03
weapon	1	0.03

NUMBER OF RESPONSES	31
PRIMARY RESPONSE STRENGTH	0.16
DIFFERENT RESPONSES	25
UNIQUE RESPONSES	22

Appendix 4.1

RRP	Frequency of response	Associative strength
price	11	0.26
recommended retail price	6	0.14
	5	
clothes	2	0.05
dead	2	0.05
respond	2	0.05
rip	2	0.05
animal protection	1	0.02
company	1	0.02
death	1	0.02
file	1	0.02
grave	1	0.02
money	1	0.02
purchase	1	0.02
recommended price	1	0.02
repetition	1	0.02
Reply	1	0.02
responding	1	0.02
rest	1	0.02
retail	1	0.02
retail prices	1	0.02
role play	1	0.02
shops	1	0.02
sleep	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.26
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	17

Appendix 4.1

RSPB	Frequency of response	Associative strength
bird	20	0.53
	9	
royal society for the protection of birds	4	0.11
respond	3	0.08
letter	2	0.05
animals	1	0.03
bank	1	0.03
charity	1	0.03
invitation	1	0.03
responsible	1	0.03
royal society of pole bearers	1	0.03
RSPCA	1	0.03
rugby	1	0.03
write back	1	0.03

NUMBER OF RESPONSES	38
PRIMARY RESPONSE STRENGTH	0.53
DIFFERENT RESPONSES	13
UNIQUE RESPONSES	9

RSPCA	Frequency of response	Associative strength
animals	28	0.64
	3	
children	2	0.05
pets	2	0.05
royal society for the protection of cruelty to animals	2	0.05
animal charity	1	0.02
animal welfare	1	0.02
animals in need	1	0.02
cats	1	0.02
cruelty	1	0.02
dogs	1	0.02
organisation	1	0.02
Rescue	1	0.02
royal society for the prevention of cruelty to animals	1	0.02
society for	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.64
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	10

Appendix 4.1

RSVP	Frequency of response	Associative strength
reply	10	0.23
repondez s'il vous plait	7	0.16
respond	5	0.12
	4	
envelope	2	0.05
invitation	2	0.05
letter	2	0.05
party	2	0.05
reserve	2	0.05
respond s'il vous plait	2	0.05
attend	1	0.02
call back address	1	0.02
letter reply	1	0.02
ORGANIZATION	1	0.02
possible	1	0.02
reception	1	0.02
respond soon	1	0.02
return	1	0.02
weddings	1	0.02

NUMBER OF RESPONSES	43
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	9

Appendix 4.1

SAE	Frequency of response	Associative strength
	12	
safe	10	0.29
envelope	6	0.17
stamped addressed envelope	4	0.11
letter	2	0.06
sail	2	0.06
sale	2	0.06
self addressed envelope	2	0.06
company	1	0.03
nation	1	0.03
postcode	1	0.03
say	1	0.03
Sea	1	0.03
special air emergency	1	0.03
stamps	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.29
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	7

SAS	Frequency of response	Associative strength
army	16	0.41
	8	
force	2	0.05
help	2	0.05
special armed service	2	0.05
emergency	1	0.03
gun	1	0.03
kippers	1	0.03
letting	1	0.03
military	1	0.03
postcode	1	0.03
Private	1	0.03
Sarah	1	0.03
secret	1	0.03
secret army service	1	0.03
secret service	1	0.03
Sennybridge	1	0.03
shooting	1	0.03
soldier	1	0.03
special air services	1	0.03
squad	1	0.03
surfers	1	0.03

NUMBER OF RESPONSES	39
PRIMARY RESPONSE STRENGTH	0.41
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	17

SCUBA	Frequency of response	Associative strength

diving	28	0.62
dive	4	0.09
	2	0.04
bubbles	1	0.02
diver	1	0.02
Sarah can usually buy apples	1	0.02
scrub	1	0.02
scuba Steve	1	0.02
sometimes crazy urbans bite ass	1	0.02
submersible underwater breathing apparatus	1	0.02
swim	1	0.02
swimming	1	0.02
water	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.62
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	10

SMS	**Frequency of response**	**Associative strength**
text	24	0.53
message	5	0.11
texting	3	0.07
Email	2	0.04
short messaging service	2	0.04
	2	0.04
computer	1	0.02
messaging service	1	0.02
messenger	1	0.02
mobile phone	1	0.02
msn	1	0.02
Sims	1	0.02
standard messaging system	1	0.02
telephones	1	0.02
text messages	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.53
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	9

SPSS	**Frequency of response**	**Associative strength**

stats	14	0.35
statistics	7	0.18
	7	
psychology	3	0.08
math	2	0.05
awful	1	0.03
computer	1	0.03
computer programme	1	0.03
format	1	0.03
program	1	0.03
program of statistical software package	1	0.03
programme	1	0.03
revision	1	0.03
shite	1	0.03
Special	1	0.03
special services	1	0.03
Star	1	0.03
statistics package	1	0.03
work	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.35
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	14

STD	Frequency of response	Associative strength
disease	15	0.34
sex	8	0.18
sexually transmitted disease	7	0.16
	3	
infection	2	0.05
stud	2	0.05
telephone	2	0.05
aids	1	0.02
clap	1	0.02
diseased	1	0.02
health	1	0.02
sexual disease	1	0.02
standard	1	0.02
stupid	1	0.02
virus	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.34
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	8

Appendix 4.1

TBA	Frequency of response	Associative strength
to be announced	12	0.30
	7	
announced	3	0.08
arrange	2	0.05
injection	2	0.05
to be arranged	2	0.05
announce	1	0.03
announcement	1	0.03
CONCERT	1	0.03
film	1	0.03
future	1	0.03
illness	1	0.03
later	1	0.03
meeting	1	0.03
Room	1	0.03
sandwich	1	0.03
tab	1	0.03
talk	1	0.03
tea	1	0.03
teacher	1	0.03
to	1	0.03
to be addressed	1	0.03
to be affirmed	1	0.03
to be answered	1	0.03
unknown	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.3
DIFFERENT RESPONSES	24
UNIQUE RESPONSES	19

TBD	Frequency of response	Associative strength
	17	
to be decided	3	0.10
tired	2	0.07
to be declared	2	0.07
unknown	2	0.07
bug	1	0.03
conclusion	1	0.03
continuing	1	0.03
film	1	0.03
Health	1	0.03
replied	1	0.03
table	1	0.03
taco bell	1	0.03
TB	1	0.03
teacher	1	0.03
teeth	1	0.03
thing	1	0.03
tibidabo	1	0.03
to be	1	0.03
to be dated	1	0.03
to be determined	1	0.03
to be discussed	1	0.03
to be done	1	0.03
to be drawn	1	0.03
totally bollocks day	1	0.03
tuberculosis	1	0.03

NUMBER OF RESPONSES	30
PRIMARY RESPONSE STRENGTH	0.1
DIFFERENT RESPONSES	25
UNIQUE RESPONSES	21

Appendix 4.1

TCP	Frequency of response	Associative strength
	12	
medicine	6	0.17
antiseptic	4	0.11
pain	2	0.06
liquid	2	0.06
infection	2	0.06
cuts	2	0.06
wound	1	0.03
twitch care project	1	0.03
top	1	0.03
to collect people	1	0.03
the court process	1	0.03
soothe	1	0.03
smelly	1	0.03
post	1	0.03
pc	1	0.03
ointment	1	0.03
lotion	1	0.03
frozen yogurt	1	0.03
drug	1	0.03
Cream	1	0.03
Contact	1	0.03
cellotape	1	0.03
burn	1	0.03

NUMBER OF RESPONSES	35
PRIMARY RESPONSE STRENGTH	0.17
DIFFERENT RESPONSES	23
UNIQUE RESPONSES	17

Appendix 4.1

TFT	Frequency of response	Associative strength
	23	
monitor	4	0.17
screen	2	0.08
America	1	0.04
bomb	1	0.04
club	1	0.04
Friday	1	0.04
symmetry	1	0.04
teaching	1	0.04
tefel	1	0.04
tent	1	0.04
thank fuck that	1	0.04
the first time	1	0.04
time for tea	1	0.04
TNT	1	0.04
to	1	0.04
to forward to	1	0.04
tough	1	0.04
tuft	1	0.04
TV	1	0.04
weekend	1	0.04

NUMBER OF RESPONSES	24
PRIMARY RESPONSE STRENGTH	0.17
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	18

TLC	Frequency of response	Associative strength
tender loving care	17	0.39
care	7	0.16
love	7	0.16
caring	3	0.07
	3	
attention	1	0.02
band	1	0.02
loving	1	0.02
shopping	1	0.02
taco	1	0.02
telephone	1	0.02
tender	1	0.02
waterfalls	1	0.02
wrestling	1	0.02
yoghurt	1	0.02
NUMBER OF RESPONSES	44	
PRIMARY RESPONSE STRENGTH	0.39	
DIFFERENT RESPONSES	14	
UNIQUE RESPONSES	10	

TNT	Frequency of response	Associative strength
bomb	11	0.25
dynamite	10	0.23
explosion	5	0.11
explosive	5	0.11
	3	
TV	2	0.05
channel	1	0.02
drink	1	0.02
parcel	1	0.02
roadrunner	1	0.02
sin	1	0.02
small	1	0.02
television	1	0.02
tent	1	0.02
the nice tree	1	0.02
tint	1	0.02
TV channel	1	0.02
NUMBER OF RESPONSES	44	
PRIMARY RESPONSE STRENGTH	0.25	
DIFFERENT RESPONSES	16	
UNIQUE RESPONSES	11	

UCAS	Frequency of response	Associative strength
universities	21	0.47
uni	6	0.13
points	3	0.07
application	2	0.04
college	2	0.04
university and college application system	2	0.04
university application	2	0.04
	2	
form	1	0.02
grades	1	0.02
higher education agency UK central association of	1	0.02
school	1	0.02
university challenges and school	1	0.02
university college admissions system	1	0.02
university entrance site	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.47
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	7

UEFA	Frequency of response	Associative strength
football	33	0.80
	6	
cup	4	0.10
east	1	0.02
UFO	1	0.02
united European federation association	1	0.02
united European football association	1	0.02

NUMBER OF RESPONSES	41
PRIMARY RESPONSE STRENGTH	0.8
DIFFERENT RESPONSES	6
UNIQUE RESPONSES	4

UFC	Frequency of response	Associative strength
football	15	0.38
	8	
fighting	7	0.18
ultimate fighting championship	3	0.08
wrestling	3	0.08
alien	2	0.05
KFC	1	0.03
rugby	1	0.03
sport	1	0.03
UFO	1	0.03
ultimate fighting	1	0.03
unidentified flying object	1	0.03
united football cup	1	0.03
university	1	0.03
usually frankies chair	1	0.03

NUMBER OF RESPONSES	39
PRIMARY RESPONSE STRENGTH	0.38
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	9

UFO	Frequency of response	Associative strength
alien	22	0.50
unidentified flying object	9	0.20
space	7	0.16
	3	
flying object	1	0.02
flying saucer	1	0.02
sky	1	0.02
spacemen	1	0.02
spaceship	1	0.02
unidentified	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.5
DIFFERENT RESPONSES	9
UNIQUE RESPONSES	6

Appendix 4.1

UHF	Frequency of response	Associative strength
	16	
milk	8	0.26
UFO	3	0.10
glue	2	0.06
health	1	0.03
Huff	1	0.03
illness	1	0.03
long life milk	1	0.03
loud	1	0.03
medical	1	0.03
noise	1	0.03
product	1	0.03
Sky	1	0.03
udder	1	0.03
ultra high frequency	1	0.03
under	1	0.03
under home front	1	0.03
unidentified foreign object	1	0.03
unidentified herpes fluid	1	0.03
vhf	1	0.03
video	1	0.03
wavelength	1	0.03

NUMBER OF RESPONSES	31
PRIMARY RESPONSE STRENGTH	0.26
DIFFERENT RESPONSES	21
UNIQUE RESPONSES	18

USA	Frequency of response	Associative strength
America	25	0.54
united states of America	13	0.28
country	4	0.09
American	1	0.02
flag	1	0.02
place	1	0.02
yankies	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.54
DIFFERENT RESPONSES	7
UNIQUE RESPONSES	4

USB	Frequency of response	Associative strength
computer	10	0.23
memory stick	7	0.16
stick	5	0.11
cable	3	0.07
	3	
drive	2	0.05
pen drive	2	0.05
port	2	0.05
Connection	1	0.02
data	1	0.02
device	1	0.02
lead	1	0.02
memory	1	0.02
post	1	0.02
stuck	1	0.02
united home front	1	0.02
united states board	1	0.02
universal sandwich box	1	0.02
universal serial port	1	0.02
USB stick	1	0.02
work	1	0.02

NUMBER OF RESPONSES	44
PRIMARY RESPONSE STRENGTH	0.23
DIFFERENT RESPONSES	20
UNIQUE RESPONSES	13

USSR	Frequency of response	Associative strength
Russia	33	0.83
	7	
united states of soviet Russia	2	0.05
Beatles song	1	0.03
boat	1	0.03
logo	1	0.03
united sovereignty of states in Russia	1	0.03
united soviet state Russia	1	0.03

NUMBER OF RESPONSES	40
PRIMARY RESPONSE STRENGTH	0.83
DIFFERENT RESPONSES	7
UNIQUE RESPONSES	5

VCR	Frequency of response	Associative strength
video	24	0.53
video cassette recorder	4	0.09
old	2	0.04
tape	2	0.04
	2	
camera	1	0.02
cassette	1	0.02
lianne	1	0.02
machine	1	0.02
recorder	1	0.02
tape recorder	1	0.02
TELEVISION	1	0.02
vicar	1	0.02
video channel recorder	1	0.02
video colour recorder	1	0.02
video player	1	0.02
video recorder	1	0.02
visual	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.53
DIFFERENT RESPONSES	18
UNIQUE RESPONSES	13

VHS	Frequency of response	Associative strength
video	25	0.60
tape	7	0.17
	5	
video home system	2	0.05
car	1	0.02
cassette	1	0.02
CD	1	0.02
channel	1	0.02
friends	1	0.02
VCR	1	0.02
very handy saw	1	0.02
visual	1	0.02

NUMBER OF RESPONSES	42
PRIMARY RESPONSE STRENGTH	0.6
DIFFERENT RESPONSES	12
UNIQUE RESPONSES	8

VIP	Frequency of response	Associative strength
important	15	0.33
very important person	12	0.27
celebrity	3	0.07
special	3	0.07
	2	
person	2	0.04
club	1	0.02
important celebrity	1	0.02
limo	1	0.02
luxury	1	0.02
nightclub	1	0.02
Party	1	0.02
treatment	1	0.02
valuable international person	1	0.02
very	1	0.02
visible	1	0.02

NUMBER OF RESPONSES	45
PRIMARY RESPONSE STRENGTH	0.33
DIFFERENT RESPONSES	15
UNIQUE RESPONSES	10

	Frequency of response	Associative strength

WWF		
wrestling	27	0.59
panda	4	0.09
world wrestling federation	3	0.07
wildlife	2	0.04
	1	
charity	1	0.02
computer	1	0.02
visible panty line	1	0.02
world	1	0.02
world war free	1	0.02
worldwide federation	1	0.02
world wildlife federation	1	0.02
world wildlife fund	1	0.02
wrestling federation	1	0.02
WTF	1	0.02

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.59
DIFFERENT RESPONSES	14
UNIQUE RESPONSES	10

YMCA	**Frequency of**	**Associative**

	response	strength
song	6	0.13
club	5	0.11
gay	5	0.11
dance	4	0.09
church	2	0.04
dancing	2	0.04
gym	2	0.04
hostel	2	0.04
young men's Christian association	2	0.04
brother	1	0.02
cowboy	1	0.02
disco	1	0.02
homeless	1	0.02
men	1	0.02
Music	1	0.02
oh!	1	0.02
party	1	0.02
pool	1	0.02
village people	1	0.02
wildlife	1	0.02
young males Christian association	1	0.02
young man's association	1	0.02
youth hostel and activity centre	1	0.02
youth hostels	1	0.02
youth malice chair Alice	1	0.02
	1	

NUMBER OF RESPONSES	46
PRIMARY RESPONSE STRENGTH	0.13
DIFFERENT RESPONSES	25
UNIQUE RESPONSES	16

General category

AGM
APR
AWOL
BAFTA
BBC
BHS
BLT
BNP
BST
BYOB
CEO
CIA
CSI
DHL
DIY
DUI
ESP
ETA
FAO
FAQ
FBI
FIFA
FYI
GCSE
GMT
GPA
HMS
HSBC
ITN
ITV
KFC
MBA
MGM
MTV
NATO
NBA
NCIS
OBE
OCR
PTA
QVC
RAF
RBS
RRP
SAE
SAS
TBA
TBC
UEFA
UFC

Technology category

ACDC
ADHD
AOL
ATM
BMI
BMW
BPM
BPS
BSE
CBT
CCTV
CJD
CPU
DNA
DOA
DVD
DVT
EEG
ENT
GPS
HIV
HMO
HMV
HRT
IBM
IMDB
ISP
IVF
LCD
LSD
MDMA
MMR
MRI
MRSA
NASA
NHS
OCD
PDA
PDF
PSP
PTSD
PVC
RPG
SMS
SPSS
STD
TCP
TFT
UHF
USB

Appendix 5.2

Acronyms:

1. BMI
2. CEO
3. DNA
4. DOA
5. ENT
6. HIV
7. MRI
8. NASA
9. NATO
10. NBA
11. PVC
12. UEFA
13. UFO
14. VIP

Words:

1. ADD
2. AID
3. AIM
4. BAR
5. BUY
6. CUP
7. CUT
8. DUE
9. ERA
10. FAT
11. GOD
12. HAY
13. HEY
14. WET

Illegal non-words:

1. CNZ
2. CRN
3. DTF
4. FCL
5. HPB
6. LPF
7. MRQ
8. MVF
9. NPL
10. PNC
11. PVT
12. RQP
13. RRC
14. TNN

Legal non-words:

1. BERM
2. MAV
3. OIT
4. OND
5. PAG
6. PALT
7. ROAK
8. SEP
9. SHET
10. SOGE
11. SUND
12. THAM
13. WOSE
14. WUSH

Ambiguous Atypical acronyms

ABBA
ASBO
AWOL
BAFTA
BOGOF
FIFA
NAAFI
NATO
UCAS
UEFA

Ambiguous Typical acronyms

AOL
CEO
ENT
ESP
FAO
HIV
IBS
OCD
PAYE
SAS

Unambiguous Typical acronyms

BHS
BLT
BPM
CNN
DVT
LCD
RBS
SPSS
TBC
TNT

Regular words

DEAL
DRUG
FAITH
FATE
GRANT
SHOCK
SITE
THEME
TRAIN
TRUST

Irregular words

BEING
BRIEF
CAST
DEBT
DENY
HEAD
HIRE
HOST
LAYER
SWEAR

Ambiguous Atypical acronyms

ABBA
ASBO
AWOL
BAFTA
BOGOF
FIFA
NAAFI
NATO
UCAS
UEFA

Ambiguous Typical acronyms

AOL
CEO
ENT
ESP
FAO
HIV
IBS
OCD
PAYE
SAS

Unambiguous acronyms

BBC
BHS
BLT
BMI
BMW
BNP
BPM
BPS
BRB
BSE
BST
BTW
CBT
CCTV
CNN
CPU
CSI
DHL
DNA
DVLA
DVT
ECG
ESRC
FBI
FYI
GBH
GCSE
GMT
GPA
GPS
HDTV
HGV
HMO
HMS
HMV
HRT
HSBC
KFC
LBW
LCD
LMAO
LSD
MBA
MDMA
MGM
MMR
MRI
MRSA
MSN
MTV
NBA
NCIS
NHS
NYPD
PSP
PTA
PTO
PTSD
PVC
QVC
RBS
RNLI
RPG

RRP
RSPB
RSPCA
RSVP
SMS
SPSS
STD
TBA
TBC
TCP
TFT
TLC
TNT
VCR
VHS
WWF
YMCA

Regular word fillers

act
add
aim
ban
bend
big
breed
brown
cod
cow
cry
cube
deal
dent
die
doe
drum
eat
fate
fell
fit
fly
foal
glue
goat
gorge
got
grate
hang
him
hot
how
kid
left
leg
let
loud
maid
man
mark
may
mirth
moan
new
now
nun
odd
pat
plane
pop
posh
rag
ran
rat
rear
red
ride
ring
rob
sad
sail
sat
sea
see
shot
sing
site
six
sob
tale
tan

ten
thump
too
top
try
use
way
why
yet

Ambiguous Atypical acronyms

ABBA
ASBO
AWOL
BAFTA
BOGOF
FIFA
NAAFI
NATO
UCAS
UEFA

Regular words

DEAL
DRUG
FAITH
FATE
GRANT
SHOCK
SITE
THEME
TRAIN
TRUST

Ambiguous Typical acronyms

AOL
CEO
ENT
ESP
FAO
HIV
IBS
OCD
PAYE
SAS

Irregular words

BEING
BRIEF
CAST
DEBT
DENY
HEAD
HIRE
HOST
LAYER
SWEAR

Unambiguous Typical acronyms

BHS
BLT
BPM
CNN
DVT
LCD
RBS
SPSS
TBC
TNT

Ambiguous Atypical acronyms	Regular words
ABBA	DEAL
ASBO	DRUG
AWOL	FAITH
BAFTA	FATE
BOGOF	GRANT
FIFA	SHOCK
NAAFI	SITE
NATO	THEME
UCAS	TRAIN
UEFA	TRUST

Ambiguous Typical acronyms	Irregular words
AOL	BEING
CEO	BRIEF
ENT	CAST
ESP	DEBT
FAO	DENY
HIV	HEAD
IBS	HIRE
OCD	HOST
PAYE	LAYER
SAS	SWEAR

Unambiguous Typical acronyms	Non-words
BHS	ane
BLT	ang
BPM	arp
CNN	ast
DVT	bern
LCD	bhj
RBS	blp
SPSS	briet
TBC	cleng
TNT	cralt
	dar
	deyt
	doal
	dony
	drun
	dzs
	ele
	elg
	ete

fale
fam
fim
fom
fon
froad
gask
gat
gax
ged
gex
gop
grint
gup
hab
haf
hft
hib
hoft
hund
hure
ist
jat
jsp
kbm
khl
laper
lave
lbf
leing
lfd
lin
mab
maf
meen
minth
moct
mon
mool
mub
mund
mut
ncd
nid
nie
oit
oke
ond
ort
osk
ote
pag
palt
pjp
qbs
rab
reb
rense
rin
rnt
roal
rog
rox
rpx
sal
san
sed
sep
sete
sheck
shew
shus
sil
sode
sul
sund
sut
swall
szd
tal
tbr
teb
tek
tep
tham
tib
toin
trest
tul
uff
urf
urp
usp
vin
vun
wam
wose
wush