

https://dspace.org/

The modelling of spelling processes : a developmental perspective

Antoine, Wendy

1991

http://hdl.handle.net/10539/22131

Antoine, Wendy (1995) The modelling of spelling processes: a developmental perspective, University of Witwatersrand, Johannesburg, <http://wiredspace.wits.ac.za/handle/10539/22131>

Downloaded from a DSpace repository. https://dspace.org/

The Modelling of Spelling Processes: A Developmental Perspective

Wendy Antoine

Degree awarded with distinction 2 April 1992

A thesis submitted to the Faculty of Arts,
University of the Witwatersrand, Johannesburg
in fulfilment of the requirements for the
degree of Master of Arts.

Johannesburg, 1991.

Declaration

I declare that this thesis is entirely my own work. It is being submitted for the degree of Master of Arts in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other University.



Wendy Antoine

This 13th day of November, 1991.

To Guy and Jacques

ACKNOWLEDGEMENTS

I wish to thank those whose contributions helped in the successful completion of this study. I express my appreciation for the help, guidance and constructive criticism offered by Professor E A Doctor. I would also like to thank my colleagues, Denise Klein, Yvonne Broom, Marilyn Adan and Merle Wulfsohn for our many useful discussions.

The financial assistance of the Institute for Research Development towards this research is hereby acknowledged. Opinions expressed in this work, or conclusions arrived at, are those of the author and are not to be attributed to the Institute for Research Development.

The study was performed during the tenure of a Senior Bursary provided by the University and this assistance is gratefully acknowledged, too.

Last but not least, I would like to thank my husband for his help and encouragement.

Contents

1 Introduction 1
1.1 Writing Systems . . . 2
1.1.1 English Orthography and Spelling . . . 2
1.1.2 English Orthography and Development of Spelling . . . 4
1.2 Evidence from Studies of Acquired Disorders in Writing . . . 5
1.2.1 The Dissociation Between Speech and Writing . . . 6
1.2.2 The Theoretical Significance of Phonological Dysgraphia . . . 7
1.2.3 The Theoretical Significance of Surface Dysgraphia . . . 8
1.3 Contemporary Models of Spelling . . . 9
1.4 The Functional Organisation of the Spelling Process . . . 11
1.4.1 The Grapheme Output Lexicon . . . 11
1.4.2 The Graphemic Buffer . . . 15
1.4.3 The Phoneme-Grapheme Conversion Mechanism . . . 16
1.4.4 The Theoretical Significance of the Ambiguity Effect . . . 21
1.5 Aims and Objectives . . . 23

2 Method 26
2.1 Subjects . . . 26
2.2 Design . . . 26
2.2.1 Psycholinguistic Factors as Variables . . . 26
2.2.2 Outline of the Design . . . 28
2.3 Materials . . . 29
2.3.1 Word list . . . 29
2.3.2 Working Memory-Counting Task . . . 32
2.3.3 Response Sheets . . . 33
2.4 Procedure . . . 33

3 Results 34
3.1 Quantitative Analysis . . . 36
3.1.1 Letter-Type, Ambiguity, Word Frequency and Mapping Frequency Interaction . . . 38
3.1.2 Development, Letter-Type, Ambiguity and Mapping Frequency Interactions . . . 44
3.1.3 Development, Letter-Type, Word Frequency and Mapping Frequency Interaction . . . 51
3.1.4 Development, Letter-Type, Ambiguity and Word Frequency Interaction 54
3.2 Qualitative Analyses . . . 58
3.2.1 Macro Level Error Analysis . . . 59
3.2.2 Micro Level of Error Analysis . . . 63

4 Discussion **77**
4.1 Global Response Patterns 78
4.1.1 Consonants 78
4.1.2 Vowels 79
4.2 The Strategies Children Use 81
4.2.1 Consonants 81
4.2.2 Vowels 84
4.2.3 89
4.3 Model of How Children Learn to Spell 89

5 Conclusion **103**
APPENDICES

A Table of Phoneme-Grapheme Correspondences

B Mapping Frequenci

C Concrete and Abstract Nouns

D The Word List

E The Spelling Test

F Sample Answer Sheets

G Instructions for the Spelling Test

H Revised Test Stimuli

List of Figures

1.1 Schematic diagram of the spelling process. 10

3.1 Graphic representation of the interactions between consonants, Ambiguity, Word Frequency and Mapping Frequency. 38
3.2 Graphic representation of the interactions between consonants, Ambiguity, Word Frequency and Mapping Frequency, with each level of Mapping Frequency separated in terms of Word Frequency level. 40
3.3 Graphic representation of the interactions between consonants, Ambiguity, Word Frequency and Mapping Frequency, showing performance in terms of Ambiguity at each level of Word Frequency, which is separated in terms of Mapping Frequency. 40
3.4 Graphic representation of the interactions between vowels, Ambiguity, Word Frequency and Mapping Frequency. 41
3.5 Graphic representation of the interactions between vowels, Ambiguity, Word Frequency and Mapping Frequency, showing performance in terms of Ambiguity, at each level of Mapping Frequency, separately for low- and high-frequency words. 43
3.6 Graphic representation of the interactions between vowels, Ambiguity, Word Frequency and Mapping Frequency, showing performance in terms of Ambiguity, at each level of Word Frequency, separately for frequent- and infrequent-mappings. 44
3.7 Performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Mapping Frequency, coded to show how Ambiguity effected responses at each level of Mapping Frequency. 45
3.8 Performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Mapping Frequency, coded to show how Mapping Frequency effected responses at each level of Ambiguity. 46
3.9 Performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Mapping Frequency, coded to show how Mapping Frequency effected responses at each level of Ambiguity. 47
3.10 Performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Mapping Frequency, coded to show how Ambiguity effected responses at each level of Mapping Frequency. 49
3.11 The performance profiles along the Development spectrum for consonants, in terms of Frequency. 51
3.12 The performance profiles along the Development spectrum for vowels, in terms of Frequency. 52
3.13 The performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Word Frequency, coded to show how Word Frequency effected responses at each level of Ambiguity. 54

3.14 The performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Word Frequency, coded to show how Ambiguity effected responses at each level of Word Frequency. 55
3.15 The performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Word Frequency, coded to show how Word Frequency effected responses at each level of Ambiguity. 56
3.16 The performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Word Frequency, coded to show how Ambiguity effected responses at each level of Word Frequency. 57
3.17 Micro level error analysis of phonemes with frequent-mapping consonants in high-frequency words. (rep = rcement, del = deletion, snd = alphabetic) . . 65
3.18 Micro level error analysis of phonemes with frequent- mapping consonants in low-frequency words. (rep = replacement, snd = alphabetic, del = deletion, trans = transposition, id = idiosyncratic, aud = auditory) 66
3.19 Micro level error analysis of phonemes with infrequent-mapping consonants in high-frequency words. (reg = regularisation, rep = replacement, snd = alphabetic, sub = substitution,) 67
3.20 Micro level error analysis of phonemes with infrequent-mapping consonants in low-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory,) 68
3.21 Micro level error analysis of phonemes with frequent-mapping vowels in high-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory.) 71
3.22 Micro level error analysis of phonemes with frequent-mapping vowels in low-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory.) 72
3.23 Micro level error analysis of phonemes with infrequent-mapping vowels in high-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory.) 73
3.24 Micro level error analysis of phonemes with infrequent-mapping vowels in low-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory.) 74

4.1 A normal learning curve 82
4.2 Signal from a data adaptive algorithm, showing "learning" by adjustment of a weighting until error = 0. Efficiency is demonstrated by there being few iterations before the signal steadies at zero. 83
4.3 Conceptualised closed-loop adaptation in the conversion mechanism 90
4.4 Model of spelling processes, showing development status of children in the first quarter of their Grade 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity) 94
4.5 Model of spelling processes, showing development status of children in the second quarter of their Grade 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity) 95

4.6 Model of spelling processes, showing development status of children in the third quarter of their Grade 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity) 96
4.7 Model of spelling processes, showing development status of children in the first quarter of their Standard 1 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity, circle = model word) 97
4.8 Model of spelling processes, showing development status of children from mid-year of Standard 1 to mid-year of Standard 2. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity, circle = model word) 98
4.9 Model of spelling processes, showing development status of children in the third quarter of their Standard 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity, circle = model word) 99

List of Tables

1.1 List of grapheme correspondences for three phonemes, each showing a different level of mapping ambiguity. 21

2.1 Ambiguity categories, showing bands of number-of-corresponding graphemes. 27
2.2 The phonemes used to represent each Ambiguity level. 27
2.3 Study design. (IV's = Independent Variables, LT = Letter-Type, WF = Word Frequency, AMB = Ambiguity, MF = Mapping Frequency, freq = frequent, infreq = infrequent.) 29
2.4 Crosstabulation analysis of the selected high-frequency words, showing they are counterbalanced for log normal Word Frequency across the dimensions of Grammatical Word Class (GWC), Mapping Frequency (MF) and Ambiguity. 30
2.5 Crosstabulation analysis of the selected low-frequency words, showing they are counterbalanced for log normal Word Frequency across the dimensions of Grammatical Word Class (GWC), Mapping Frequency (MF) and Ambiguity. 31
2.6 Showing how, within each Ambiguity (AMB) category, words with phonemes of frequent- and infrequent-mapping were pairwise-matched across Word Frequency (WF) on targetted phoneme, within-syllable position of that phoneme, and number-of-phonemes. (MF = Mapping Frequency) 32

3.1 Basic data on errors made on the target consonant segments. Abbreviations AMB, MF and WF represent Ambiguity, Mapping Frequency, and Word Frequency respectively. 35
3.2 Basic data on errors made on the target vowel segments. Abbreviations AMB, MF and WF represent Ambiguity, Mapping Frequency and Word Frequency respectively. 35
3.3 Revised basic data on errors made on the target consonant segments. Abbreviations AMB, MF and WF represent Ambiguity, Mapping Frequency, and Word Frequency respectively. 35
3.4 Mean error scores for Letter-Type, Ambiguity, Mapping Frequency, Word Frequency and Development 36
3.5 Results of the t Tests (Least Squares Difference) for significant groupings of the error means in Development. Any two or more means with a common underscore are not significantly different ($p < .05$). Abbreviations G, S, and T represent Grade, Standard and Time-interval, respectively. 37
3.6 Examples of the various error-types. 60
3.7 Macro Level Error Analysis of Consonants. (FREQ = Word/Mapping Frequency, AMB = Ambiguity, STD = Grade/Standard, ALPHA = Alphabetic, PHONO = Phonological, LEXI = Lexical, PERT = Perturbation, IDIO = Idiosyncratic, MISIN = Misinformation) 61

3.8 Macro Level Error Analysis of Vowels. (FREQ = Word/Mapping Frequency, AMB = Ambiguity, STD = Grade/Standard, ALPHA = Alphabetic, PHONO = Phonological, LEXI = Lexical, PERT = Perturbation, IDIO = Idiosyncratic, MISIN = Misinformation) 62

4.1 Types of mapping option probability (MOP) frequency distributions. 91

Chapter 1

Introduction

Literacy includes both the ability to read and to spell. Yet until recently, and despite its importance, there has been less research on spelling than on reading. Perhaps this was because writing as a linguistic skill was considered in a marginal way as secondary to, and derivative from, speech. It was conceptualised as a photograph of spoken language (de Saussure, 1916), or as a code of transcription (Luria, 1970) with spelling presumed to be based on inner pronunciation of the phonic (sound) forms of the spoken language. Cognitive researchers were slow to recognise that written language is neither a complete isomorph of the spoken language (Gelb, 1963), nor a process of reading-in-reverse (Bradley and Bryant, 1979; Bradley, 1983), but rather, is a complex and autonomous system of representation, both of the deeper lexical-morphemic levels of language (Venezky, 1970; Ellis, 1982), as well as of the mappings of phonology. As such, spelling proficiency is a highly complex intellectual achievement in its own right, and is worthy of psycholinguistic interest in the same way as other language-based skills, such as speech perception, speech production and reading comprehension.

Because of the limited attention to spelling, much about the cognitive process remains to be addressed. This research aims to give attention to some of the issues arising. To begin, I describe the background from which the research impetus of the last ten years springs. Recent advances in knowledge of the spelling process were motivated by work from two quarters: linguistic analyses of writing systems out of which developed the consideration of spelling as a language-based skill with developmental stages, and case studies of neurological deficits in cognitive processing which seriously challenged the heretofore assumptions. Thus, firstly,

relevant considerations of the writing system will be outlined, followed by a description of spelling development as understood from educational research with children. Secondly, the evidence from neuropsychological studies will be presented. Next, I turn to a theoretical review of the current models of the spelling process and identify the focus of the present study.

1.1 Writing Systems

The writing systems of the world are divided into three types: logographic writing, such as Chinese, where each symbol represents a different spoken word; syllabic systems, such as Japanese Kana, where each symbol represents one syllable of the spoken language; and alphabetic writing, such as English, where in principle each graphic symbol represents a particular phoneme (distinctive sound) of speech (Ellis, 1982).

There are limitations in each of these systems (Harris and Coltheart, 1986). For example, in a logographic system, one cannot write a word if one has never actually been taught its corresponding representational symbol; and in using a syllabary, it would be difficult to learn each symbol for each syllable in a language such as English, which contains a great many different syllables. The versatility of the alphabetic system obviates both these limitations, since the number of different graphemic combinations possible approximates the number of permissible phonemic combinations. However, the system is fraught with difficulties of its own. While some language communities, such as Finnish, Italian, and Hawaiian, have shallow orthographies that closely approach the ideal alphabetic system, in which a single phoneme is always matched by a single grapheme, others, such as English, possess a deep orthography that bears a complex correspondence between spelling and speech (Hanna, Hanna, Hodges and Rudolf, 1966).

1.1.1 English Orthography and Spelling

In the English alphabetic system, several orthographic features serve to complicate the alphabetic principle (Hanna et al., 1966). A grapheme, the written representation of a phoneme, is not necessarily represented by one letter. For example, the phoneme /o/ in the word *though* is represented by the four-letter graphemic option <ough>. In addition, some graphemes

represent two or more phonemes, such as <ea> in *head, beat* and *break*, for example. Further complication arises in that the same phoneme may be represented by different graphemes, for example, /t/ in the words *to* and *two*. There are also many borrowed words from other languages, and since their incorporated written form is not based upon the same underlying phoneme-grapheme relationship, they disobey the normal correspondence, for example, *choir*. Another complicating feature is that the relationship between spelling and phonetic representations is often sacrificed to preserve morphological, syntactic, and semantic information (Chomsky and and Halle, 1968). For example, although /ed/ is pronounced differently in *frayed, landed* and *kissed*, the spellings of these words preserve information about their common syntactic structure; similarly, although the pronunciation of <g> in *sign* and *signature* differ, their spellings preserve their common derivation.

Given these complications and inconsistencies in the relationship between pronunciation and orthography, it was realised accurate spelling cannot be accomplished solely by means of access to a system specifying phoneme-grapheme conversion rules, as the traditional phonic mediation theories assumed. In order to spell all English words accurately, there must also be access to a lexical system containing whole-word spelling representations (Ellis, 1982). Moreover, to stop with this observation is to oversimplify the difficulties of spelling. Fischer, Shankweiler and Lieberman (1985) indicate it is more accurate to view orthography as a rational system that requires *linguistic sensitivity* whereby the regularities of word structure at various levels of linguisitc representation are implicitly apprehended and utilised by ordinary spellers.[1] They outline three levels of linguistic representation: a basic level of phoneme-grapheme correspondences; a morphemic level, that requires learning morphemes and the conventions for combining morphemes to form new words; and an advanced level, which requires knowledge of phonological rules that map underlying morphophonemic segments to their surface phonetic form, for example *heal* and *health* (Fischer et al, 1985)

In their examination of college students, Fischer et al (1985) found correctness of spelling to be related to accuracy in analysing written words into their component morphemes, all of which had been represented by both good and poor spellers. Several other studies with

[1] This approach is consonant with the view of *emergent literacy* (Teale and Sulaby, 1986) which sees children as active participants in the process, as dynamic learners who generate hypotheses about their environment and consequently about print, including productive written text.

young children have shown that pattern abstraction occurs as part of spelling acquisition. Schwartz and Doehring (1977) demonstrated that spelling ability is associated with an orderly acquisition of morphological and orthographic patterns. They found good spellers to be in advance of poor spellers in the mastery of these patterns. Rubin (1988) showed that children in both kindergarten and first grade vary considerably in their implicit and explicit knowledge of morphology and that this variability reflected in early writing ability.

In spite of the complexities, most children become proficient spellers, and it has been demonstrated that by the third year in primary school young children have phonological, orthographic, morphological and visual knowledge of words, and both good and poor spellers attempt to use all of these sources of knowledge in spelling (Waters, Bruck, and Malus-Abramowitz, 1988). Any model of the spelling process must, then, take into account both the mapping of the written language and the internal mental representations derived from the primary linguistic activities of listening and speaking and the secondary activity of reading.

1.1.2 English Orthography and Development of Spelling

The interaction of the structure of English orthography with the emerging process capacity of children results in a developmental pattern involving a number of stages through which children progress as they master the consistent use of correct spelling (Henderson and Beers, 1980; Marsh, Friedman, Welch and Desburg, 1980; Seymour, 1987, 1990)

These stages of learning to spell have been found to proceed as follows, irrespective of the method of instruction (Henderson, 1980).

1. The *pre-phonetic* or *logographic* stage, in which children start to represent speech sounds with letters of the alphabet, but they achieve partial representation only. They use the first letter to stand for the whole word (for example, B for back), or they write the first and last consonant (for example, BC for back, FT for feet).
2. The *phonetic* or *alphabetic* stage where children fairly reliably use a letter-name strategy to provide a total mapping of the phonological pattern of each word. Not only are first and last consonants used but also vowels appear (for example, back → bac). A common misspelling of short vowel sounds at this stage involves using the letter-name of a vowel spoken from a similar articulatory place in the mouth

(for example, fish → fes) (Read, 1971).

3. In the *transitional* or *orthographic* stage, the speller increasingly uses visual and morphological representations, instead of sole reliance on a phonological strategy. Also, short vowel forms are represented correctly (for example, stick → stik), and long vowels are given a marker (for example, feet → fete). This represents a breakthrough in conceptualisation because children can then go beyond the one-to-one sound-letter strategy and use a group or pattern of letters to represent a sound (that is, use phoneme-to-grapheme mappings). They cannot yet use the correct spelling correspondences, though.
4. The fourth stage of *competent spelling* is attained when children are able to spell words correctly, using consonant blends (for example, flip), digraphs (for example, chop) and vowel markers (for example, came) appropriately.

Seymour (1987) points out that the boundaries of these stages are not necessarily mutually exclusive, and that progress through the stages need not be strictly successive or independent. Their theory differs from others in suggesting that logographic development coexists with alphabetic/orthographic development. Also, theirs is the only theory which places the model of spelling development within a broader theory of literacy development.

This study will investigate some of the transitional aspects of the orthographic stage. Few people will not admit to the difficulties of learning to spell, and few teachers will not admit to the difficulties in teaching spelling. An understanding of the patterns of transition will inform how better to facilitate learning to spell.

1.2 Evidence from Studies of Acquired Disorders in Writing

Neuropsychological studies have subsequently provided evidence in support both of the idea that traditional theories are flawed, and that indeed two writing processes exist (Ellis and Young, 1988). Reports of patients who can still spell words although they cannot retrieve those words orally from memory (Levine, Calvanio and Popovics, 1982; Bub and Kertesz, 1982; Ellis, Miller and Sin, 1983; Carramazza, Miceli and Villa, 1986), validate the first-

stated observation. Further, using the distinction between a phonological dysgraphic patient (one who can write words but not non-words) (Shallice, 1981), and a surface dysgraphic patient (one who can write nonwords and regular words, but not irregularly spelled words) (Beauvois and Dérousné, 1981), as evidence of a double dissociation, separate phonological and lexical writing processes have been demonstrated.

1.2.1 The Dissociation Between Speech and Writing

According to the traditional view, the writing system was assumed to be associated with the speech system so that spelling was held to have obligatory dependence upon phonological mediation or *inner speech*. One reason for the perpetuation of this view stemmed from the association of writing disorders with particular forms of aphasia, particularly Wernicke's aphasia. However, it is now realised that Wernicke's aphasia does not necessarily specify a corresponding writing disorder (Shallice, 1981) and that the normal association between writing and speaking in Wernicke's aphasia might well be a consequence of the lesions involved being of large size, thereby affecting multiple functional systems (Hier and Mohr, 1977).

Furthermore, if the argument for solely phonological mediation in spelling were correct, then a patient who appears to have no *inner speech*, that is, who has no capacity to generate the spoken forms of words internally, will be unable to write. Yet, patient EB (Levine et al, 1982) who was just such a patient, had well preserved writing ability. His speech was reduced to inarticulate sounds, there was no evidence of any internal access to the sounds of the words he could write, yet his spelling of real words was excellent and his spontaneous writing was unimpaired.

Likewise the anomic patient MH, (Bub and Kertesz, 1982), whose fluent speech was circumlocutory and virtually devoid of content words. She had great difficulty in naming pictures of objects, and in one task she managed only one out of 20. Nonetheless, she could write the names of objects and performed 15 out of 20 correctly. Her performance on different naming tasks showed no inner knowledge of the sounds of words, and analysis of the errors on a spelling-to-dictation task indicate her ability to write was not based on a strategy of assembling spellings. Her errors were either morphologically related to the target word (for example, ACQUIRE for acquisition) or were visually similar (for example, COMPREHEN-

SION for apprehension), while other errors showed partial knowledge of irregular spellings (for example, ORCHATRIA for orchestra).

Additional corroborating evidence is provided by patients JS (Caramazza et al, 1983) and RD (Ellis et al, 1983), who were neologistic jargonaphasics. Their speech was full of distorted, incorrect attempts at words, yet both were able to spell correctly words they could not say correctly. For example, in an oral and written naming task, RD called a penguin a "senstenz" but then immediately wrote its name correctly. If writing were based on inner pronunciation, then the spellings of patients like RD and JS would reproduce their mispronunciations, yet they do not.

1.2.2 The Theoretical Significance of Phonological Dysgraphia

If the argument for obligatory phonological mediation in spelling were correct, then a patient who cannot transform phonemic information into its graphic form will be unable to write. However, Shallice (1981) describes a patient, PR, who had a severe deficit in phoneme-grapheme transformation whereas his ability to write words remained remarkably spared.

PR presented with only very slight difficulty in spelling words. He was able to write correctly over 90% of a set of common words dictated to him. In addition, the regularity of a word did not affect his spelling of the word. PR's errors were mostly morphological (for example, "navigation" written as NAVIGATOR) or structurally similar real words which often sounded like the target word (for example, "custom" misspelled as CUSTARD).

In direct contrast to his ability to spell words, PR had a striking inability to write invented nonwords. The significance of nonwords lies in that they function as possible words one has never met before, so they provide a clear means of testing a person's ability to spell using the phoneme-grapheme conversion strategy (Ellis and Young, 1988). His ability to repeat nonwords suggests that his deficit was due neither to a perceptual problem with nonwords, nor to an inability to hold the nonword sufficiently well in order to transform it to its graphemic representation, since he could even repeat the nonword after his attempt at spelling it. Interestingly, his strategy in spelling nonwords was to use a word as a mediator. For example, he spelled "sim" as "sym", mediating from "symbol", and he spelled "sult" as "ault", mediating from "assault". It can be seen, however, that once the mediation word was

obtained, PR was unable to use phonology effectively to provide the appropriate modification.

Indeed, although PR was able to write down a letter when told its letter-name, (for example, K for "kay"; H for "aitch"), it is clear that he was unable to transform phonemes into graphemes in that he was unable to write down a letter when dictated its letter-sound, (for example, K for "kuh"; H for "huh"). Concerning segmentation skills, PR was unable to *sound out* a word, for example, cat - '/k/.../ae/.../t/", or to decide whether underlined letters sound the same in two visually similar words, for example, *stage, fig*.

The case of PR is significant because apart from adding to the converging evidence that contradicts the traditional assumption of writing being dependent upon speech and an obligatory phonic mediation, it provides evidence in support of the existence of a lexical route which does not involve phoneme-grapheme transformation (Ellis and Young, 1988). Of further significance, Beauvois and Dérousné (1981) describe a French patient (RG) whose writing deficit is the opposite of the writing dissociation in PR.

1.2.3 The Theoretical Significance of Surface Dysgraphia

In writing nonwords to dictation, RG performed perfectly. Most of the words (71%) were written in the most economical way, (for example, /o/ was most often written "o" and not "eau"). Beauvois and Dérousné differentiated ambiguous words (which are written in accordance with phoneme-grapheme conversion rules, but which can be written in several ways) and irregular words (where the phoneme-grapheme mapping is exceptional) from regular, predictably-spelled words. RG spelled correctly less than 40% of ambiguous and irregular words, but over 90% of regular words. Errors were mainly phonic in that the misspellings sounded like the target word.

The results are consonant with the argument that because the spellings of words such as those in the former group cannot be predicted with confidence from their pronunciations, the successful speller must store the spellings of familiar such words in memory, not assemble them from sound.

obtained, PR was unable to use phonology effectively to provide the appropriate modification.

Indeed, although PR was able to write down a letter when told its letter-name, (for example, K for "kay"; H for "aitch"), it is clear that he was unable to transform phonemes into graphemes in that he was unable to write down a letter when dictated its letter-sound, (for example, K for "kuh"; H for "huh"). Concerning segmentation skills, PR was unable to *sound out* a word, for example, cat - "/k/.../ae/.../t/", or to decide whether underlined letters sound the same in two visually similar words, for example, *stage, fig*.

The case of PR is significant because apart from adding to the converging evidence that contradicts the traditional assumption of writing being dependent upon speech and an obligatory phonic mediation, it provides evidence in support of the existence of a lexical route which does not involve phoneme-grapheme transformation (Ellis and Young, 1988). Of further significance, Beauvois and Dérousné (1981) describe a French patient (RG) whose writing deficit is the opposite of the writing dissociation in PR.

1.2.3 The Theoretical Significance of Surface Dysgraphia

In writing nonwords to dictation, RG performed perfectly. Most of the words (71%) were written in the most economical way, (for example, /o/ was most often written "o" and not "eau"). Beauvois and Dérousné differentiated ambiguous words (which are written in accordance with phoneme-grapheme conversion rules, but which can be written in several ways) and irregular words (where the phoneme-grapheme mapping is exceptional) from regular, predictably-spelled words. RG spelled correctly less than 40% of ambiguous and irregular words, but over 90% of regular words. Errors were mainly phonic in that the misspellings sounded like the target word.

The results are consonant with the argument that because the spellings of words such as those in the former group cannot be predicted with confidence from their pronunciations, the successful speller must store the spellings of familiar such words in memory, not assemble them from sound.

In all then, there is evidence that the writing system is not an isomorph of the speech system, although there may be an overlap, and that cognitive processes exist which are specific to spelling and do not involve spoken-word forms. Moreover, successful spelling is achieved through two processing routes, a lexical route and a phonological route. Having postulated this system, further interesting questions arose, and as investigations proceeded, growing specification of the writing system has resulted.

1.3 Contemporary Models of Spelling

During the last ten years an increasing number of investigations into acquired spelling disorders have been conducted within the framework of information processing (Caramazza, Miceli and Villa, 1986). According to this approach a detailed model which reflects the discrete stages thought to be involved in the particular internal cognitive process, as well as the order in which they come into play, is developed (Harris and Coltheart, 1986). The model is expressed in terms of specific processing components, such as auditory recognition of words, segmentation of verbal sounds into phonemes, and working memory units with specific buffer functions. The patterns of dysgraphia reported in this way have been used to formulate some of the major features of the writing process. The rationale guiding this method of developing models turns on two interlocking assumptions: that a particular form of dysgraphia serves as empirical evidence for a model of spelling if the observed pattern of errors in spelling performance can be explained in terms of damage to one or more components of the postulated model (Caramazza, Miceli, Villa and Romani, 1987); and that any systematic variation in the type of factors that influence word spelling ability is a reflection of the organisational principles of the spelling system (Goodman and Caramazza, 1986).

By focussing in this way on the relationship between the pattern of spelling errors in patients with a neurological deficit and the cognitive mechanisms that give rise to these error patterns, a fairly detailed model of the spelling process has been mapped (Nolan and Caramazza, 1983; Margolin, 1984; Caramazza et al., 1986; Goodman and Caramazza, 1986a; Goodman and Caramazza, 1986b; Caramazza, et al., 1987; Goodman-Schulman and Cara-

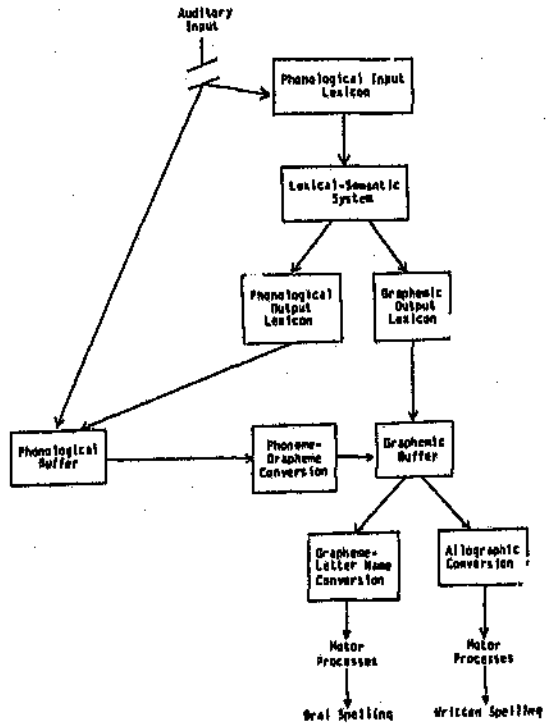


Figure 1.1: Schematic diagram of the spelling process.

mazza, 1987). A schematic representation of the process is presented in Figure 1.1. The unit of analyses provided by these components, and their hierarchical structure, yields a powerful and coherent framework within which to investigate and explicate several theoretical and applied issues related to the process by which normal users of a language spell, yet little empirical research on normal subjects has been undertaken using this framework. Such research is important because several algorithmic aspects related to the process by which normal language users spell can never be explicated through investigations of dysgraphic patients, and the final specification of a cognitive system must be consonant with performance of normal children and adults. In addition, the developmental approach inherent in the notion of spelling as a language-based skill presumes spelling competence involves a qualitative as well as a quantitative difference between children and adults (Marsh et al, 1980). My research

addresses some of these issues.

To this end, the components of central processing will be described below, in order to establish the base from which this investigation will spring.

1.4 The Functional Organisation of the Spelling Process

The model represented in Figure 1.1 can be summarily described thus: (1) the abstract representation of a spoken word is accessed in the phonological input lexicon; before the word is spelled it may or may not pass through the lexical-semantic system, whereby the meaning of the word is accessed; the abstract representation of the written word is then accessed in the graphemic output lexicon, from where it is stored in the graphemic buffer, until the processes of written spelling (via the allographic conversion mechanism) or oral spelling (via the letter-name conversion mechanism) takes place; (2) alternatively, if a word does not have a whole word representation in the graphemic output lexicon (such as an unknown word or a nonword) an abstract phonological representation is assembled in the phonological output lexicon, from where it is stored in the phonological buffer until it is converted into a graphemic representation via the phoneme-grapheme conversion mechanism; (3) further, it is postulated that after auditory/phonetic analysis, an auditory input may proceed directly to the phonological buffer, shortcutting the processes described above.

1.4.1 The Grapheme Output Lexicon

The evidence from previously mentioned patients EB, MH, JS, RD, and PR (see Section 1.2) suggest they attempted to retrieve the spellings of familiar words from some internal long-term memory store of whole-word representations, referred to as the graphemic output lexicon. [2] Simply stated, it is proposed that the spelling of each new word is coded and stored in the graphemic output lexicon; subsequently, every time the word is required to be written, that representation will be activated, thereby making available its spelling. Details of the source of activation and questions regarding the representational format in the graphemic output lexicon, are considered below.

[2] Alternative labels are the graphemic output logogen system (Ellis, 1982; Morton, 1980), the orthographic lexicon (Allport and Funnell, 1981), and the graphemic word production system (Ellis, 1984).

Two sources of input, which normally work in tandem, have been demonstrated to activate entries in the graphemic output lexicon:

1. Activation comes from the lexical-semantic system. When asked to write 20 concrete and 20 abstract nouns of roughly equal length and frequency, JC (Bub and Kertesz, 1982b) correctly wrote 17 out of 20 concrete nouns but only 9 out of 20 abstract nouns. Performance was not influenced by whether a word required regular correspondences or not, but there was a grammatical word class effect, in that she was fairly poor at writing function words (only 6/20 correct), despite their being the most common words in the language. Many of JC's errors were semantic errors, for example, she wrote "time" as CLOCK, "sky" as SUN. JC was also very poor at writing nonwords (5/37 correct). Evidence suggests, then, impairment to a direct connection between the lexical-semantic component and the graphemic output lexicon.

2. There is input that bypasses the semantic system (Patterson, 1986; Goodman and Caramazza, 1986a; Lesser, 1989), that is, there is a lexical-phonological input system directly from the phonological input lexicon to the graphemic output lexicon. For example, Patterson's patient, GE, could neither write spontaneously, nor write the names of objects, but could write dictated words, spelling them correctly despite no understanding of their meaning. His spelling performance showed no effect of regularity, imageability or grammatical word class, which together suggests while he could still address entries in the graphemic output lexicon, a clear disconnection exists between the lexical-semantic system and the graphemic output lexicon. This indicates activation via lexical-phonological input. An alternative but less parsimonious explanation of the sematic bypass is given by Hatfield and Patterson (1983) to account for homophone confusion errors. They suggest the semantic bypass includes involvement of the phonological output lexicon, that is, from the phonological input lexicon to the graphemic output lexicon via the phonological output lexicon. Although they admit the evidence is weak, Ellis and Young (1988) consider this would also account for slip-of-the-pen errors such as

SURCE for "search" and COULD for "good".

There are several conceptions of the representational format of information stored in the graphemic output lexicon. Each has important implications for how the process is characterised. One conception is that it is a visual memory, in which spellings are coded with information about the visual configuration of words (Barron, 1980). Spellers were found to have greater accuracy when they visualised alternatives rather than when they *thought* a solitary output (Tenney, 1980). Hence the idea of accessed visual information is considered useful in that it allows for a checking-selection process. A second conception is that spellings may be stored as serial lists of letters. Wing and Baddeley (1980) found the probability of a spelling error is greatest in the middle of the word, and decreases toward the ends, similar to a bow-shaped serial list recall curve. The misspellings of some patients, such as previously mentioned JS and RD, do not follow this bow-shaped distribution pattern, though. Their errors show partial lexical knowledge; it is known they were able to access the words from the graphemic output lexicon, because parts of their incorrect spellings contained the correct idiosyncratic mappings of the words in question, for example, RD wrote SICESSE for "scissors", and JS wrote PYMINIA for "pyramid". This partial representation is commonly apparent in patients, across many forms of aphasia or dysgraphia (Ellis and Young, 1988). Such errors are sometimes seen in normal spellers too, and this type of partial spelling knowledge is also found in beginners. [3] It has been suggested that the graphemic output lexicon contains only the irregular portions of irregular words (for example, Dodd, 1980; Frith, 1980). However, there is evidence to the contrary from PR, who spelled lexically, but who had access to the complete spellings of both regular and irregular words.

Hillis and Caramazza (1989) have used both ideas to elaborate a conceptualisation of an activated representation as having the quality of an abstract image on an *inner screen*, which is *read out* (in contrast to the notion of being released) from this lexicon. Thus, for high-frequency short words, salient information in this screen pertaining to orthographic patterns seems to be initial letter, presence of double letters and length. However, it would be simplistic to assume that the graphemic output lexicon functions merely to specify the ordered

[3] It is useful to know the source of this type of error, because it will be possible to separate them from other error types when doing a finer-grained analysis.

sequence of graphemes that comprise a word. That would imply that the development of the lexicon involves passive storage of words. Indeed, Caramazza and his colleagues provide interesting evidence that these screened abstract images hold additional graphotactic structure, in the form of morphemic units (Badecker, Hillis and Caramazza, 1990; Miceli and Caramazza, 1988 as citied in Badecker et al 1990). Importantly, the implication that coding occurs which abstracts regularities of morphological patterns is consonant with the ideas arising from educational reseach (see Section 1.1.1).

Thus the graphemic output lexicon can be seen to develop qualitatively as well as quantitatively. Seymour's (1990) developmental model describes how this may come about. He proposes that the organisational structure that defines such graphotactic characteristics, and in terms of which information is processed, is derived from a *foundational system of phonological awareness* of both speech segments and language structure, including the internal organisation of the syllable. Elaboration of the structure is progressive, beginning with the development of an elemetary core structure which is systematically augmented by inclusion of more complex forms. In this way, spelling ability draws on a variety of linguistic abilities which continue to develop with maturation and experience, even into adolescence (Fischer et al, 1985).

It has been demonstrated that frequency of words plays a role in the accessing of representations from the graphemic output lexicon. Goodman and Caramazza (1986b) report their patient, MW, lost the ability to successfully address low-frequency words. Many of the symptoms in the speech of Wernicke's aphasics can be accounted for in terms of the selective loss of all but high-frequency words (Marshall, 1977, as cited in Ellis, 1982), and it would appear that such a selective loss is also possible for written words (Ellis, 1982). Since activation via the lexical-phonological system is based solely on word sound, its effectiveness would presumably be related to the number of times the association has been made. Thus, the word frequency effect is thought to be associated with the lexical-phonological system, and can be used as a research index.

The information read out from the graphemic output lexicon is a string of graphemes, that is, an abstract description of the letter sequence, albeit in morphemic units, which can be output as print, handwriting, typing, or oral spelling (Ellis and Young, 1988). This graphic

representation is temporarily stored in the graphemic buffer for conversion into specific letter shapes.

1.4.2 The Graphemic Buffer

Caramazza et al. propose that

> a working memory system should be postulated whenever the computational units in a processing component are incommensurate with - that is, smaller or larger than - the representations that serve as input to the processing component in question (1987:63).

The processing component in question here is the allographic conversion mechanism and the letter-name conversion mechanism, whose units of analysis are single graphemes or letters. The input to these mechanisms arises both from representation generated by the graphemic output lexicon and from phoneme-grapheme conversion, whose units of analysis range from whole-word units to single letters. So, a series of grapheme representations are temporarily stored in the graphemic buffer while they are being converted into forms which can be used to guide the peripheral motor processes of writing. The graphemic buffer, then, has a central role, for it interposes between output and the two strategies of processing.

Caramazza et al (1987:63, 75) have outlined the diagnostic implications of selective damage to this component for spelling performance :

- errors will be made on both familiar and novel words;
- errors will occur independently of both the modality of input (that is, writing to dictation, delayed copy, written naming, or spontaneous writing) and the modality of output (that is, oral or written spelling or typing);
- since the units of analysis in this component are graphemic representations, errors will be characterised by graphemic degradation, and lexical (for example, grammatical word class) and phonological factors will not play a role;
- owing to its storing function, spelling difficulties will become increasingly severe with longer stimuli.

Patients FV (Micell et al., 1987), LB (Caramazza et al., 1987), DH and ML (Hillis and Caramazza, 1989) have been described whose spelling performances were indeed characterised by the specifications outlined above. Spelling errors consisted of additions (GAMRE for "game"), deletions (MOSE for "mouse"), substitutions (DAT for "cat"), and transpositions (PALY for "play"). In the case of LB, deletions were associated with long words and transpositions with short words. It is argued that graphemic representation of longer stimuli becomes so deformed as to be rendered unusable for guiding the selection of specific [illegible] On the other hand, while graphemic representation of shorter stimuli is sufficiently [illegible] to contain information about specific graphemes, their respective order is not retained. In addition, while errors by FV occurred with roughly equal probability across all word positions, for LB more errors occurred for the medial positions than for the initial and final flanking positions. This indicates that information from this system may not be homogeneously accessible. How pertinent this factor is in the acquiring of spelling proficiency of normal children is not known. It is possible that some learner spellers may have poorly developed graphemic buffer functions. In this regard, it is of particular interest that Hillis and Caramazza argue the possibility that the opposing pattern found in the distribuiton of errors of DH and ML reflect modulation of performance by attentional deficits at this level of internal *spatial* representations of the to-be-spelled word in the graphemic buffer.

The specific characterisations of spelling performance related to the graphemic buffer is very relevant to this study. Performance errors arising in the graphemic buffer could mask factors of spelling competence related to stages in the process that precede the graphemic buffer stage. In an analysis, one would need to separate this effect.

1.4.3 The Phoneme-Grapheme Conversion Mechanism

The spellings of words not stored in the graphemic output lexicon can be created by using the phonemic form of the words in order to arrive at their graphemic and ultimately orthographic forms via access to a system of rules specifying which graphemic units to assign to phonemes. Children, who presumably have yet to build up a large store of entries in the graphemic output lexicon, may rely heavily on this stopgap strategy (Ellis and Young, 1988). The procedure involves the breakdown or segmentation of the phonological form of the word into

phonemes or phoneme clusters in the phonological output lexicon. These are held in the phonological buffer ready for the replacement of each phoneme by the appropriate letter or letters according to correspondence rules of phoneme-grapheme conversion,[4] the resultant abstract letter string being stored in the graphemic buffer as it is created.

Patients RG (Beauvois and Dérousné, 1981), TP (Hatfield and Patterson, 1983) and KT (Baxter and Warrington, 1987) all have impairments that affect the retrieval of lexical representations of words from the graphemic output lexicon. Because they have recourse to the alternative strategy of assembling spellings, they are able to produce plausible spellings for nonwords, they can still spell many regular words correctly, and their errors are misspellings which, when pronounced sound like the target word, (for example, CASSEL for "castle"), that is, they are *phonologically plausible errors* (Caramazza, Miceli and Villa, 1986). This pattern of spelling performance, together with a systematic knowledge of the inconsistencies of phoneme-grapheme relationships (Hanna, Hanna, Hodges and Rudorf, 1966), informs us of how to describe the algorithm operating this mechanism.

Correspondence rules are thought to be based on abstraction of phoneme-grapheme pairs from spelling patterns of known words (Barry and Seymour, 1988; Goodman-Schulman and Caramazza, 1987). The alternative correspondence mappings for each sound are graded from most to least frequently occurring according to a probability relationship between phoneme and grapheme. The assumption is phonemes will activate all their corresponding spelling patterns according to rules of synaptic weighting demonstrated in biological systems. In these terms, a phoneme-grapheme conversion mechanism capable of generating a plausible spelling for a word would be more effective for words consisting of frequently occurring, rather than infrequent, phoneme-grapheme correspondence mappings. In other words, this grading reflects what has variously been termed *regularity, ambiguity, mapping probability* (Goodman-Schulman et al, 1987; Goodman-Schulman, 1988), or *sound-to-spelli… contingency* (Barry and Seymour, 1988).

Verification for these ideas comes from several sources. Goodman and Caramazza (1986),

[4] While there is general agreement that these phonological processes work at a subword level, not all theorists accept that graphemes can be assigned to phoneme segments using the alexical correspondence rules of phoneme- grapheme conversion. Some posit a lexical method of retrieving information about the spelling of such segments by analogy with known words (Glushko, 1979; Marcel, 1980; Campbell, 1983). However, mounting evidence from research lends certain validity to the notion of the conversion mechanism being nonlexical.

describe patient MW, who had difficulty accessing whole-word representation of low-frequency words in the graphemic output lexicon. Assuming that these words were spelled via the phoneme-grapheme conversion, they investigated the pattern of the errors in terms of the probability relationship between phoneme and grapheme, based on the Hanna et al (1966) listing of probability estimates. Their analysis showed the expected effect of probability weighting. In addition, Goodman-Schulman and Caramazza (1987), have examined the performance of two patients, JG and MO, in similar terms. Both patients had a deficit to the lexical mechanism, and were matched on level of overall spelling ability. Their performance on a set of words that varied according to whether they were composed of frequently or infrequently occurring phoneme-grapheme mappings, was comparable (75% for JG and 71% for MO). However their performance contrasted in that JG, who could spell nonlexically, made frequent use of phoneme-grapheme mapping options and was sensitive to the correspondence distribution (90% of words containing frequent-mappings were spelled correctly, compared to 70% correct for those of infrequent-mappings); while MO, who had an additional deficit in the nonlexical process, showed no effect of the probability relationship, (63% and 74% of each type was spelled correctly).

In a study based on similar principles, Barry and Seymour (1988) distinguish both between high contingency (commonly occurring) and low contingency (rarely occurring) phoneme-grapheme correspondences, and between the most common and the second most common spelling pattern within the high contingency correspondences. They found significant effects of sound-spelling contingency upon normal subjects' nonword spelling in both a free-spelling task, in which only nonwords were presented, and a lexical priming task, in which nonwords were preceded by rhyming words that contained alternative mapping options (for example, "lane" - /tein/ versus "brain" - /tein/). In both tasks, high rather than low contingency spelling patterns were produced. In addition, subjects were more likely to produce the most common rather than the second most common spelling pattern.

Goodman-Schulman and Caramazza (1987:145), characterise the nature of the phoneme-grapheme conversion mechanism as a *passive component*. It is conceived as a resident device, like the receiver in a radio - as long as it is tuned in correctly it will transmit a clear signal. Indeed, conceptualisation of the mechanism is analogous to a *signal processing filter*

as described in simple numerical modelling terms (Widrow and Stearns, 1985). Thus, the input signal is a phoneme which activates an array of appropriate grapheme options, each of which is coded with a weight vector (for which mapping option probabilities serve as indices). The phoneme is processed in terms of a numerical algorithm by which the *best* option is selected as the output signal, the derived spelling of that phoneme. As such, it is, as Lesser (1990) suggests, more exact to call the component the *phonographeme-to-letter conversion mechanism*. A phonographeme is accessed and converted into an abstract representation of a letter/letters. Accepting this conceptualisation, two major issues can be addressed. Firstly, the question of how functional phoneme-grapheme mappings come to be established (Barry, 1988). This will most appropriately be addressed by investigating the spelling process in young children, particularly since use of the phonographeme-to-letter conversion is thought to be a dominant strategy. Phonologically plausible errors are common in children, yet there has been little formal investigation into the pattern of these errors that they make.

Secondly, while by definition the conversion algorithm is non-deterministic (Simon and Simon, 1977), one has to consider if it is necessarily of a simple type, which is implied by the prescription that conversion procedures will always result in the most-frequent mapping being used. This question gains added weight in the light of the following evidence. Both KT (Baxter and Warrington, 1987) and the majority of normal subjects reported by Barry and Seymour (1988) produced more second-most common than most common correspondences for the vowels /ei/ and /au/. Barry (1988) explored the possibility that the crucial factor is the distribution in terms of the token measure (the mean frequency of occurrence of words containing each spelling pattern) rather than that of the type measure (how many words exist with each spelling pattern) upon which their analyses were based. He found this re-analysis made no difference to the results. Goodman-Schulman (1988) points out that frequency distribution estimates change with syllable position, and suggests that re-analysis of the data in these terms may well yield results that are not anomalous.

However, in our study of the spelling of primary school children (Doctor and Antoine, in preparation), we also report unexpected results with regard to the spelling of the /aw/ phoneme, along with several others. Of interest, we found the common factor in these phonemes was the even spread in their probability frequency/weight distributions. Using the

Hanna et al (1966) probability estimates, we noted some sounds have frequency distributions where one letter is clearly more probable than the rest. For example, the sound /i:/ has only one high contingency correspondence, <e>, and so it's probability weighting is high (69.54%). The second-most common correspondence for this sound, <ee>, has a probability weighting that is considerably lower (9.81%). In contrast, /aw/ has three high contingency correspondences, <o>, <a> and <au>, of lesser weight (40.87%, 21.51% and 19.03% respectively), with the spread in probability distribution frequencies being more even. When the probability weightings of the most common graphemes corresponding with a particular phoneme are similar, then their availability becomes equiprobable, and this acts as a confounding factor in the conversion process. This begs the question, if then we are seeing errors arising because of simple non-deterministic conversion, is the limitation in this instance related to stage of development? Not enough is known about how spelling proficiency develops to be able to address this question.

It can, nonetheless, be balanced against the proposition that correspondence activation is influenced by application of context-sensitivity rules (Barry, 1988; Goodman-Schulman and Caramazza, 1987). For example, alexical *rules of local constraint* accompany syllable position (Goodman-Schulman, 1988), and conditional rules are applied, such as *I before E except after C* (Barry, 1988). These influences could be interpreted as the *body system* of a sophisticated non-deterministic algorithm (as suggested by Simon and Simon, 1977). However, the way that these function is underspecified, and nor is there agreement about their place in the process. Seymour (1987, 1990) suggests they function as *address modifications* lodged in the phonological output lexicon. (Perhaps thought in this matter is being hindered by the entrenched idea that distinguishes the two routes along lines of nonlexical/lexical, synonomous with phonological/whole-word. A less inhibiting and sufficient distinction, and one that I think may serve the purpose more fruitfully, is that of assembled/accessed spelling.) This aside, an alternative conceptualisation of these influences has been offered by Baxter and Warrington (1987). In order to explain their data obtained from KT, they explored the possibility that the conversion mechanism may use multi-phoneme, as well as uni-phoneme correspondences. For example, KT spelled words of low contingency pattern, such as "word" and "world" correctly, *appearing* in each case to treat the two targetted phonemes as a single

MAPPING AMBIGUITY					
High		Intermediate		Low	
/i/		/ju/		/ɔi/	
i	wiggle	u	fusion	oi	oil
y	myth	u-e	use	oy	royal
i-e	give	ew	news	oi-e	voice
a-e	senate	eu	feud	oy-e	gargoyle
ey	donkey	ue	value		
ie	mischief	ui	suit		
ui	build	iew	view		
ai	captain	eau	beauty		
ei	forfeit	ieu	lieu		
ee	been	eu-e	deuce		
e	pretty	ew-e	ewe		
a	spinach				
ia-e	marriage				
u	busy				
u-e	minute				
e-e	privelege				
ea	guinea				
ie-e	sieve				
o	women				
y-e	apocalypse				

Table 1.1: List of grapheme correspondences for three phonemes, each showing a different level of mapping ambiguity.

unit and using the most common spelling of that unit. Barry (1988) argues it is superfluous to postulate higher-order correspondence units, since KT's processing can equally well be said to reflect the operation of context sensitivity rules. The issue remains open.

1.4.4 The Theoretical Significance of the Ambiguity Effect

Doctor and Antoine (in preparation) and Scholnick (1988) investigated another aspect of the relationship between phoneme and grapheme. The effect on spelling of increased number of graphemes per phoneme was evaluated, using level of mapping ambiguity as an indicator. Thus, while some sounds may be represented by only a few different graphemes, indicating low correspondence mapping ambiguity, other sounds can be represented by many different graphemes, indicating a high correspondence mapping ambiguity (see Table 1.1). Scholnick found in secondary school children there was a constant pattern of increased ambiguity leading

to increased error rate, though differential for vowels and for consonants. The same was found in young spellers, although the ambiguity effect was not linear because most errors occurred on words in the moderate rather than in the high ambiguity category.

Baxter and Warrington (1987) are disparaging about this method of defining ambiguity. They find it insufficient for their purpose because it does not include account of correspondence contingencies. However, use of this index has served to elucidate a crucial point. While the idea of separate routes for accessed or assembled spelling is well established in essence, the degree of their autonomy is not resolved and the extent and nature of interaction between these two systems is a matter of conjecture (Miceli et al., 1985; Nolan et al., 1983; Ellis, 1982). Does the spelling of a word depend on parallel processing? Or do the routes process a spelling independently in an on/off system? Some have argued that the phonographeme-to-letter conversion system plays no role in the skilled spelling of known words (Shallice, 1981) Others assume use of this strategy is at least partially necessary (Marsh et al, 1980). Scholnick (1988) suggested if the spelling of familiar words requires the parallel operation of both routes, then there will be a phoneme-grapheme correspondence effect on the spelling of words. Using the ambiguity index, her investigation found support for the hypothesis that both routes contribute in the processing of familiar real words. In a follow-up study, Doctor, Antoine and Scholnick (1989) found additional evidence in the spellings of primary school children. This indicates the phonographeme-to-letter conversion mechanism is more than a stopgap strategy. Thus, while we can reject the classical model of spelling which proposes that spelling is totally reliant on speech, their intuitive assumption that spelling is assisted by speech is psychologically valid. In addition, Barry and Seymour, (1988) found a lexical priming effect in the spelling of nonwords, which again suggests an interaction of the two routes.

Caramazza and his colleagues (1983, 1985) have attempted to specify more fully the nature of the interaction, by enlarging on the central role played in the spelling process by the graphemic buffer. They propose interaction is necessary for the purpose of maintaining the contents of the graphemic buffer. Thus, concurrent with the read-out from the graphemic output lexicon into the graphemic buffer, a corresponding phonological form is selected and placed in the phonological buffer, so that both the graphemic and phonemic forms of the word

become available simultaneously. Assuming that the information in a buffer is subject to decay unless refreshment occurs and accepting that the contents of the phonological buffer is better maintained than those of the graphemic buffer, (because rehearsal in the phonological buffer via the phonological output lexicon is easier than rehearsal between the graphemic buffer and the graphemic output lexicon); then it is possible that a necessary input occurs from the phonological buffer via the conversion mechanism to refresh the rapidly decaying contents of the graphemic buffer. However, Caramazza et al. (1986) suggest the degree to which the conversion mechanism is used in this way may depend on language. In a language such as Italian, where there is a near perfect correspondence between phonemes and graphemes, its contribution could be significant, but it may be of limited utility in a language such as English.

1.5 Aims and Objectives

In summary, then, there are at least two ways in which a word can be spelled. Either the whole-word representation is accessed directly, or spelling is assembled by analysing the word into phonemic segments and converting them to graphemes using specific rules of phoneme-to-grapheme correspondence. It has been assumed the access strategy is the default route in a normal, proficient speller, and only when words cannot be located in the graphemic output lexicon is there recourse to a strategy of assembling spelling (Ellis and Young, 1988). However, even if the skilled writer has become able to spell words using alphabetic writing as if it were logographic, how this lexical proficiency is established is not known. Research is required to evaluate the relative contribution of each route in the process of learning spelling by normal users of the language. Previous research has indicated phoneme-to-grapheme correspondences are indispensible for the child during the learning process (Seymour, 1987; Bradley, 1985) and that by the end of their third year in primary school, children have well established phoneme-grapheme correspondences which they use in spelling, in addition to drawing on the lexical knowledge which they have acquired (Waters et al, 1988; Doctor et al, 1989). Presumably, phoneme-to-grapheme correspondences help the beginner writer to spell new or insufficiently familiar words, therefore assisting in the task of acquiring a store of lexical representations. Yet how they become established and how autonomously

they operate is not known. The purpose of this study is to empirically investigate the early stages of spelling acquisition in young children with the aim of explicating the role phoneme-grapheme correspondences may play in this process.

The units of analysis provided by the functional delineation of the processing components involved in spelling yields a powerful tool with which to investigate some of the issues related to the process by which normal users of a language spell. Using as variables the factors indicated as relevant to the specific components in the spelling process, that is, word frequency, ambiguity, mapping option probability frequency, grammatical word class, and concreteness, my study will examine some aspects of childrens' spelling development.

While the model suggests that children and adults use both strategies in spelling, the nature of phonographeme-to-letter conversion in the spelling of familiar words is yet relatively underspecified. In particular, there is a need to investigate further the relationship between phoneme and grapheme with respect to mapping frequency distributions and ambiguity in familiar words; and to evaluate the extent to which different performance factors influence spelling. My study sets out to do this. To this end, the following hypotheses will be investigated.

1. There will be a difference in the number of spelling errors made with words in which a particular phoneme maps onto one of many different graphemes (high ambiguity) compared to words in which a particular phoneme maps onto one of a moderately few different graphemes (moderate ambiguity) compared to words in which a particular phoneme maps onto one of very few graphemes (low ambiguity).
2. There will be a difference in the number of errors made on phonemes where the corresponding grapheme is of infrequent mapping distribution compared to phonemes where the corresponding grapheme is of frequent mapping distribution.
3. There will be a difference in errors due to word frequency.
4. There will be a difference in errors on words due to letter type (consonants and vowels).
5. There will be a difference in the number of errors due to developmental difference.

In terms of the model, some predictions about the outcome can be made, as follows.

- If number-of-graphemes-per-phoneme is an influential criterion, then there is a likelihood of more errors being made as the number of available alternatives increases.

- If an even distribution spread in Mapping Frequencies increases the likelihood of errors, then the above-mentioned effect of Ambiguity might be amplified in the moderate and high ambiguity categories because the frequencies for some of the phonemes in these categories have an even distribution spread.

- Conversion rules are less successful for phoneme-grapheme correspondences which do not have a high probability of occurring, so young children should make more errors on phonemes with infrequent- compared to frequent-mapping options.

- Further, if the conversion process is a simple non-deterministic one, then errors on phonemes with infrequent-mappings should always be regularisations using the most-common grapheme correspondence.

- Ambiguity and Mapping Frequency effects should be less evident in children who are spelling lexically

- Previous studies have focussed mainly on vowels, and consonants have not been as thoroughly investigated. However, vowels are expected to be more difficult to spell than consonants, since few letters are used in many graphemic combinations, with the same letter-pair often representing several different phonemes. The contrast is amply demonstrated by an analysis of the modified Hanna et al (1966) list. While 26 letters are used to represent 30 consonant phonemes, only 10 letters or used to represent 25 vowel phonemes. Also, many infrequent grapheme correspondences for vowels are very obscure.

- In addition, vowels have a higher incidence in the moderate-ambiguity category of phonemes where the corresponding graphemic options have an even spread in probability frequency distribution. If this feature increases the likelihood of errors, then most errors overall will occur on vowels in the moderate-ambiguity category.

Chapter 2

Method

2.1 Subjects

The subjects were 80 children who attend an English-speaking primary school in a middle-class area in Johannesburg. From the total sample tested, 20 children without learning disabilities and whose native language is English, were randomly selected from each of Grade 2, Standard 1 and Standard 2.

2.2 Design

In order to assess the variety of performance factors known to influence spelling accuracy, a Multivariate Analysis design was adopted, using as stimulii a list of words which was compiled to incorporate the following psycholinguistic dimensions as categorical variables for manipulation and control.

2.2.1 Psycholinguistic Factors as Variables

Levels of Ambiguity

Ambiguity has been defined in relation to phoneme-grapheme correspondences so that as the number of corresponding graphemes increase, the phoneme is defined as more ambiguous (Roeltgan and Heilman, 1984). In a previous study (Doctor et al, 1989) the Hanna, Hanna, Hodges and Rudorf (1966) list of phonemes with their corresponding graphemes was modified to account for the different pronunciation used in this country. The phonemes were ranked hierarchically according to their number of corresponding graphemes. Using this list (see

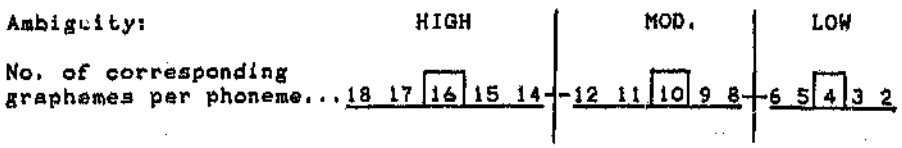


Table 2. Ambiguity categories, showing bands of number-of-corresponding graphemes.

AMBIGUITY LEVEL	CONSONANTS	VOWELS
High	/ʃ/ wish /k/ colt	/u:/ boot /ei/ play
Moderate	/s/ self /t/ talk	/ju/ cubs /ɛ:/ bear /ɔ:/ water
Low	/d/ doll /g/ leg /l/ long	/au/ out /æ/ plan /oi/ oil

Table 2.2: The phonemes used to represent each Ambiguity level.

Appendix A), bands of phonemes of high-, moderate- and low-ambiguity can be identified, taking those that cluster around the 16:1, 10:1 and 4:1 correspondence categories respectively, as illustrated in Table 2.1). The specific phonemes used to represent each level are shown in Table 2.2.

Mapping Frequency

The Hanna et al. correspondence list includes the calculated probability of occurrence of each phoneme-grapheme option according to its within-syllable position. Referring to the same modified list as above, graphemes with a >20% mapping option probability were categorised as being of frequent-mapping, and graphemes with a <15% mapping option probability were categorised as being of infrequent-mapping. Using this distinction, words with graphemes of

both frequent (ranging from 21%-97%, $\bar{x}$=55.14) and infrequent (ranging from 0.1%-16.86%, $\bar{x}$=7.66) mappings were selected to represent targetted phonemes (see Appendix B).

Word Frequency

Frequency measures were obtained from norms for children provided by Carroll, Davies and Richman (1971). Based on the range and distribution of frequencies within the *U* distribution of the norms, and following Goodman et al. (1986), the high-frequency range for nouns and verbs was restricted to words occurring between 51 and 313 times per million ($\bar{x}$=151) and the low-frequency range was restricted to words occurring between 0.5 and 25 times per million ($\bar{x}$=7).

Letter-Type

An equal number of consonants and vowels were targetted.

Abstractness-Concreteness

Concrete words have been defined as words referring to "tangible objects, materials, or persons which can be easily perceived with the senses"; abstract words have been defined as words referring to "abstract concepts which are not easily objectified or perceived" (Friendly, Franklin, Hoffman and Rubin, 1982:376-377). Measures were obtained for nouns primarily from norms provided by Gilhooly and Logie (1980). For some words not included on their list, measures were obtained from Friendly, Franklin, Hoffman and Rubin (1982) and from Paivio, Yuille and Madigan (1968). They all use a 1-7 rating scale, with 1 representing the greatest degree of abstractness, and 7 the greatest degree of concreteness. Based on these distributions, words selected as abstract ranged from 2.5 to 4.8 ($\bar{x}$ = 4.2) and words selected as concrete ranged from 5.7 to 7.0 ($\bar{x}$ = 6.6) (see Appendix C).

2.2.2 Outline of the Design.

In order to track the development of spelling ability, a repeated measures design was used. The dependent variable was accuracy of spelling the target segment in a word. A *target segment* is the selected phoneme within a word, the selection of which is predicated by the cate-

IV's	LEVELS											
STD	$Standard_n$											
Time	$Time_n$											
LT	consonants											
WF	low						high					
AMB	low		moderate		high		low		moderate		high	
MF	freq	infreq	freq	infreq	freq	infreq	freq	infreq	freq	infreq	freq	infreq

IV's	LEVELS											
STD	$Standard_n$											
Time	$Time_n$											
LT	vowels											
WF	low						high					
AMB	low		moderate		high		low		moderate		high	
MF	freq	infreq	freq	infreq	freq	infreq	freq	infreq	freq	infreq	freq	infreq

Table 2.3: Study design. (IV's = Independent Variables, LT = Letter-Type, WF = Word Frequency, AMB = Ambiguity, MF = Mapping Frequency, freq = frequent, infreq = infrequent.)

gorical considerations of the research design. As shown in Table 2.3, the categories consisted of six independent variables: Standard, Time, Letter-Type, Ambiguity, Word Frequency and Mapping Frequency. Standard had three levels, being Grade 2, Standard 1 and Standard 2; Time had three levels, each being one of three three-monthly test administrations; Letter-Type had two levels, that of consonants and vowels; Word Frequency had two levels, that of high-frequency and low-frequency words; Ambiguity had three levels, that of high, moderate or low; and Mapping Frequency had two levels, that of frequent- and infrequent-mapping.

2.3 Materials

2.3.1 Word list

A list of words was compiled to test spelling with age-appropriate stimuli. Drawing on words that contain the phonemes selected to represent the different levels of ambiguity, a list of 48 words was compiled (see Appendix D). The words were equally divided according to Word Frequency, Letter-Type, Mapping Frequency and Ambiguity. An equal number were nouns and verbs. Of the nouns, 13 were concrete and 11 were abstract. Only monosyllabic, four- or five-lettered words were used, each containing three or four phonemes. As shown in Tables 2.4 and 2.5, they were counterbalanced for lognormal Word Frequency.

(a) High-Frequency Words: Consonants.

GWC	MF	AMBIGUITY						$\overline{x}$ log normal freq.
		High		Moderate		Low		
nouns	freq	ship	2.2	tube	1.8	legs	2.2	2.1
	infreq	stick	2.0	space	2.4	eggs	2.1	
verbs	freq	fish	2.4	base	2.2	hole	1.9	2.1
	infreq	talk	2.3	dress	1.8	sell	1.9	
$\overline{x}$ log normal freq			2.2		2.1		2.0	total $\overline{x}$ = 2.1

median = 2.15; $SD = 0.22$.

(b) High-Frequency Words: Vowels.

GWC	MF	AMBIGUITY						$\overline{x}$ log normal freq.
		High		Moderate		Low		
nouns	freq	moon	2.3	tube	1.8	cloud	1.7	2.1
	infreq	tail	2.0	bear	2.0	house	2.6	
verbs	freq	gave	2.4	talk	2.3	plan	2.1	2.2
	infreq	grew	2.2	cause	1.9	voice	2.3	
$\overline{x}$ log normal freq			2.2		2.0		2.2	total $\overline{x}$ = 2.1

median = 2.15; $SD = 0.26$.

Table 2.4: Crosstabulation analysis of the selected high-frequency words, showing they are counterbalanced for log normal Word Frequency across the dimensions of Grammatical Word Class (GWC), Mapping Frequency (MF) and Ambiguity.

(a) Low-Frequency Words: Consonants.

GWC	MF	AMBIGUITY						$\bar{x}$ log normal freq.
		High		Moderate		Low		
nouns	freq	hush	0.9	self	0.8	lords	0.8	0.82
	infreq	stack	0.8	grace	0.8	odds	0.8	
verbs	freq	shield	0.8	bites	0.8	hail	0.8	0.83
	infreq	chalk	0.9	kiss	0.8	yell	0.9	
$\bar{x}$ log normal freq			0.85		0.80		0.83	total $\bar{x}$ = 0.83

median = 0.80; $SD = 0.16$.

(b) Low-Frequency Words: Vowels.

GWC	MF	AMBIGUITY						$\bar{x}$ log normal freq.
		High		Moderate		Low		
nouns	freq	boot	0.8	cube	1.0	clown	0.9	0.93
	infreq	hail	0.8	pear	0.8	mouse	1.4	
verbs	freq	fade	0.8	chalk	0.9	flap	0.7	0.78
	infreq	chew	0.9	draws	0.9	axt	0.5	
$\bar{x}$ log normal freq			0.83		0.88		0.88	total $\bar{x}$ = 0.86

median = 0.85; $SD = 0.22$.

Table 2.5: Crosstabulation analysis of the selected low-frequency words, showing they are counterbalanced for log normal Word Frequency across the dimensions of Grammatical Word Class (GWC), Mapping Frequency (MF) and Ambiguity.

AMB	LOW				MODERATE				HIGH			
MF	Frequent		Infrequent		Frequent		Infrequent		Frequent		Infrequent	
WF	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
	legs	lords	eggs	odds	tube	self	space	grace	ship	shield	stick	stack
	hole	hail	sell	yell	base	bites	dress	kiss	fish	hush	talk	chalk
	cloud	clown	house	mouse	tube	cube	bear	pear	moon	boot	tail	hail
	plan	flap	voice	axe	talk	chalk	cause	draws	gave	fade	grew	chew

Table 2.6: Showing how, within each Ambiguity (AMB) category, words with phonemes of frequent- and infrequent-mapping were pairwise-matched across Word Frequency (WF) on targetted phoneme, within-syllable position of that phoneme, and number-of-phonemes. (MF = Mapping Frequency)

Within each Ambiguity category, words with targetted phonemes of frequent- and infrequent-mapping were, in most instances, pairwise-matched across Word Frequency on the targetted phoneme, the within-syllable position of that phoneme, and also the number-of-phonemes, (see Table 2.6).

Additionally, the pairwise-matched words with targetted vowels were balanced across Mapping Frequency for sounds whose distribution frequency weightings are evenly spread, and those whose weightings have a discontinuous spread (Doctor et al., 1989). The words were controlled for consonantal strength by consisting of predominantly obstruent sounds (Stuart and Coltheart, 1988).

With the selected words controlled and counterbalanced in this way, these stimuli were used to assess the variety of performance factors known to influence spelling accuracy. In addition, development of spelling ability will be tracked by repeated assessment at three-monthly intervals. The words were randomly ordered for each of the three test administrations (see Appendix E).

2.3.2 Working Memory-Counting Task

This task was designed by Case et al, (1982). It involves counting yellow dots from a field of blue and yellow dots arranged in a randomly determined irregular pattern on a 5 x 8-inch index card. The cards are presented in sets of 2, 3, 4, or 5, and the task is to recall the counts for each set in the correct order. The task is graded into levels, there being three trials each

of two- three- four- and five-card sets.

2.3.3 Response Sheets

For both the spelling test and the working memory-counting task, each subject was presented with a blank answer sheet which included space for demographic data (see Appendix F).

2.4 Procedure

Subjects were group-tested in their classrooms and each class was given identical instructions (see Appendix G).

Prior to the main experiment, the children were given a working memory-counting task (Case, Kurland and Goldberg, 1982). Since poor performance on this task correlates highly with learning-disabled children (both those who have reading and/or arithmetic deficits) between the ages of seven and 13 years old (Siegal and Ryan, 1989), this test served to indicate subjects who are possibly learning disabled, and their responses to the spelling test were not included in the main analysis.

The spelling test was administered, consisting of a list of 44 words (four stimuli were duplicate words presented only once). Each word was read first in isolation, then embedded in a sentence, and then repeated in isolation (see Appendix E). The children were then allowed time to write the word. The list was administered in one session.

This procedure was repeated three times, at three-monthly intervals. The dates of data collection were 26 March, 25 June and 17 September, 1990.

Chapter 3

Results

Spelling errors that children make are used to evaluate aspects of the process by which normal children spell. The nature and distribution of the errors are analysed in terms of the performance factors relevant to specific components in the Caramazza model. In this way results will serve to elucidate the extent to which various factors, namely Letter-Type, Ambiguity, Word Frequency and Mapping Frequency, influence spelling performance. Further, concatinating the variables of Standard and Time provides an index of developmental trend. Using this new variable, Development, will serve to assess the way in which these performance factors influence learning to spell.

The children's errors on targetted segments of words only, were analysed. Tables 3.1 and 3.2 contain the basic data on errors made on the target consonant and vowel segments respectively. Preliminary examination of the distribution of errors within category cells show anomalous results in one cell, that of moderate-ambiguity consonants with frequent-mapping in in high-frequency words (/s/ or /t/)(see asterisked column Table 3.1) Responses to both stimuli were not consonant with the dataset and were likely to have an influential role of high leverage, thereby blurring the pattern of results. Unlike the trend in any of the other 23 cells, the number of errors increased, instead of decreased, with age. In addition, contrary to expectations, the number of errors was inordinately greater than those of the same category but of low-frequency words.

Investigation into alternative stimuli for this category amongst the response data confirmed the anomaly. Statistical data analysis therefore proceeded with a revised dataset, using the error responses to two substituted stimuli for that category. Table 3.3 contains the

AMB	LOW				MODERATE*				HIGH			
MF	Frequent		Infrequent		Frequent*		Infrequent		Frequent		Infrequent	
WF	High	Low	High	Low	High*	Low	High	Low	High	Low	High	Low
Gr. 2	17	19	21	40	17	2	60	83	0	1	56	69
Std 1	4	8	11	13	22	1	23	26	1	0	28	45
Std 2	2	4	11	20	31	1	6	8	0	0	4	36

Table 3.1: Basic data on errors made on the target consonant segments. Abbreviations AMB, MF and WF represent Ambiguity, Mapping Frequency, and Word Frequency respectively

AMB	LOW				MODERATE				HIGH			
MF	Frequent		Infrequent		Frequent		Infrequent		Frequent		Infrequent	
WF	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Gr. 2	46	17	85	70	72	91	94	95	21	26	92	97
Std 1	27	3	30	33	31	47	22	40	1	15	37	59
Std 2	19	3	18	18	12	43	31	12	1	23	46	48

Table 3.2: Basic data on errors made on the target vowel segments. Abbreviations AMB, MF and WF represent Ambiguity, Mapping Frequency and Word Frequency respectively.

AMB	LOW				MODERATE				HIGH			
MF	Frequent		Infrequent		Frequent		Infrequent		Frequent		Infrequent	
WF	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Gr. 2	17	19	21	40	0	2	60	83	0	1	56	69
Std 1	4	8	11	13	1	1	23	26	1	0	28	45
Std 2	2	4	11	20	0	1	6	8	0	0	4	36

Table 3.3: Revised basic data on errors made on the target consonant segments. Abbreviations AMB, MF and WF represent Ambiguity, Mapping Frequency, and Word Frequency respectively.

revised dataset for targetted consonant segments.[1]

The revised data were subjected to analysis of variance, with item means as units, using standard software (SAS Institute Inc., 1985). Planned comparisons were carried out via t tests.

[1]See Appendix H for the revised balanced and counterbalanced tables.

FACTOR	LEVEL	MEAN
Letter-Type	Consonants	0.14
	Vowels	0.33
Ambiguity	Low	0.19
	Moderate	0.28
	High	0.25
Word Frequency	High	0.21
	Low	0.26
Mapping Frequency	Frequent	0.13
	Infrequent	0.34
Development	Grade 2, Time 1	0.46
	Grade 2, Time 2	0.40
	Grade 2, Time 3	0.36
	Standard 1, Time 1	0.23
	Standard 1, Time 2	0.16
	Standard 1, Time 3	0.14
	Standard 2, Time 1	0.17
	Standard 2, Time 2	0.13
	Standard 2, Time 3	0.09

Table 3.4: Mean error scores for Letter-Type, Ambiguity, Mapping Frequency, Word Frequency and Development

3.1 Quantitative Analysis

A 5-way analysis of variance was run on the data. The error means are shown in Table 3.4. Results show that responses varied as a function of Letter-Type [$F(1, 8424) = 607.96, p < .001$]. As can be seen in Table 3.4, the error mean was higher for vowels than for consonants. There was also a main effect of Ambiguity [$F(2, 8424) = 54.96, p < .001$]. More errors were made at the moderate- than at the high-ambiguity level, while least errors occurred at the low-ambiguity level. A main effect of Mapping Frequency was also found [$F(1, 8424) = 740, 60, p < .001$]. There were more errors on words spelled with infrequent-mappings than those with frequent-mappings. In addition, there was a main effect of Word Frequency [$F(1, 8424) = 38.56, p < .001$]. The number of errors was greater on low- than on high-frequency words. The analysis of variance also found a main effect of Development

	DEVELOPMENT								
	G2T1	G2T2	G2T3	S1T1	S2T1	S1T2	S1T3	S2T2	S2T3
MEAN	.46	.40	.36	.23	.17	.16	.14	.14	.13

Table 3.5: Results of the t Tests (Least Squares Difference) for significant groupings of the error means in Development. Any two or more means with a common underscore are not significantly different ($p < .05$). Abbreviations G, S, and T represent Grade, Standard and Time-interval, respectively.

$[F(8, 8424) = 137.72, p < .001]$. The result of the post hoc analysis is shown in Table 3.5.

In each case, the factor's effect on the response depended on the other factors, and there were four fourth-order interactions:

- Letter-Type, Ambiguity, Word Frequency and Mapping Frequency $[F(2, 8424) = 15.62, p < .001]$
- Development, Letter-Type, Ambiguity and Mapping Frequency $[F(16, 8424) = 8.31, p < .001]$
- Development, Letter-Type, Word Frequency and Mapping Frequency $[F(8, 8424) = 3.30, p < .001]$
- Development, Letter-Type, Ambiguity and Word Frequency $[F(16, 8424) = 1.8, p < .05]$.

In order to provide a clear and parsimonious characterisation of the interactions, a strategy of analysis (Freeman, 1987) was adopted as follows.

1. Since Letter-Type was present in each of the fourth-order interactions, the association between the factors and the error responses was considered as heterogeneous for vowels and consonants, and were looked at separately.
2. The Development spectrum was analysed, separately for consonants and for vowels, in terms of the pattern of association of the other two variables in each particular interaction model.
3. Word Frequency and Mapping Frequency were collapsed into a single Frequency category, giving four levels, namely low-frequency words with infrequent-mappings,

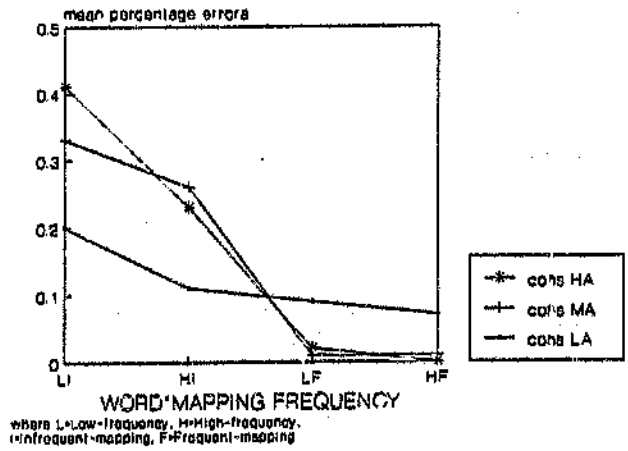


Figure 3.1: Graphic representation of the interactions between consonants, Ambiguity, Word Frequency and Mapping Frequency.

high-frequency words with infrequent-mappings, low-frequency words with frequent-mappings and high-frequency words with frequent-mappings.

3.1.1 Letter-Type, Ambiguity, Word Frequency and Mapping Frequency Interaction

Consonants

Figure 3.1 illustrates for consonants the interactions in the Letter-Type, Ambiguity, Word Frequency and Mapping Frequency analysis. Analysis of the effect of Frequency at each level of Ambiguity shows performance followed the same pattern at the high and moderate levels, with most errors made on low-frequency words with infrequent-mappings [low-infrequent compared to: high-infrequent, $t(8424) = 6.02, p > .01$, $t(8424) = 2.69, p > .01$; low-frequent, $t(8424) = 15.0, p > .01$, $t(8424) = 12.31, p > .01$; and high-frequent, $t(8424) = 15.77, p > .01$, $t(8424) = 12.69, p > .01$; for high- and moderate-ambiguity respectively], few on both low- and high-frequency words with frequent-mappings, and an intermediate number on high-frequency words with infrequent-mappings [high-infrequent compared to: low-frequent, $t(8424) = 8.08, p > .01$, $t(8424) = 9.62, p > .01$; and high-frequent, $t(8424) = 8.85, p > .01$, $t(8424) = 9.62, p > .01$; for high- and moderate-ambiguity respectively]. The pattern

of performance at the low-ambiguity level was similar [low-infrequent compared to: high-infrequent, $t(8424) = 3.46, p > .01$; low-frequent, $t(8424) = 4.23, p > .01$; and high-frequent, $t(8424) = 5.0, p > .01$], except the number of errors on high-frequency words with infrequent-mappings did not differ from those on low- and high-frequency words with frequent-mappings.

Analysis of the pattern of Ambiguity effect at each level of Frequency reveals that of the low-frequency words with infrequent-mappings, more errors occurred in the high-ambiguity category than in both the moderate- [$t(8424) = 3.08, p > .01$] and low-ambiguity categories [$t(8424) = 8.08, p > .01$], and in turn more errors occurred in the moderate- than the low-ambiguity category [$t(8424) = 5.0, p > .01$]. This expected pattern of results did not replicate within the other Frequency categories, however. Of the high-frequency words with infrequent-mappings, while fewer errors occurred in the low- compared to both the high- [$t(8424) = 4.62, p > .01$] and moderate-ambiguity categories [$t(8424) = 5.77, p > .01$], there was no difference between performance on high- and moderate-ambiguities. In both low- and high-frequency words with frequent-mappings, most errors occurred in the low-ambiguity category while there was almost none in the other two categories. [low- compared to high-ambiguity, $t(8424) = 2.69, p > .01$ for both Word Frequency comparisons; low- compared to moderate-ambiguity, $t(8424) = 3.08, p > .01$ and $t(8424) = 2.31, p > .05$ respectively].

Analysis of the effect of Word Frequency within the category of Mapping Frequency (see Figure 3.2), shows there was a Word Frequency effect on infrequent-mappings at all levels of Ambiguity, with less errors made on high- than on low-frequency words [high-ambiguity, $t(8424) = 6.92, p > .01$; moderate-ambiguity $t(8424) = 2.69, p > .01$; low ambiguity, $t(8424) = 3.46, p > .01$]. This effect was more marked in the high-ambiguity category than in the other two, which resulted in the same number of errors occurring on high-frequency words at the high- and moderate-ambiguity levels.

Analysis of the effect of Mapping Frequency at each level of Word Frequency (see Figure 3.3) shows there was a marked and constant effect of Mapping Frequency on both low- and high-frequency words in both the moderate- and high-ambiguity categories [low-frequency, $t(8424) = 12.42, p > .01$ and $t(8424) = 15.0, p > .01$ respectively; high-frequency, $t(8424) = 8.85, p > .01$ and $t(8424) = 9.62, p > .01$ respectively]. In each case fewer errors were made on frequent- than on infrequent-mappings. In the low- ambiguity category, there was an

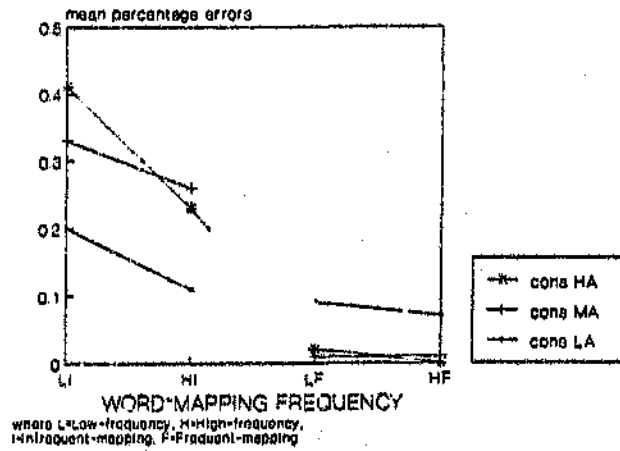


Figure 3.2: Graphic representation of the interactions between consonants, Ambiguity, Word Frequency and Mapping Frequency, with each level of Mapping Frequency separated in terms of Word Frequency level.

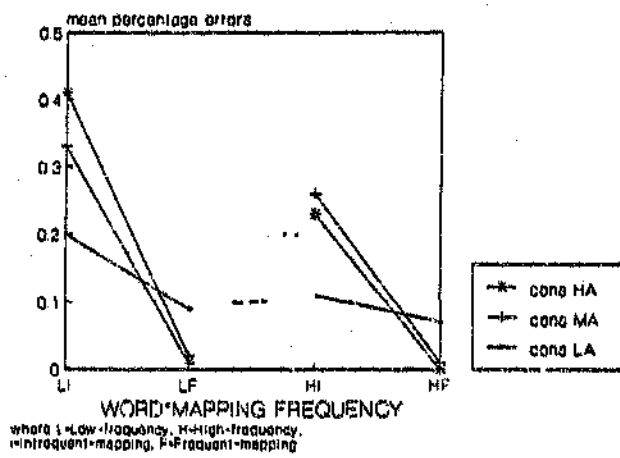


Figure 3.3: Graphic representation of the interactions between consonants, Ambiguity, Word Frequency and Mapping Frequency, showing performance in terms of Ambiguity at each level of Word Frequency which is separated in terms of Mapping Frequency.

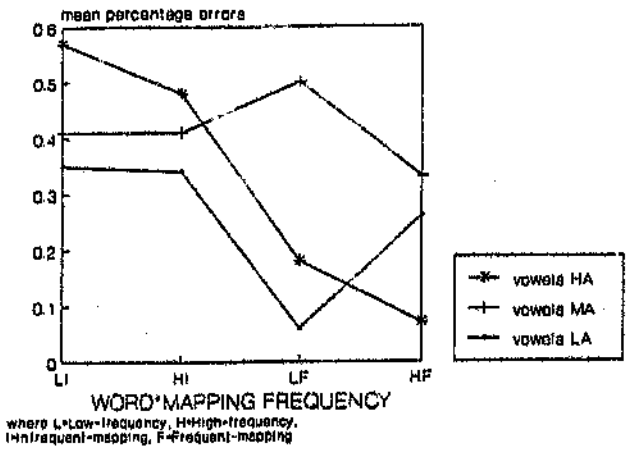


Figure 3.4: Graphic representation of the interactions between vowels, Ambiguity, Word Frequency and Mapping Frequency.

effect on low-frequency words only [$t(8424) = 4.23, p > .01$]. Errors in this instance were less effective by Mapping Frequency than those in the other ambiguity categories, to the extent that more errors occurred on low-frequency words with frequent-mappings in this category than in the other being a cross-over from the pattern in low- frequency words with infrequent-mappings.

Vowels

The curves in Figure 3.4 show the error response on vowels, in terms of Ambiguity, Word Frequency and Mapping Frequency. Results show performance at each Ambiguity level differed in the pattern of response to the Frequency variable. At the high-ambiguity level, the pattern followed the expected trend, with most errors made on low-frequency words with infrequent-mappings [low-infrequent compared to: high-infrequent, $t(8424) = 3.46, p > .01$; low- frequent, $t(8424) = 15.0, p > .01$; and high-frequent, $t(8424) = 19.23, p > .01$], least errors on high-frequency words with frequent-mappings [high-frequent compared to: high-infrequent, $t(8424) = 15.77, p > .01$; and low-frequent, $t(8424) = 4.23, p > .01$], and intermediately, more errors made on high-frequency words with infrequent-mappings than

on low-frequency words with frequent-mappings [$t(8424) = 11.54, p > .01$]. However, in the moderate-ambiguity category, low-frequency words with frequent- mappings accounted for most errors [low-frequent compared to: low-infrequent, $t(8424) = 3.46, p > .01$; high-infrequent, $t(8424) = 3.46, p > .01$; and high-frequent, $t(8424) = 6.54, p > .01$], while least errors occurred on high-frequency words with frequent-mappings [high-frequent compared to low-infrequent and high infrequent, $t(8424) = 3.08, p > .01$ for both], and an equal amount were made on low-and high-frequency words with infrequent- mappings. In the low-ambiguity category, conversely, low- frequency words with frequent-mappings accounted for least errors [low-frequent compared to: low-infrequent, $t(8424) = 11.15, p > .01$; high-infrequent, $t(8424) = 10.77, p > .01$; and high- frequent, $t(8424) = 7.69, p > .01$], while an equally high amount of errors were made on low- and high-frequency words with infrequent-mappings [low-infrequent compared to high-frequent, $t(8424) = 3.46, p > .01$; high-infrequent compared to high- frequent, $t(8424) = 3.08, p > .01$], so that an intermediate number occurred on high-frequency words with frequent-mappings.

Analysis of the pattern of Ambiguity effect at each level of Frequency shows, for both low- and high-frequency words with infrequent-mappings, the expected pattern resulted, with more errors occurring in the high- than in both the moderate- [$t(8424) = 6.15, p > .01$ and $t(8424) = 2.69, p > .01$ respectively] and low-ambiguity categories [$t(8424) = 2.31, p > .05$ and $t(8424) = 2.6, p > .01$ respectively], and in turn more errors occurring in the moderate- than in the low-ambiguity category [$t(8424) = 8.46, p > .01$ and $t(8424) = 5.39, p > .01$ respectively]. Of the low-frequency words with frequent-mappings, however, more errors occurred in the moderate- than in both the high- [$t(8424) = 12.31, p > .01$] and low-ambiguity categories [$t(8424) = 16.92, p > .01$], while in turn, more errors occurred in the high- than in the low-ambiguity category [$t(8424) = 4.62, p > .01$]. Finally, of the high-frequency words with frequent-mappings, while more errors occurred in the moderate- than in both the high- [$t(8424) = 10.0, p > .01$] and low-ambiguity categories [$t(8424) = 2.69, p > .01$], fewer errors occurred in the high- than in the low-ambiguity category [$t(8424) = 7.31, p > .01$].

Analysis of the effect of Word Frequency within the category of Mapping Frequency (see Figure 3.5), shows there was an effect in the high-ambiguity category, on both infrequent- [$t(8424) = 3.46, p > .01$] and frequent-mappings [$t(8424) = 4.23, p > .01$], such that fewer

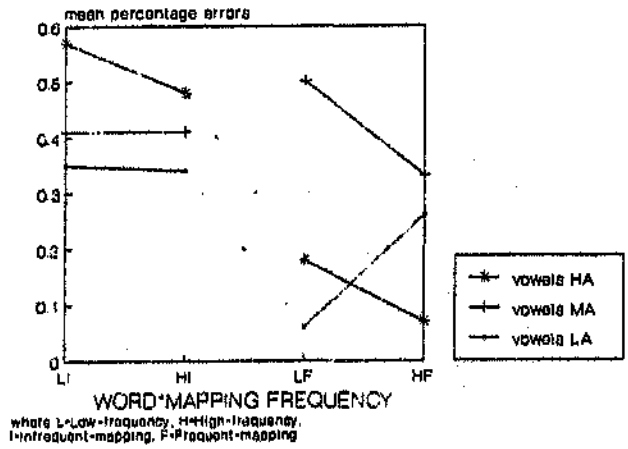


Figure 3.5: Graphic representation of the interactions between vowels, Ambiguity, Word Frequency and Mapping Frequency, showing performance in terms of Ambiguity, at each level of Mapping Frequency, separately for low- and high-frequency words.

errors were made on high- than on low-frequency words. There was also an effect on spellings with frequent-mappings in both the low- [$t(8424) = 7.69, p > .01$] and moderate-ambiguity categories [$t(8424) = 6.54, p > .01$], but not on infrequent-mappings. In the low-ambiguity category this effect was in a negative direction, with more errors made on high- than on low-frequency words.

Analysis of the effect of Mapping Frequency at each level of Word Frequency (see Figure 3.6), showed an effect on both low- and high-frequency words at all Ambiguity levels [high-ambiguity, $t(8424) = 15.0, p > .01$ and $t(8424) = 15.77, p > .01$ respectively; moderate-ambiguity, $t(8424) = 3.46, p > .01$ and $t(8424) = 3.08, p > .01$ respectively; low-ambiguity, $t(8424) = 11.15, p > .01$ and $t(8424) = 3.08, p > .01$ respectively]. In all but one instance, fewer errors were made on frequent- than on infrequent-mappings. The exception was on low-frequency words in the moderate-ambiguity category, where the effect was in the opposite direction. With high-frequency words, the Mapping Frequency effect was more marked in the high- than in both the low- and moderate-ambiguity categories. With low-frequency words, the effect was very strong in both the high- and moderate-ambiguity levels, and was more marked than the negative effect in the low-ambiguity category.

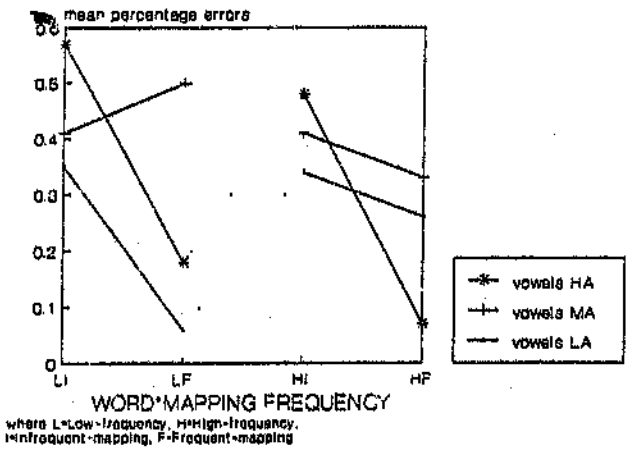


Figure 3.6: Graphic representation of the interactions between vowels, Ambiguity, Word Frequency and Mapping Frequency, showing performance in terms of Ambiguity, at each level of Word Frequency, separately for frequent- and infrequent-mappings.

3.1.2 Development, Letter-Type, Ambiguity and Mapping Frequency Interactions

Consonants

The curves in Figure 3.7 show the performance on consonants along the Development spectrum, in terms of Ambiguity and Mapping Frequency. The profiles show the different patterns of response to spellings with frequent- and infrequent-mappings at each Ambiguity level. Performance on spellings with infrequent-mappings show a similar trend at all Ambiguity levels, where, within the general trend of a steady decrease in the occurrence of errors from Grade 2, Time 1, ere was an anomalous peak in the Grade 2 error responses at the third time-interval [Grade 2, Time 2 compared to Grade 2, Time 3: high, $t(8424) = 2.67, p > .01$; moderate, $t(8424) = 1.96, p > .05$; low, $t(8424) = 3.39, p > .01$]. The low-ambiguity profile differed from the other two in that there was also an increased occurrence of errors in Standard 2 at the second interval [Standard 2, Time 2 compared to Standard 1, Time 3, $t(8424) = 2.14, p > .05$], with the result that, contrary to expectations, more errors were made in the low- than in the moderate-ambiguity category by the Standard 2's [$t(8424) = 2.14, p > .05$].

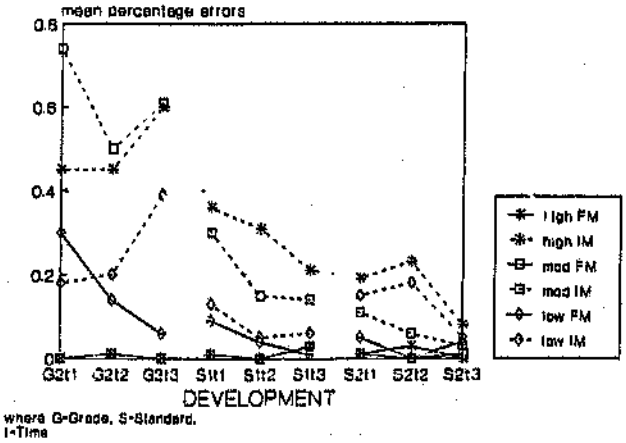


Figure 3.7: Performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Mapping Frequency, coded to show how Ambiguity effected responses at each level of Mapping Frequency.

Along the spectrum, the pattern of Ambiguity effect on spellings with infrequent-mappings was variable. Performance differed markedly at each Ambiguity level in Grade 2, Time 1, and more errors were made in the moderate than in both the high [$t(8424) = 5.18 p > .01$] and low categories [$t(8424) = 10.00, p > .01$], and in turn there were more errors in the high than in the low category [$t(8424) = 4.82, p > .01$]. However, this pattern of effect did not hold, and at the second and third intervals in Grade 2, and at the first interval in Standard 1, fewer errors occurred in the low than in both the high and moderate categories [Grade 2, Time 2: $t(8424) = 4.46, p > .01$ and $t(8424) = 5.36, p > .01$, respectively; Grade 2, Time 3: $t(8424) = 3.75, p > .01$ and $t(8424) = 3.93, p > .01$, respectively; Standard 1, Time 1: $t(8424) = 4.11, p > .01$ and $t(8424) = 3.04, p > .01$]. The pattern differed again at the second interval in Standard 1, where more errors were made in the high than in both the moderate [$t(8424) = 2.86 p > .01$] and the low categories [$t(8424) = 4.64, p > .01$], but there was no difference between the errors made in the moderate and low categories. The only significant difference in performance (in terms of Ambiguity) at the third interval in Standard 1 was between the high and low ambiguity categories, with more errors made in the high than the low category [$t(8424) = 2.68, p > .01$]. At the second interval in Standard 2, fewer errors

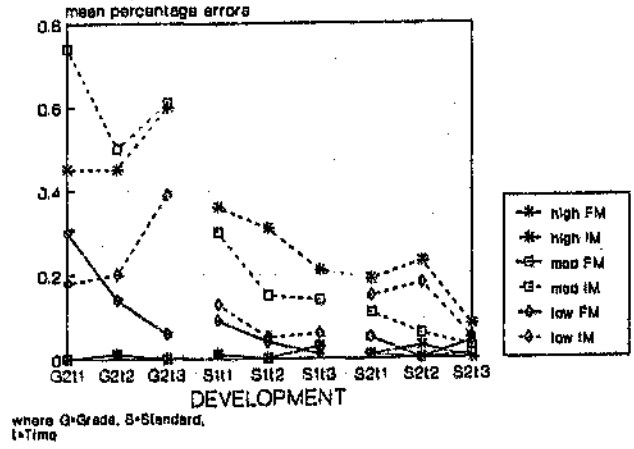


Figure 3.8: Performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Mapping Frequency, coded to show how Mapping Frequency effected responses at each level of Ambiguity.

were made in the moderate than in both the high [$t(8424) = 3.04, p > .01$] and low categories [$t(8424) = 2.14, p > .05$]. There was no effect of Ambiguity at the first and third intervals in Standard 2.

For spellings with frequent-mappings, the performance profiles were flat along the spectrum at both the moderate- and high-ambiguity levels, and except for the response pattern in the first two intervals in Grade 2, there was no Ambiguity effect. The pattern of the effect in Grade 2 was consistent, with more errors occurring in the low than in both the high and moderate categories [Grade 2, Time 1: $t(8424) = 5.36, p > .01$ for both comparisons; Grade 2, Time 2: $t(8424) = 2.32, p > .05$ for both comparisons].

The curves in Figure 3.8 are coded to enhance how Mapping Frequency effected responses at each level of Ambiguity. Analysis along the spectrum shows a consistent pattern of effect at the high- and moderate-ambiguity levels, where most errors were made on spellings with infrequent-mappings. This effect was time-dependent, being marked in Grade 2, [for example, at the third interval, $t(8424) = 10.71, p > .01$ and $t(8424) = 10.89, p > .01$ for high- and moderate-ambiguities respectively], and absent in Standard 2, (at the first time-interval for the moderate level and at the third time-interval for the high level), with a gradual decline

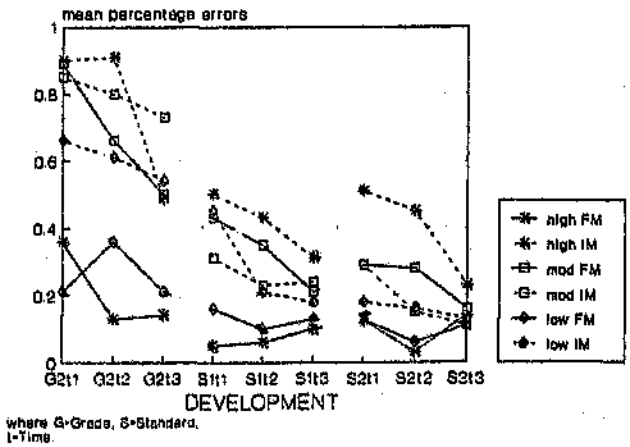


Figure 3.9: Performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Mapping Frequency, coded to show how Mapping Frequency effected responses at each level of Ambiguity.

in strength inbetween [for example, at Standard 1, Time 2, $t(8424) = 5.54, p > .01$ and $t(8424) = 2.68, p > .01$ for high- and moderate-ambiguities respectively].

The pattern of response to Mapping Frequency in the low-ambiguity category was variable, and the profiles do not show the characteristic time-dependency behaviour. There were only three instances where Mapping Frequency had an effect on responses. There was a negative effect at the first interval in Grade 2, with more errors occurring on spellings with frequent-mappings [$t(8424) = 2.14, p > .05$]. At both the third interval in Grade 2, and the second in Standard 2, few errors occurred on spellings with frequent-mappings, while significantly more errors were made on spellings with infrequent-mappings [$t(8424) = 5.89, p > .01$ and $t(8424) = 3.21, p > .01$ respectively].

Vowels

The curves in Figure 3.9 show the performance on vowels along the Development spectrum, in terms of Ambiguity and Mapping Frequency. They are coded to facilitate analysis of how Mapping Frequency effected responses at each level of Ambiguity. Analysis of the profiles shows a consistent pattern of effect in the high- and low-ambiguity categories. Most errors

occurred on spellings with infrequent-mappings, and the effect was time-dependent, with progressive weakening of the effect along the spectrum from being marked at the beginning of Grade 2, [for example, at the second interval: high, $t(8424) = 13.93, p > .01$; low, $t(8424) = 4.46, p > .01$], to absent in the high-ambiguity category at the third interval of Standard 2, and in the low-ambiguity at the third interval of Standard 1.

The pattern of response to Mapping Frequency in the moderate-ambiguity level contrasted sharply. As shown by the common grouping of the profiles in Figure 3.9, performance on both levels was characteristically time-dependent, and unlike in the other two categories, the performance on spellings with frequent-mappings differed little in Grade 2 and Standard 1 from that on infrequent-mappings. The nature of the effect was erratic along the entire spectrum, both in it's presence and it's direction. In Grade 2, Times 2 and 3, there were more errors on spellings with infrequent- than with frequent-mappings [$t(8424) = 2.5, p > .05$ and $t(8424) = 4.11, p > .01$ respectively]. The direction of the effect on responses changed in Standard 1, Times 1 and 2, where more errors were made on spellings with frequent- than with infrequent-mappings [$t(8424) = 2.14, p > .05$ for both comparisons]. A similar negative effect was present in the responses of Standard 2, Time 2 [$t(8424) = 2.32, p > .05$].

The curves in Figure 3.10 are coded to enhance the different patterns of response to spellings with frequent- and infrequent-mappings at each level of Ambiguity. While the profiles for spellings with infrequent-mappings were grouped together along the spectrum and followed the same general trend, with more errors made by the Grade 2's than by the Standards, they differed in detail at each Ambiguity level. In the low-ambiguity category, there was a significant drop in errors at the second interval of Standard 1 [$t(8424) = 4.29, p > .01$]. The profile pattern for the moderate-ambiguity category was similar. However, the sharp drop in errors occurred earlier, at the first interval in Standard 1, and was more considerable [$t(8424) = 7.5, p > .01$]. In addition, a second drop-off in the number of errors occurred at Standard 2, Time 2 [$t(8424) = 2.5, p > .05$]. In the high-ambiguity category, the characteristic drop-off in errors occurred at the third interval of Grade 2 [$t(8424) = 7.5, p > .01$], this being earlier than that in the other two Ambiguity categories. The character of the high-ambiguity profile differed from the other two, with an increase in errors at the first interval in Standard 2 [$t(8424) = 3.57, p > .01$], so that the same amount of errors were made

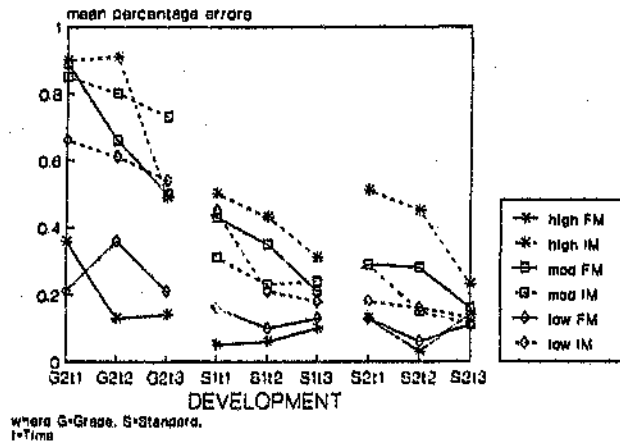


Figure 3.10: Performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Mapping Frequency, coded to show how Ambiguity effected responses at each level of Mapping Frequency.

as by the Standard 1's, Time 1. However, as in the moderate-ambiguity, a second significant decrease occurred, in this instance at the third interval of Standard 2 [$t(8424) = 3.93, p > .01$].

Along the spectrum, the pattern of Ambiguity effect on spellings with infrequent-mappings was variable. In Grade 2, Time 1, less errors were made in the low category than in both the high [$t(8424) = 4.29p > .01$] and the moderate categories [$t(8424) = 3.39, p > .01$]. At the second interval in Grade 2, while fewer errors occurred in the low than i a the high and moderate categories [$t(8424) = 5.56, p > .01$ and $t(8424) = 3.39, p > .01$, respectively], most errors occurred in the high category [$t(8424) = 1.96, p > .05$]. The pattern differed again at the third interval in Grade 2. More errors were made in the moderate than in both the high [$t(8424) = 4.29p > .01$] and low categories [$t(8424) = 3.39, p > .01$]. In contrast, at the first interval in Standard 1, fewer errors were made in the moderate than in both the high [$t(8424) = 3.39, p > .01$] and low categories [$t(8424) = 2.5, p > .05$]. In the response pattern at the second intervals of both Standard 1 and Standard 2, more errors occurred in the high than in both the moderate and low categories [Standard 1: [$t(8424) = 3.57, p > .01$ and $t(8424) = 3.93, p > .01$ respectively; Standard 2: $t(8424) = 5.36, p > .01$ and $t(8424) = 5.18, p > .01$ respectively]. The onl, significant difference in performance (in terms of Am-

biguity) at the third interval in Standard 1 was between the high and low categories, with more errors made in the high than the low category [$t(8424) = 2.32, p > .05$]. A similar pattern occurred at the third interval in Standard 2, where there was a difference between the number of errors in the high and moderate categories [$t(8424) = 2.14, p > .05$], with more errors occurring in the high than the moderate category. At the first interval in Standard 2, fewer errors were made in the low than in both the high [$t(8424) = 5.89, p > .01$] and moderate categories [$t(8424) = 1.96, p > .05$], and more errors occured in the high than the moderate category [$t(8424) = 3.93, p > .01$].

The performance profiles for spellings with frequent-mappings differed at each ambiguity level, too. While the profiles were low and relatively flat in both the high- and low-ambiguity categories, there were several distinguishing features. In the low-ambiguity category there was an anomalous peak in the Grade 2 error responses at the second interval. In the high-ambiguity category, more errors occurred at Grade 2, Time 1 than anywhere else along the spectrum, which was similar to the overall trend in performance on spellings with infrequent-mappings. Similarly, there was the characteristic drop-off in errors, where half as many errors occurred at the second compared to the first interval, Grade 2. This occasioned earlier in the spectrum compared to the other instances, however. The profile for moderate-ambiguity was similar in character to those for spellings on infrequent-mappings, with the difference being there was a significant gradient along most of the curve instead of the characteristic single or dual drop-off in errors.

Along the spectrum, the pattern of Ambiguity effect on spelling with frequent-mappings was consistent, with most errors made in the moderate category. This effect was time-dependent, being marked in Grade 2, [for example, at the first interval, $t(8424) = 9.46, p > .01$ and $t(8424) = 12.14, p > .01$ for high and low categories respectively], and absent at the third interval in Standard 2, with a gradual decrease in strength inbetween [for example, $t(8424) = 5.18, p > .01$ and $t(8424) = 4.46, p > .01$ for high and low categories respectively, at the second interval, Standard 1]. There were three instances where the response to low and high categories also differed: at the first two intervals of Grade 2, and the first interval in Standard 1. The expected pattern occurred in the first instance, with more errors in the high than low category [$t(8424) = 2.68, p > .01$]. In the other two instances, the effect was

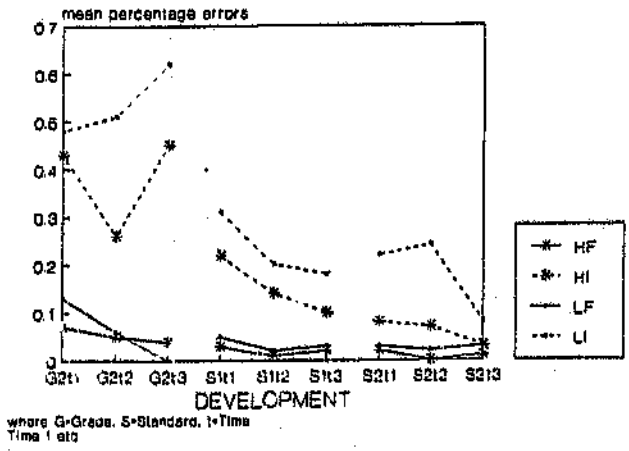


Figure 3.11: The performance profiles along the Development spectrum for consonants, in terms of Frequency.

in a negative direction [$t(8424) = 4.11, p > .01$ and $t(8424) = 1.96, p > .05$, respectively].

3.1.3 Development, Letter-Type, Word Frequency and Mapping Frequency Interaction

Consonants

The curves in Figure 3.11 show the performance on consonants along the Development spectrum, in terms of Frequency. Analysis of the profiles show there was a consistent pattern of Mapping Frequency effect, where, in both high- and low-frequency words, most errors were made on spellings with infrequent-mappings, with the highest occurrence at the third interval in Grade 2. This effect was time-dependent, being marked in Grade 2, [Time 1: low, $t(8424) = 7.61, p > .01$ and high, $t(8424) = 8.04p > .01$; Time 2: low, $t(8424) = 9.18, p > .01$ and high, $t(8424) = 4.57p > .01$; Time 3: low, $t(8424) = 13.26, p > .01$ and high, $t(8424) = 8.91p > .01$], and absent by the third interval, Standard 2, in low-frequency words, and by the third interval, Standard 1, in high-frequency words. Performance on high-frequency words deviated from the general pattern with an anomalous low occurrence of errors on spellings with infrequent-mappings at the second interval in Grade 2 [Time 1 compared to Time 1, $t(8424) = 13.7, p > .01$; Time 2 compared to Time 3,

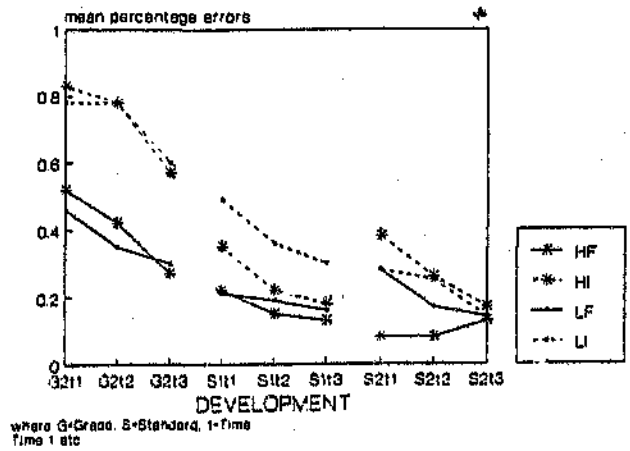


Figure 3.12: The performance profiles along the Development spectrum for vowels, in terms of Frequency.

$t(8424) = 4.13$ $p > .01$].

Analysis of the responses to low- and high-frequency words at each level of Mapping Frequency shows, in spellings with infrequent-mappings, there was a difference in performance between high- and low-frequency words at the second and third intervals in Grade 2 [$t(8424) = 5.44, p > .01$ and $t(8424) = 3.7p > .01$, respectively], and at the first and second intervals in Standard 2, [$t(8424) = 3.04, p > .01$ and $t(8424) = 3.7, p > .01$, respectively]. There was no Word Frequency effect on spellings with frequent-mappings.

Vowels

The curves in Figure 3.12 show the performance on vowels along the Development spectrum, in terms of Frequency. Analysis of the profiles show that up to Standard 1, Time 1, there was a constant Mapping Frequency effect, with more errors made on spellings with infrequent- than with frequent-mappings, for both low- [$t(8424) = 6.96, p > .01$; $t(8424) = 9.35, p > .01$; $t(8424) = 6.52, p > .01$; $t(8424) = 6.09, p > .01$; for Grade 2, Times 1, 2, and 3, and Standard 1, Time 1 respectively] and high-frequency words [$t(8424) = 6.74, p > .01$; $t(8424) = 7.83, p > .01$; $t(8424) = 6.52, p > .01$; $t(8424) = 3.04, p > .01$; for Grade 2,

Times 1, 2, and 3, and Standard 1, Time 1 respectively]. Also, at each level of Mapping Frequency there was no difference in performance in terms of Word Frequency. This pattern changed in Standard 1 at the latter two intervals, where Mapping Frequency had an effect on low-frequency words only, so that most errors were made on low-frequency words with infrequent-mappings [$t(8424) = 3.7, p > .01$ and $t(8424) = 3.0, p > .01$, for Times 2 and 3 respectively].

In Standard 2, the pattern of performance was different again. At the first interval there was a Mapping Frequency effect on high-frequency words only [$t(8424) = 6.52, p > .01$], such that most errors were made on high-frequency words with infrequent-mappings [high-infrequent compared to: high-frequent, $t(8424) = 6.52, p > .01$; low-frequent and low-infrequent, $t(8424) = 2.17, p > .05$ for both], least were made on high-frequency words with frequent-mappings and an equal amount were made intermediately on low-frequency words with frequent-and infrequent-mappings [low-frequent and low-infrequent compared to high-frequent, $t(8424) = 4.35, p > .01$ for both]. In addition, there was also a Word Frequency effect at both levels of Mapping Frequency. With frequent-mappings, more errors were made on low-than on high-frequency words [$t(8424) = 4.35, p > .01$]. However, with infrequent-mappings the effect was in a negative direction, and more errors occurred on high- than on low-frequency words [$t(8424) = 2.17, p > .05$]. The pattern of performance at the second interval was similar, but the Word Frequency effect was on spellings with frequent-mappings only [$t(8424) = 3.91, p > .05$], so that least errors were made on high-frequency words with frequent-mappings, and there was no difference in performance on the other levels of Frequency [high-frequent compared to: high-infrequent, $t(8424) = 3.91, p > .01$; low-frequent, $t(8424) = 1.96, p > .05$; low-infrequent, $t(8424) = 3.7, p > .01$]. At the third interval there was neither a Mapping Frequency nor a Word Frequency effect, the number of errors made at each Frequency level being similar.

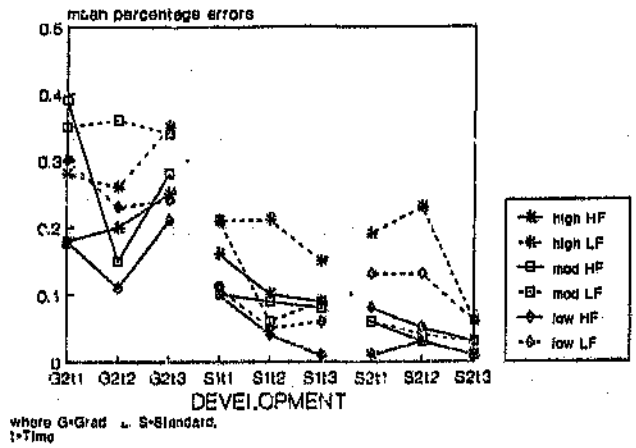


Figure 3.13: The performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Word Frequency, coded to show how Word Frequency effected responses at each level of Ambiguity.

3.1.4 Development, Letter-Type, Ambiguity and Word Frequency Interaction

Consonants

The curves in Figure 3.13 show the performance on consonants along the Development spectrum, in terms of Ambiguity and Word Frequency. The profiles show the separate performances on high- and low-frequency words at each level of Ambiguity. The close grouping of the profiles shows there was a relatively even distribution of error responses over the category levels. The apparent flatness of the profiles indicates the response pattern was not time-dependent.

The curves in Figure 3.13 are coded to facilitate analysis of how Word Frequency effected responses at each level of Ambiguity. The effect of Word Frequency within each of the Ambiguity levels was sporadic along the spectrum. It was evident in performance on high-ambiguity words by children in Standard 1, Time 2, and in Standard 2, Times 1 and 2 [$t(8424) = 1.96, p > .05$; $t(8424) = 3.21, p > .01$; $t(8424) = 3.57, p > .01$; respectively], with more errors occurring on low- than on high- frequency words. In the moderate-ambiguity

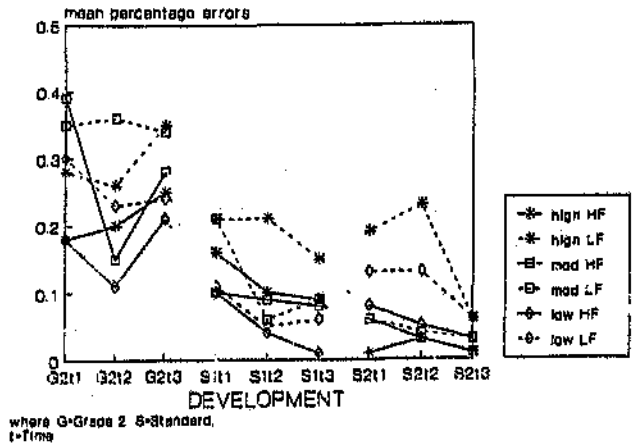


Figure 3.14: The performance profiles along the Development spectrum for consonants, in terms of Ambiguity and Word Frequency, coded to show how Ambiguity effected responses at each level of Word Frequency.

category, a similar Word Frequency effect occurred in Grade 2, Time 2, [$t(8424) = 3.75, p > .01$] and in Standard 1, Time 1 [$t(8424) = 1.96, p > .05$]. Similarly, in the low-ambiguity category, there was an effect at the first two intervals in Grade 2 [$t(8424) = 2.14, p > .05$ in both instances]. A notable feature of the results was the absence of Word Frequency effect at all levels of ambiguity at the third interval in each of the Grade/Standards.

Figure 3.14 is coded to enhance the different patterns of response in high- and low-frequency words to Ambiguity. Analysis of the effect of Ambiguity on low-frequency words showed performance differed in terms of Ambiguity level in four instances. In Grade 2 at the second interval, more errors were made on words in the moderate- than in the low-ambiguity category [$t(8424) = 2.32, p > .05$]. In Standard 1, at the second interval, more errors were made in the high- than in both the moderate- and low-ambiguity categories [$t(8424) = 2.68, p > .01$ and $t(8424) = 2.86, p > .01$ respectively]. In Standard 2, at both the first and second intervals, there were more errors in the high- than in the moderate-ambiguity category [$t(8424) = 2.32, p > .05$ and $t(8424) = 3.39, p > .01$ respectively].

Within high-frequency words, the only instance in which there was a difference in performance in terms of Ambiguity was at the first interval in Grade 2, where more errors occurred

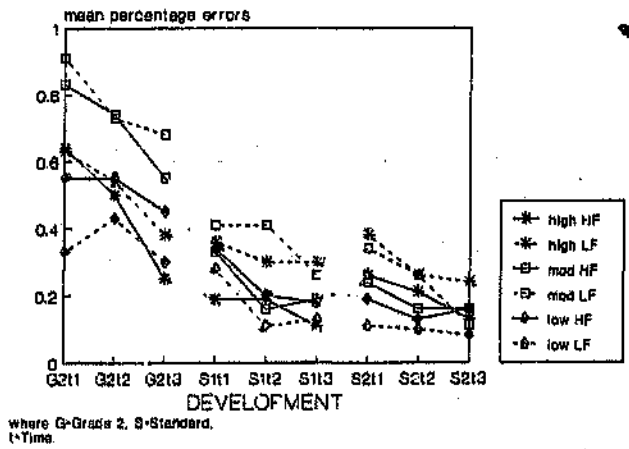


Figure 3.15: The performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Word Frequency, coded to show how Word Frequency effected responses at each level of Ambiguity.

in the moderate-ambiguity category than in the other two [$t(8424) = 3.57, p > .01$ for both].

Vowels

The curves in Figure 3.15 show the performance on vowels along the Development spectrum, in terms of Ambiguity and Word Frequency. The profiles are coded to facilitate analysis of how Word Frequency effected responses at each level of Ambiguity. Results show an effect was prevalent in the high-ambiguity category, with more errors occurring on low- than on high-frequency words. It was evident in the performance of children at each time-interval from the third in Grade 2, through to and including the first in Standard 2, and again at the third in Standard 2 [$t(8424) = 2.32, p > .05$; $t(8424) = 3.04, p > .01$; $t(8424) = 1.96, p > .05$; $t(8424) = 2.5, p > .05$; $t(8424) = 2.14, p > .05$; $t(8424) = 1.96, p > .05$ respectively]. In the moderate-ambiguity category, a similar Word Frequency effect occurred in Grade 2, Time 3, [$t(8424) = 2.32, p > .05$] and in Standard 1, Time 2 [$t(8424) = 4.46, p > .05$]. In the low-ambiguity category, there was an effect at each interval in Grade 2 [$t(8424) = 3.93, p > .01$; $t(8424) = 2.14, p > .05$ and $t(8424) = 2.68, p > .01$ respectively]. However, this effect was in a negative direction, with more errors occurring on high- than on low-frequency words.

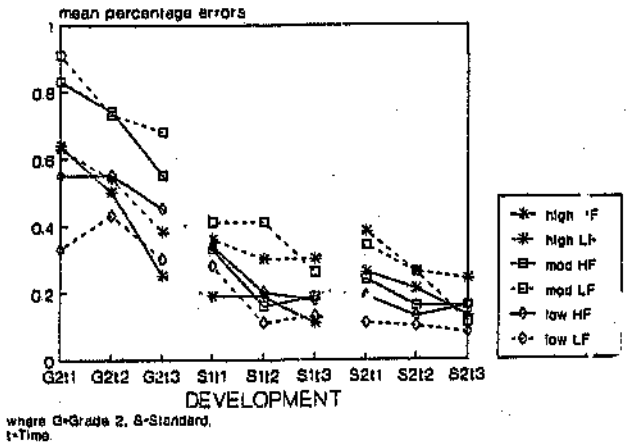


Figure 3.16: The performance profiles along the Development spectrum for vowels, in terms of Ambiguity and Word Frequency, coded to show how Ambiguity effected responses at each level of Word Frequency.

The curves in Figure 3.16 are coded to enhance the different patterns of response in words of low- and high-frequency to Ambiguity. Analysis of the effect of Ambiguity on low-frequency words showed performance differed in terms of Ambiguity level, particularly at the early part of the spectrum. At the first interval in Grade 2, more errors were made in the moderate-category than in both the high- [$t(8424) = 5.00p > .01$] and the low-ambiguity categories [$t(8424) = 10.36, p > .01$], and in turn there were more errors in the high- than in the low-ambiguity category [$t(8424) = 5.35, p > .01$]. There was a similar pattern of effect at the second interval [$t(8424) = 3.39, p > .01$; $t(8424) = 5.36, p > .01$; $t(8424) = 1.96p > .05$; respectively]. Similarly, at the third interval, more errors were made in the moderate-category than in both the high- [$t(8424) = 5.36p > .01$] and the low-ambiguity categories [$t(8424) = 6.79, p > .01$], but there was no difference between the errors made in the high- and low-ambiguity categories. In Standard 1, at the first time-interval, more errors were made in the moderate- than in the low-ambiguity category [$t(8424) = 2.32, p > .05$]. At the second interval, more errors occurred in the moderate than in both the high- [$t(8424) = 1.96p > .05$] and low-ambiguity categories [$t(8424) = 5.36, p > .01$], and in turn there were more errors in the high- than in the low-ambiguity category [$t(8424) = 3.39, p > .01$]. At the hird

interval in Standard 1 and in the first two intervals of Standard 2, the pattern was the same. Fewer errors occurred in the low than in both the high and moderate categories [Standard 1, Time 3: $t(8424) = 2.32, p > .05$ and $t(8424) = 3.04, p > .01$, respectively; Standard 2, Time 1: $t(8424) = 4.82, p > .01$ and $t(8424) = 4.11, p > .01$, respectively; Standard 2, Time 2: $t(8424) = 2.86, p > .01$ for both comparisons]. At the third interval in Standard 2, more errors occurred in the high than in both the moderate and low categories [$t(8424) = 2.32, p > .05$ and $t(8424) = 2.86, p > .01$ respectively].

Ambiguity had an effect on high-frequency words which was characteristically time-dependent, in that it was evident in the early part of the spectrum only. At the first and second interval in Grade 2, significantly more errors occurred in the moderate- than in both the high- and low-ambiguity categories [Grade 2, Time 1: $t(8424) = 3.39, p > .01$ and $t(8424) = 5.00, p > .01$ respectively; Grade 2, Time 2: $t(8424) = 4.29, p > .01$ and $t(8424) = 3.39, p > .01$ respectively]. At both the third interval in Grade 2 and the first interval in Standard 1, significantly fewer errors occurred in the high category than in both the moderate and low categories [Grade 2, Time 3: $t(8424) = 5.36, p > .01$ and $t(8424) = 3.57, p > .01$ respectively; Standard 1, Time 2: $t(8424) = 2.5, p > .05$ and $t(8424) = 2.68, p > .01$ respectively].

3.2 Qualitative Analyses

The quantitative analysis of children's spelling competence focused on gross features of performance, being concerned with the distribution of errors as a function of Development, Letter-Type, Ambiguity, Word Frequency and Mapping Frequency. Results will inform the extent to which these different factors influence spelling. A consideration of the *type* of spelling errors produced by the children will provide an additional data base for further speculation firstly, about the strategies children use, and secondly, about the nature of the phonographeme-to-letter conversion mechanism in terms of the relationship between phoneme and grapheme with respect to both mapping probability distributions and ambiguity. To this end all the spellings in which errors occurred on the target segment were analysed. Within the framework of the established categories, the error- types were classified, at both a macro and micro level, to serve each of the above-stated purposes, respectively.

The functional organisation of the spelling process is sufficiently explicit to specify the type of spelling errors that are expected to result as a consequence of the strategy used. Errors arising from assembled spelling will be either alphabetic (where sound-letter correspondences are used) or phonologically plausible (where phoneme-grapheme correspondences are used), while those arising from accessed spelling will be visual. A critical specification concerns the type of errors that are expected to result as a consequence of perturbations in the Graphemic Buffer, since these are performance errors that mask the aspects of competence that are at issue. These are errors of substitution and deletion of letters (associated with long words), and of insertion and transposition of letters (associated with short words).

3.2.1 Macro Level Error Analysis

The core system of classification categorised errors according to levels of written language: alphabetic (sound-to-letter spelling), phonological (phonologically plausible), and lexical (visual). Three other categories were added for the classification of anomalies: perturbation (performance error which does not reflect lack of knowledge of the spelling, but reflects factors such as *neglect* arising in the graphemic buffer or other attentional deficits due to tiredness, nervousness, or emotion), idiosyncratic (where the grapheme used is not associated with the target phoneme, or is a bizarre invention) and misinformation (incorrect phonological input analysis). Examples of each of these types of errors are shown in Table 3.6. Note it is not always clear how to categorise a spelling, and the procedure is inherently subjective. For example, *chgik* as chark can be classified as visual, idiosyncratic or perturbation. (In the context of other errors, I have opted for idiosyncratic in this instance.)

The distribution of errors across these classes is shown in Tables 3.7 and 3.8, for consonants and vowels respectively. As can be readily seen, the errors on consonants were predominantly phonological, and only a small proportion could be classified as lexical. Interestingly, the incidence of the latter was limited to the low and moderate ambiguity categories of high-frequency words with infrequent-mappings. Two other aspects of the data on consonants are worth noting. Firstly, the coincidence of alphabetic and perturbation errors occurring in the low-ambiguity category only, with exception of an additional occurrence of perturbation errors in high- and low- frequency words with infrequent-mapping in the high-ambiguity

ERROR-TYPE	EXAMPLES FROM CORPUS	
Alphabetic	cube->cyoob	tail->tael
	sell->sela	yell->yi
	hail->haoll	cube->cuoowb
Phonological	stick->stik	space->spas
	grace->grass	talk->tork
	sell->sel	cree ->groow
Lexical	sell->sak	chalk->chalk
	draws->drews	grew->grow
Perturbation		
transpositions	voice->vioce	bear->bera
insertions	mouse->mouese	talk->talek
deletions	house->huse	clown->clon
substitutions	dress->drees	cause->couse
Idiosyncratic	voice->vose	yell->yalew
	kiss->kixe	chalk->chark
	grew->grawe	cloud->cloild
Misinformation	lords->laws	tube->choob
	chew->true	chew->tuoo
	bites->bides	cause->calls

Table 3.6: Examples of the various error-types.

CATEGORY LEVELS			NO.	ERROR-TYPE (in percentages)					
FREQ	AMB	STD		ALPHA	PHONO	LEXI	PERT	IDIO	MISIN
HF	Low	Gr. 2	17	6	88	0	6	0	0
		Std 1	4	0	100	0	0	0	0
		Std 2	2	0	100	0	0	0	0
	Moderate	Gr. 2	0	0	0	0	0	0	0
		Std 1	1	0	100	0	0	0	0
		Std 2	0	0	0	0	0	0	0
	High	Gr. 2	0	0	0	0	0	0	0
		Std 1	1	0	100	0	0	0	0
		Std 2	0	0	0	0	0	0	0
LF	Low	Gr. 2	19	21	68	0	11	0	0
		Std 1	8	25	50	0	25	0	0
		Std 2	4	0	25	0	50	25	0
	Moderate	Gr. 2	2	0	50	0	0	0	50
		Std 1	1	0	100	0	0	0	100
		Std 2	1	0	0	0	0	0	100
	High	Gr. 2	1	0	100	0	0	0	0
		Std 1	0	0	0	0	0	0	0
		Std 2	0	0	0	0	0	0	0
HI	Low	Gr. 2	21	10	76	0	14	0	0
		Std 1	11	18	73	0	9	0	0
		Std 2	11	9	82	0	9	0	0
	Moderate	Gr. 2	60	0	97	3	0	0	0
		Std 1	23	0	96	4	0	0	0
		Std 2	6	0	83	17	0	0	0
	High	Gr. 2	50	0	100	0	0	0	0
		Std 1	28	0	93	0	7	0	0
		Std 2	4	0	100	0	0	0	0
LI	Low	Gr. 2	40	5	93	0	2	0	0
		Std 1	13	8	92	0	0	0	0
		Std 2	20	10	70	0	10	10	0
	Moderate	Gr. 2	83	0	99	0	0	1	0
		Std 1	26	0	100	0	0	0	0
		Std 2	8	0	100	0	0	0	0
	High	Gr. 2	69	0	100	0	0	0	0
		Std 1	45	0	98	0	2	0	0
		Std 2	36	0	97	0	3	0	0

Table 3.7: Macro Level Error Analysis of Consonants. (FREQ = Word/Mapping Frequency, AMB = Ambiguity, STD = Grade/Standard, ALPHA = Alphabetic, PHONO = Phonological, LEXI = Lexical, PERT = Perturbation, IDIO = Idiosyncratic, MISIN = Misinformation)

CATEGORY LEVELS			NO.	ERROR-TYPE (in percentages)					
FREQ	AMB	STD		ALPHA	PHONO	LEXI	PERT	IDIO	MISIN
HF	Low	Gr. 2	46	2	57	0	15	26	0
		Std 1	27	0	85	0	7	7	0
		Std 2	19	0	79	0	16	5	0
	Moderate	Gr. 2	72	13	30	0	9	46	3
		Std 1	31	7	24	0	7	57	7
		Std 2	12	0	33	0	17	50	0
	High	Gr. 2	21	0	86	0	5	5	5
		Std 1	1	0	100	0	0	0	0
		Std 2	1	0	0	0	100	0	0
LF	Low	Gr. 2	17	6	11	0	42	35	6
		Std 1	3	0	100	0	0	0	0
		Std 2	3	0	66	0	0	34	0
	Moderate	Gr. 2	91	14	34	0	14	36	1
		Std 1	47	11	49	0	6	32	2
		Std 2	43	16	42	0	2	40	0
	High	Gr. 2	26	0	85	0	0	15	0
		Std 1	15	0	67	0	0	33	0
		Std 2	23	0	87	0	0	13	0
HI	Low	Gr. 2	85	8	30	0	25	31	6
		Std 1	30	0	30	0	24	46	0
		Std 2	18	0	28	0	33	33	6
	Moderate	Gr. 2	94	0	63	0	10	18	9
		Std 1	22	0	59	0	18	18	5
		Std 2	31	0	23	0	32	35	10
	High	Gr. 2	92	2	87	5	1	3	1
		Std 1	37	3	70	14	5	8	0
		Std 2	46	0	67	28	2	2	0
LI	Low	Gr. 2	70	3	65	0	11	19	1
		Std 1	33	3	83	0	14	3	0
		Std 2	18	0	78	0	12	10	0
	Moderate	Gr. 2	95	0	77	3	14	6	0
		Std 1	40	0	60	13	28	9	0
		Std 2	12	0	50	29	7	14	0
	High	Gr. 2	97	8	81	0	0	9	1
		Std 1	59	14	71	0	0	15	0
		Std 2	48	4	83	0	2	8	2

Table 3.8: Macro Level Error Analysis of Vowels. (FREQ = Word/Mapping Frequency, AMB = Ambiguity, STD = Grade/Standard, ALPHA = Alphabetic, PHONO = Phonological, LEXI = Lexical, PERT = Perturbation, IDIO = Idiosyncratic, MISIN = Misinformation)

categories. Secondly, the relative absence of idiosyncratic errors. This contrasts with the distribution of errors in vowels, where idiosyncratic (and perturbation) errors occurred in most categories.

Despite the greater distribution of errors across the classes for vowels, phonological errors were again prevalent. Exception to this pattern occurred with both high- and low-frequency words of frequent-mapping at the moderate level, where errors occurred in all classes but the lexical, and the proportion of idiosyncratic errors was equal to or greater than phonological errors. Another exception was Grade 2 errors on low-frequency words of frequent-mapping at the low ambiguity level, where most were evenly distributed between the perturbation and idiosyncratic classes. Further exception occurred with high-frequency words of infrequent mapping. At the low ambiguity level, and in Standard 2 at the moderate level, there was a relatively even spread of errors between the phonological, perturbation, and idiosyncratic classes. Lastly, the distribution pattern of Standards 1 and 2 at the moderate ambiguity level in the low-frequency, infrequent-mapping category was anomalous too. It differed in that only 50% of the errors were phonological, while the rest were spread between lexical, peturbation and idiosyncratic.

Two other aspects of the data on vowels are notable. Firstly, there were few lexical errors, and their incidence was limited to two categories: those of high- and low-frequency words with infrequent-mappings, at the high and moderate ambiguity levels, respectively. Secondly, with words of frequent-mapping there was a pattern of alphabetic errors occurring at both the low- and moderate-ambiguity categories, while with words of infrequent-mappings they occurred at the low- and high-ambiguity categories.

3.2.2 Micro Level of Error Analysis

Within the classification presented above, phonological errors were further distinguished into two different types: *regularisations*, where the grapheme used has a higher mapping probability than the target grapheme, and *replacements*, where the grapheme used has a lower mapping probability than the target grapheme. Perturbations were also distinguished into different types, as shown previously in Table 3.6: deletions, substitutions, insertions and transpositions.

The results of this analysis are shown in the form of pie charts in Figures 3.17 to 3.24. The diameters of the charts show the relative proportionality, and the contents of each are sorted in an anticlockwise direction, in order of diminishing proportions.

Frequent-mapping Consonants.

(Figures 3.17 and 3.18)

In both high-and low-frequency words, most errors occurred at the low ambiguity level, and involved replacements (for example, hole → holl, legs → leggs). Although there were few of them, it is interesting to note that perturbation errors were manifested as deletions (for example, *lords* → lors). This type of error is associated with long words and was not expected to occur. Two other observations are worthy of note. Firstly, there were no alphabetic errors in the Standard 2 error distribution. Secondly, misinformation errors occurred in low-but not in high- frequency words.

Infrequent-mapping Consonants.

(Figures 3.19 and 3.20)

As can be clearly seen, most errors were regularisations, and there was little difference in the distribution pattern between high-and low-frequency words. There were, however, subtle differences between the ambiguity levels in the nature of the few exceptions. Thus, 'phabetic errors occurred in the low ambiguity categories only, replacement errors in the moderate ambiguity category only, (*space* → spass and *grace* → grass) and insertion errors in the high ambiguity category only (*talk* → talek). One other interesting aspect of the data is the manifestation of perturbation in the form of substitutions. This error-type occurred mainly in high-frequency words, (there is one instance of it in low-frequency words), and consisted of an inaccuracy in representing the double consonant, for example, *dress* → drees and *eggs* → eegs. These are interesting, because substitution errors, like deletions, are not expected to occur on short words.

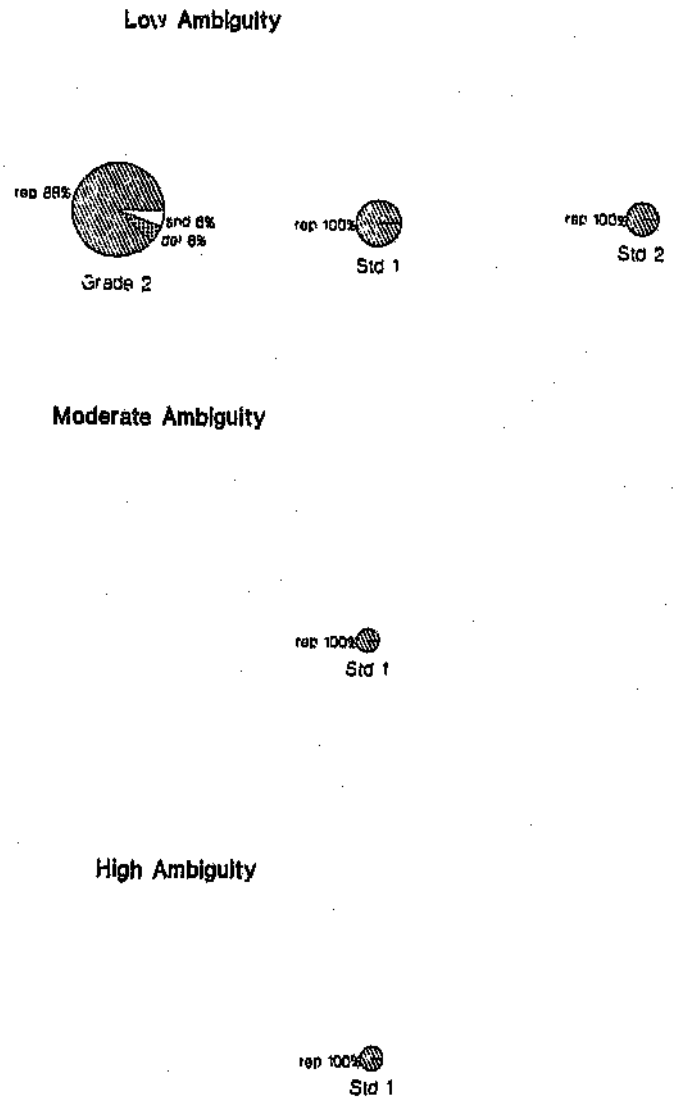


Figure 3.17: Micro level error analysis of phonemes with frequent-mapping consonants in high-frequency words. (rep = replacement, del = deletion, snd = alphabetic)

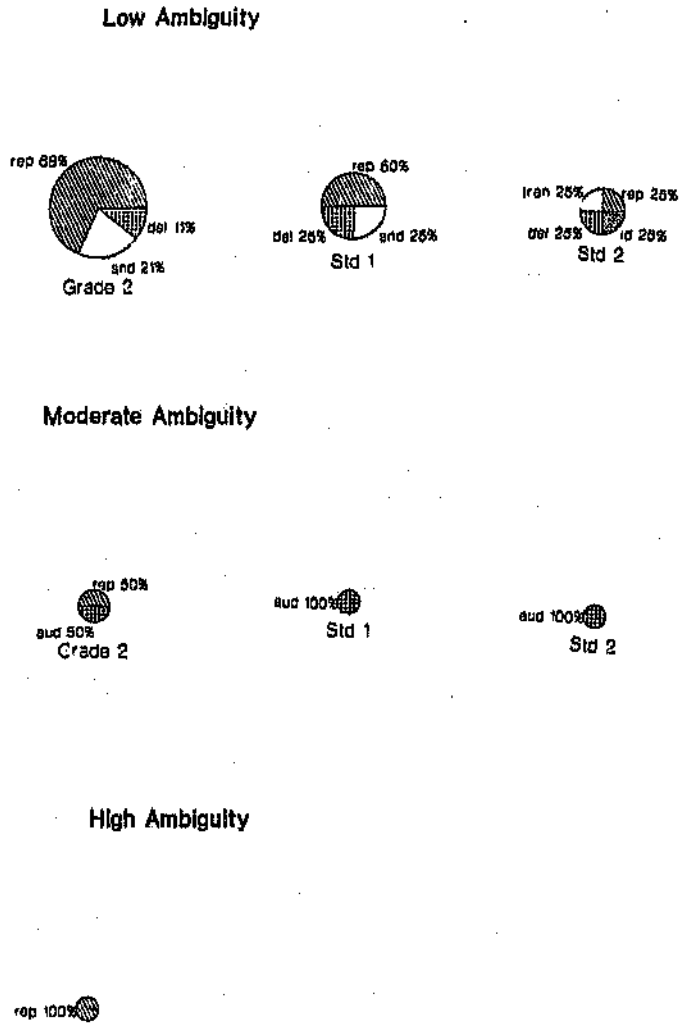


Figure 3.18: Micro level error analysis of phonemes with frequent- mapping consonants in low-frequency words. (rep = replacement, snd = alphabetic, del = deletion, tran = transposition, id = idiosyncratic, aud = auditory)

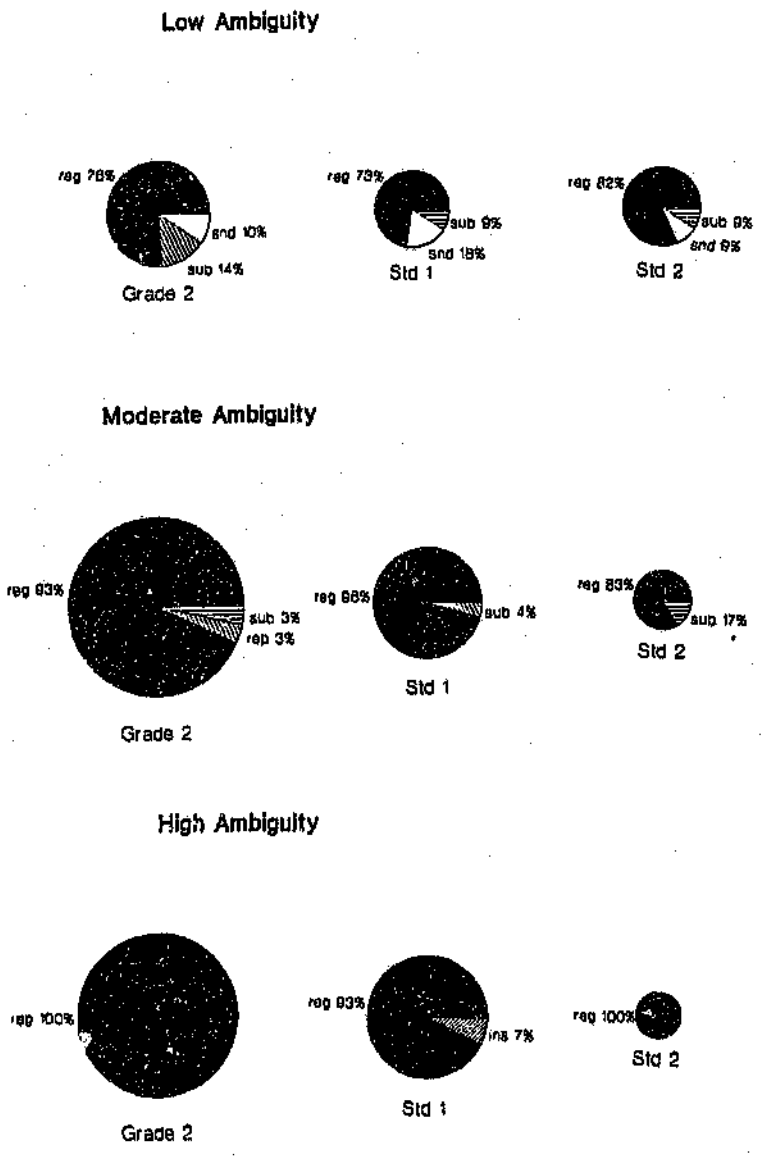


Figure 3.19: Micro level error analysis of phonemes with infrequent-mapping consonants in high-frequency words. (reg = regularisation, rep = replacement, snd = alphabetic, sub = substitution, ins = insertion)

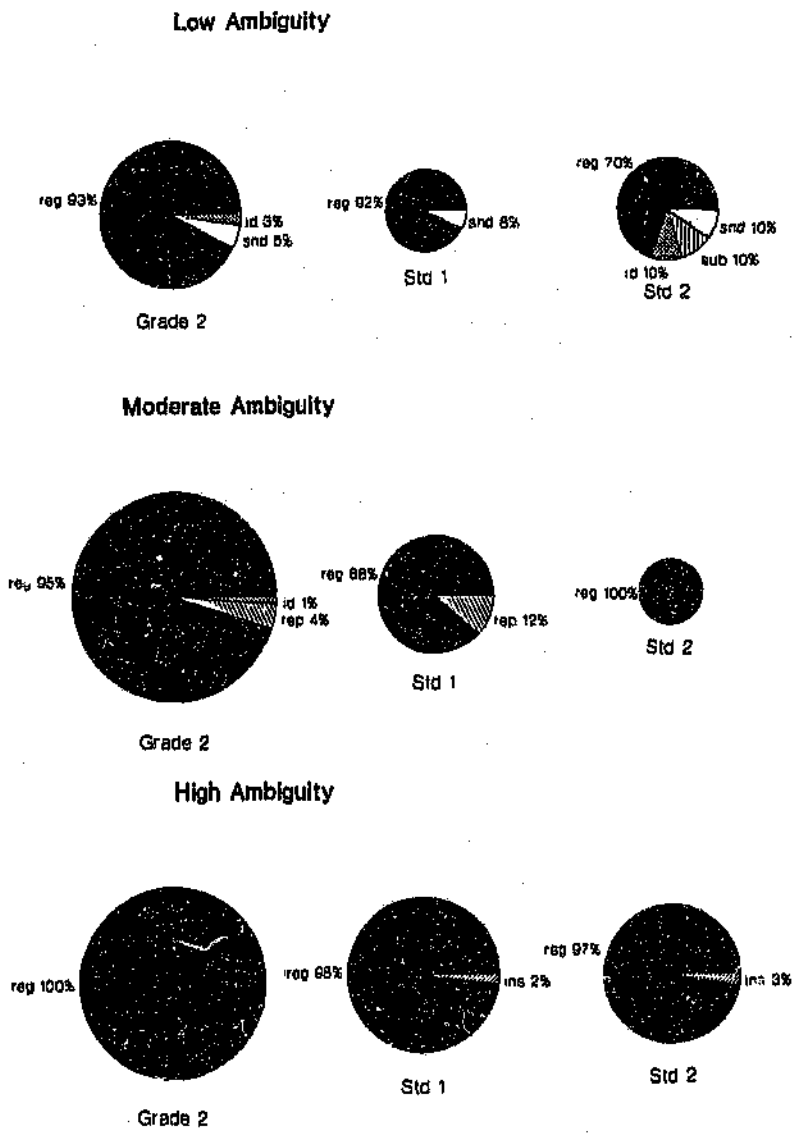


Figure 3.20: Micro level error analysis of phonemes with infrequent-mapping consonants in low-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory,)

Frequent-mapping Vowels.

(Figures 3.21 and 3.22)

The pattern of error distribution for these vowels was not dominated by replacement errors in the same way as with consonants, and except for the high ambiguity categories, there was little similarity between that of high- and low-frequency words, that is, there is a qualitative difference. Also, there is a qualitative difference between the ambiguity levels.

With high-frequency words, phonological errors were manifested as both regularisations (*talk* → tork and *tube* → tub) and replacements (*talk* → took and *tube* → tewb). There were exceptions, and they related to Standards 1 and 2: at the low ambiguity level, phonological errors were replacements only, and at the high ambiguity level, the single Standard 1 error was a replacement (*moon* → mone). Idiosyncratic errors, such as *tube* → choob, occurred at every Standard level, (except where only one error occurred), and they were particularly prevalent at the moderate ambiguity level. Indeed, it is notable that, with regard to phonological and idiosyncratic errors, the distribution pattern of Standard 1 and 2 at this level differed little from that of Grade 2, unlike at the other two ambiguity levels. A small number of alphabitic errors were also evident, and are most noticeable with Grade 2 at the moderate ambiguity level. The occurrence of perturbations are interesting both in the nature of their manifestation and in their distribution. There was a difference between ambiguity level in the type of perturbation. Deletions occurred at the low level only (*cloud* → clod or clud), and transpostions occurred at the moderate level (*tube* → tueb or teub) and also at the high level in Grade 2 (*gave* → gaev). Several insertion errors were also made by Grade 2 at the moderate level (*tube* → toube).

With low-frequency words, phonological errors were also manifested as both regularisations (*clown* → cloun and *chalk* → chork) and replacements (*chalk* → chook and *cube* → queb), although with exception. Standard 1 phonological errors at the high ambiguity level were replacements only, (*fade* → faid), while at the low ambiguity level they were regularisations only (*clown* → cloun). Also at the low ambiguity level, Grade 2 made replacement errors only, and these were limited to just several errors on one word, namely *flap* → flape.

The distribution pattern for errors by Grade 2 at this low ambiguity level is exceptional

in other ways too, and overall, is unlike any other pattern. Idiosyncratic (*clown* → clone) and perturbation errors predominated, the latter taking the form of insertions (*clown* → clouwn) as well as deletions (*clown* → clon).

The pattern at the moderate ambiguity level was similar to that of high-frequency words, in that idiosyncratic errors were prevalent, such as *chalk* → choack or chark, and *cube* → coob or cynob. Also, a notable number of alphabetic errors were evident in this ambiguity level, but while this could be said only of the Grade 2 distribution in high- frequency words, with low-frequency words this was true of all three levels of Standard.

Perturbations, in the form of insertions and deletions, were also evident at the moderate level, though to a considerably lesser degree than those by Grade 2 in the low ambiguity level. There was a difference compared to those in the moderate level of high-frequency words, where transpositions occurred instead of deletions. There were no perturbations at the high ambiguity level.

Infrequent-mapping Vowels.

(Figures 3.23 and 3.24)

As with frequent mapping vowels, there was little similarity in the distribution pattern between high- and low-frequency words (except for the phonological error pattern in the high ambiguity categories), and between the ambiguity levels. Also, there was a more variable pattern between Standards.

With high-frequency words, phonological errors were manifested as both regularisations (*voice* → voys and *grew* → groow) and replacements (*voice* → voyse and *grew* → grou), with exception of Standard 2 at both the low and moderate ambiguity levels, where they were regularisations only. Indeed, the presence of regularisations and the within-ambiguity distribution of them, is the most consistent aspect of the overall distribution pattern. However, it must be noted that unlike the general trend, many incidents of regularisation did not use the most frequent mapping, i.e. *voys, hale* and *tale* are all second-most frequent.

Idiosyncratic errors, such as *voice* → vos or voos, were prevalent at every Standard level of both low and moderate ambiguity levels. They also occurred, in smaller proportion, at the high ambiguity level. Perturbations, too, were prevalent and the diversity of their mani-

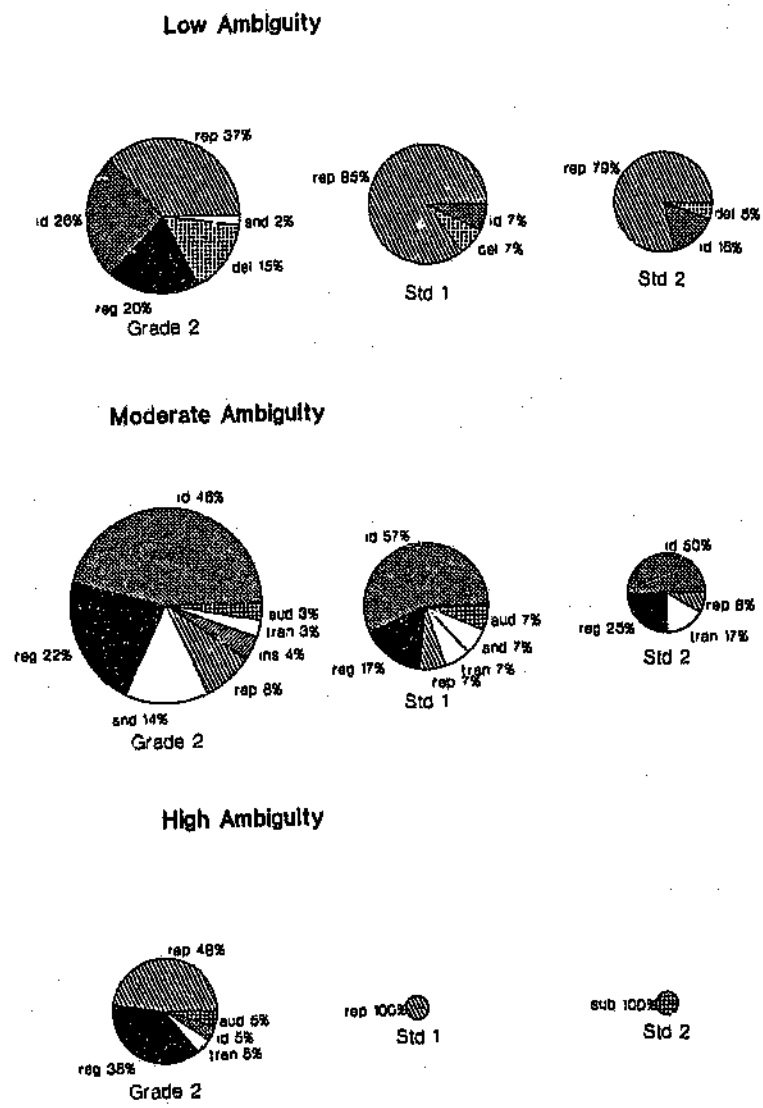


Figure 3.21: Micro level error analysis of phonemes with frequent-mapping vowels in high-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, and = alphabetic, aud = auditory.)

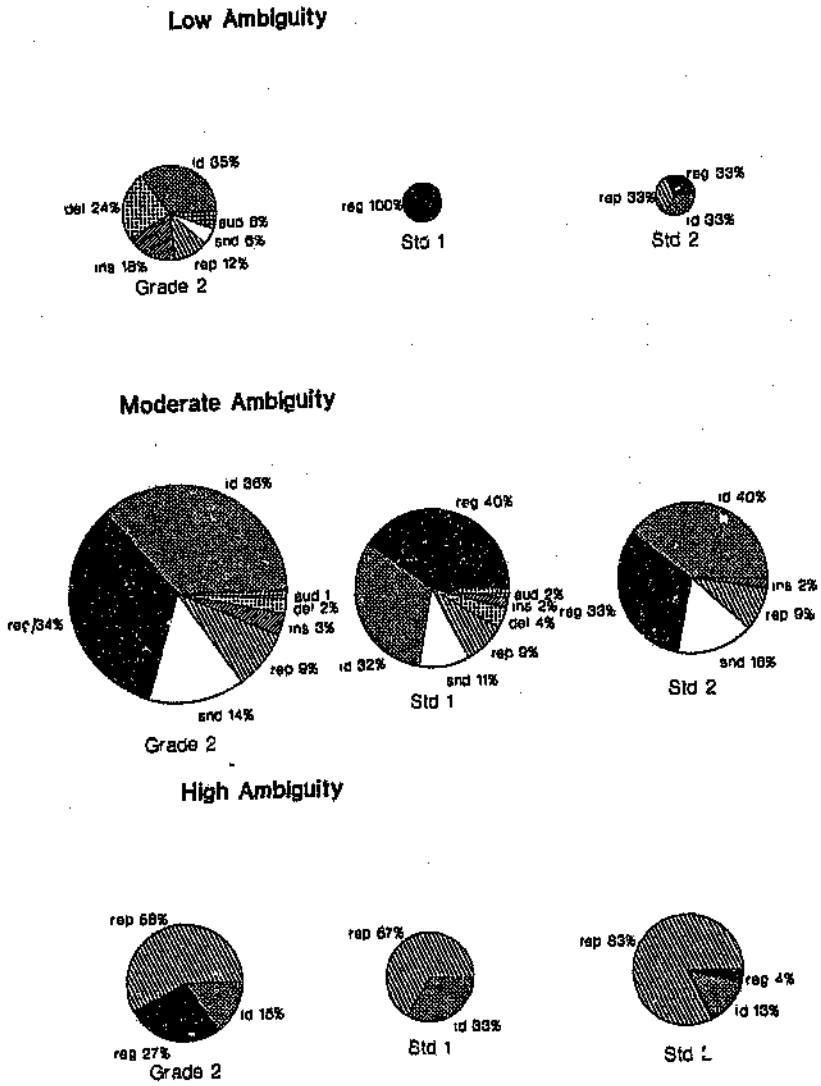


Figure 3.22: Micro level error analysis of phonemes with frequent-mapping vowels in low-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory.)

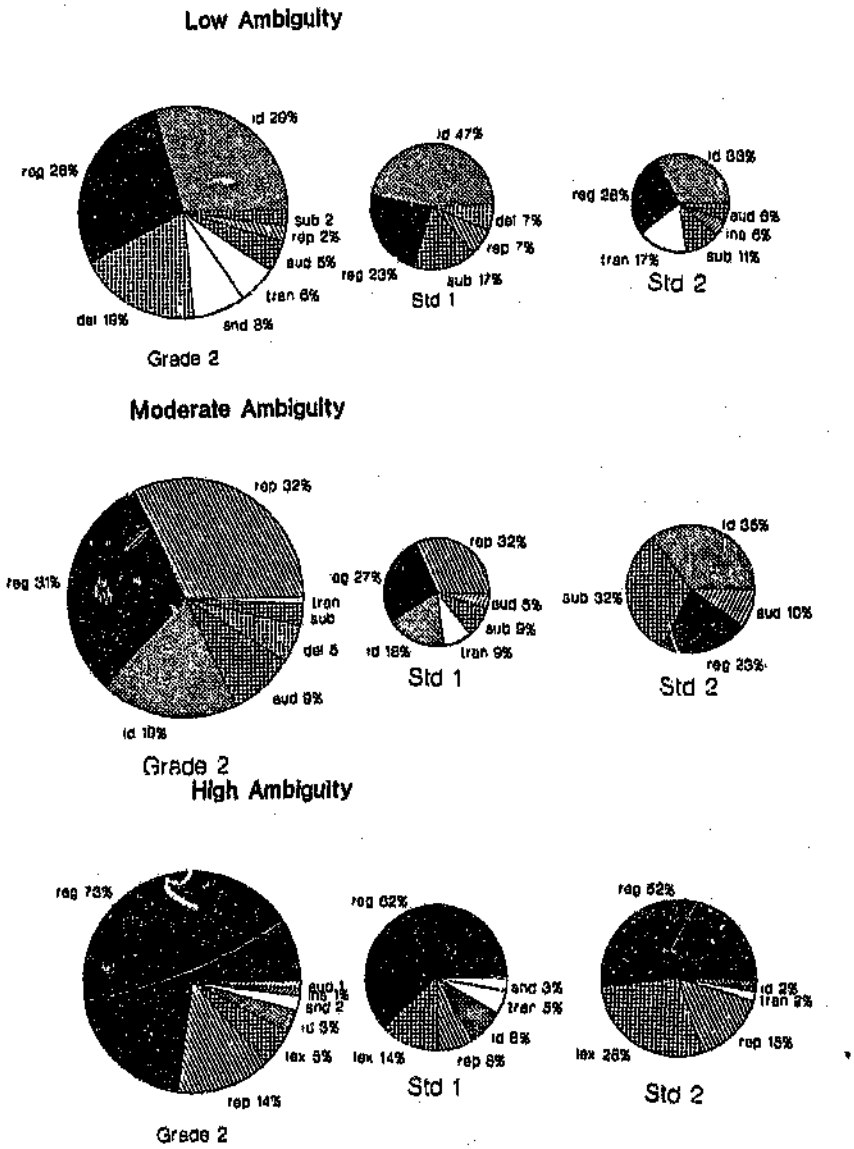


Figure 3.23: Micro level error analysis of phonemes with infrequent-mapping vowels in high-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory, lex = lexical.)

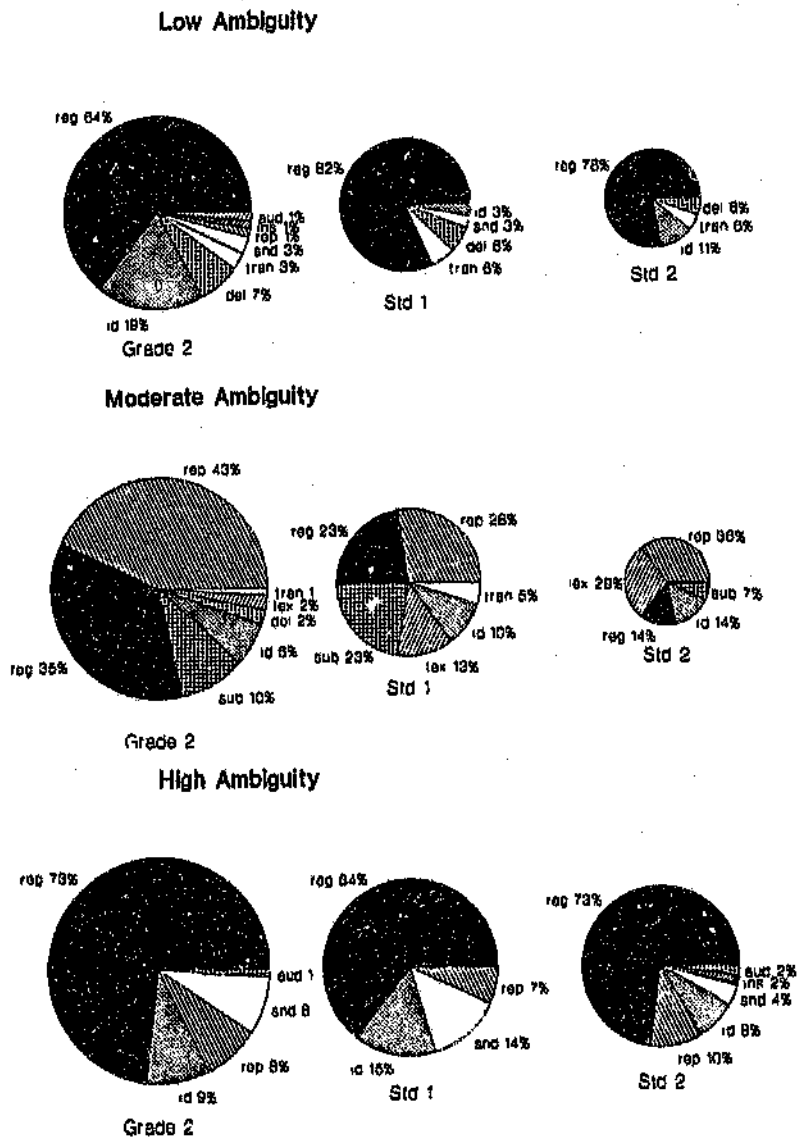


Figure 3.24: Micro level error analysis of phonemes with infrequent-mapping vowels in low-frequency words. (reg = regularisation, rep = replacement, del = deletion, sub = substitution, tran = transposition, ins = insertion, id = idiosyncratic, snd = alphabetic, aud = auditory, lex = lexical.)

festation is notable. Deletions, substitutions, insertions and transpositions occurred. At the low ambiguity level, deletions by grade 2, (*voice* → vose and *house* → hose), substitutions by Standard 1 (*voice* → vouce) , and transpostions by Standard 2 (*house* → houes or huoes) were particularly evident. At the moderate level, substitution errors occurred at each Standard level, and accounted for one third of the errors made by Standard 2. They related to one word in particular, namely *cause* → couse. At the high ambiguity level, the presence of perturbations were not notable. Of considerable interest, though, is the occurrence at this level of lexical errors, in the form of *grew* → grow. The proportion of these errors increased with each Standard level, and in Standard 2 they accounted for just over one quarter of their errors. Lastly, a small number of alphabitic errors were also evident, mainly with Grade 2 at the low ambiguity level.

With low-frequency words, phonological errors were also manifested as both regularisations (*draws* → dros and *chew* → choow) and replacements (*pear* → per), although with exception at the low ambiguity level, where only regularisations occurred. Indeed, regularisation errors overwhelmed the distribution pattern at both the low and high ambiguity levels, where they accounted for more than 70% of the errors at each Standard level. At the moderate ambiguity level, the distribution was evenly spread between the two types in both Grade 2 and Standard 1, while in Standard 2 the proportion of replacements was more than double that of regularisations. (This relates to *pear* → per which could possibly be evidence of deletion rather than replacement - a mute point).

A small proportion of errors at each Standard level were idiosyncratic, accounting on average for about 10% in each case, except in Grade 2 at the low ambiguity level where their proportion was double. Perturbations were in evidence, in similar proportion to that of idiosyncratic, both at the low and moderate ambiguity levels. They manifested as deletions (*mouse* → mose) and transpositions (*mouse* → moues or *axe* → aex) at the low level, and in the main as substitutions (*draws* → drows) at the moderate level. Two other aspects of the data are worthy of note. Firstly, lexical errors were again in evidence, though this time at the moderate ambiguity level, with instances arising from both stimulii (*draws* → drews and *pear* → pair). Again, the proportion of these errors increased with each Standard level, and in Standard 2 they accounted for nearly one third of their errors. Secondly, a small number

of alphabetic errors were evident in each Standard level at the high ambiguity level.

Chapter 4

Discussion

In this study, a multivariate design using categorical data was used to examine the spelling ability of groups of children each in their second, third and fourth year at school. The aim was to assess the nature and distribution of the target errors children make, and ascertain how this pattern of results can be meaningfully interpreted in terms of the current model of spelling, particularly with regard to the role which phoneme-grapheme correspondence may play in this process. Four major hypotheses were investigated. First, there would be a difference in the number of errors made with words in which a particular phoneme is of high-ambiguity compared to both those of moderate- and low-ambiguity, and in turn, there would be a difference in the number of errors made on words in which a particular phoneme is of moderate- compared to low-ambiguity. Second, there would be a difference between the number of errors made on phonemes where the corresponding grapheme is an infrequent- compared to a frequent-mapping option. Third, there would be a difference between the number of errors made on high- and low-frequency words. Lastly, there would be a difference in the number of errors made due to Letter-Type. A further hypothesis was that there would be a developmental difference in the number of errors.

Results provide evidence in support of these hypotheses, and also of the predictions, as follows.

1. There is an Ambiguity effect, with least errors made on phonemes of low-ambiguity, and most made on those of moderate-ambiguity. The pattern of this effect replicates those of a previous study.

2. There is a Word Frequency effect, with more errors made on low- than on high-frequency words.

3. There is a Mapping Frequency effect, with more errors made on phonemes with infrequent- compared to frequent-mappings.

4. There is a Letter-Type effect, with more errors made on vowels than on consonants.

5. There is a developmental difference, with the error means diminishing with each sample up to the second sample in Standard 1, where this trend levels off. There is further diminishing of the error means with the last sample in Standard 2.

The effect of each factor on the response is interdependent, and there is a complex pattern of interacting influences which is different for consonants and vowels. The overall response patterns are summarised below in order to provide the broad picture of how childrens' spelling performance varies in terms of these factors. This overview serves to earmark several points of interest for the developmental analysis which follows.

4.1 Global Response Patterns

4.1.1 Consonants

The pattern of factorial effect in childrens' spelling of consonants was composed of a Word Frequency effect in the responses to infrequent-mapping phonemes only, at all levels of Ambiguity, and a Mapping Frequency effect with both high- and low-frequency words containing phonemes of moderate- and high-ambiguity. In combination, these resulted in the following response patterns.

Infrequent correspondences

With low-frequency words, there was a linear progression of increasing errors with increasing Ambiguity. This pattern reflects the additive effects of Mapping Frequency together with a stronger Word Frequency effect when phonemes are of high-ambiguity. With high-frequency words, a similar number of errors were made on phonemes of high- and moderate-ambiguity. The qualitative analysis shows errors with both high- and low-frequency words were predominantly phonological regularisations. A few perturbation errors in the form of substitutions

occurred on phonemes of low- and moderate-ambiguity in high-frequency words, where the target segments were double consonants. These are interesting on several counts. Firstly, they are unexpected, because the stimuli are not long words. Secondly, of the errors on phonemes of moderate ambiguity, their proportion increases with Standard. Thirdly, despite similar stimuli in low-frequency words, substitutions do not occur on these, except, notably, in Standard 2 responses on the low-ambiguity phonemes.

Frequent correspondences

With both low- and high-frequency words, few errors were made on frequent-mapping phonemes of high- and moderate-ambiguity. Unexpectedly, most occurred on phonemes of low-ambiguity, owing to a minimal Mapping Frequency effect. The qualitative analysis shows errors with high-frequency words were predominantly phonological, consisting of replacement of the single consonant with a double, while those with low-frequency words were more variable in type - in addition to phonological replacements, there were alphabetic errors in Grade 2 and Standard 1 responses, and also deletion errors. The latter, which occurred with *lords*, are interesting because, like substitutions, they are not expected to occur since the stimulus is not a long word. It is notable, though, that the target is in the middle of a consonant cluster.

4.1.2 Vowels

The pattern of factorial effect in childrens' spelling of vowels was governed by a global Mapping Frequency effect. Also their spelling of frequent-mapping phonemes was sensitive to Word Frequency regardless of mapping-ambiguity, while of infrequent-mapping phonemes, only those with high-ambiguity were effected. With high-frequency words, the spelling of high-ambiguity phonemes was particularly sensitive to Mapping Frequency; with low-frequency words, the spelling of both high- and moderate-ambiguity phonemes was strongly effected, though that of the latter was in an inverse direction. Another irregularity complicates the pattern further: the effect of Word Frequency on childrens spelling of low-ambiguity phonemes was in an inverse direction.

Infrequent correspondences

In combination, these influences resulted in a pattern of performance where, with high- and low-frequency words in which target phonemes are spelled with infrequent correspondences, there was a linear progression of increasing errors with increasing ambiguity.

Frequent correspondences

Of the responses to phonemes with frequent correspondences, the pattern of performance on low-frequency words followed that of the main effect, with most errors on phonemes of moderate-ambiguity and least on those of low-ambiguity. However, the influences that give rise to this pattern are not as expected. The inverse Word Frequency effect is reflected in there being few errors on low-ambiguity phonemes, while the large number of errors made on phonemes of moderate-ambiguity is because of the inverse Mapping Frequency effect.

The effect of Ambiguity in the performance on phonemes with frequent correspondences in high-frequency words was anomalous, in that while most errors occurred on phonemes of moderate-ambiguity, there were few on those of high-ambiguity. Childrens' performance on moderate-ambiguity phonemes was not influenced by Mapping Frequency, and so most errors occurred on words in this category. (Notably, Word Frequency also made no difference to the number of errors made; they were equally difficult and most errors, overall, occurred on this category.) The unexpected higher number of errors on phonemes of low- than of high-ambiguity reflects the negative Word Frequency effect on low-ambiguity phonemes (such that more errors ocurred on these high-frequency words).

While the complexities of these results can be broken down in terms of developmental differences, it is obvious, though, that of the three fourth-order interactions that include Development, that of Development, Letter-Type, Word Frequency and Mapping Frequency is limited in its usefulness, due to both Word and Mapping Frequency being collapsed over Ambiguity. Because of the anomalous performance with low-ambiguity phonemes in terms of Word Frequency, and with moderate-ambiguity phonemes in terms of both Word and Mapping Frequency, there is masking of any meaningful response pattern.

4.2 The Strategies Children Use

Analysis of how these response patterns breakdown in terms of the Development factor is very instructive towards elaborating several features of how children acquire spelling proficiency, particularly with regard to the strategies they use.

4.2.1 Consonants

To begin, children rely on a strategy of assembling spelling, and therefore their spelling of words with ambiguous phonemes are sensitive to Mapping Frequency. The four-way interaction with Development, Letter-type, Ambiguity and Mapping Frequency (see Figure 3.7) shows the Mapping Frequency effect in their spelling of high- and moderate-ambiguity phonemes is time-dependent, being marked in Grade 2 responses, and absent in those of Standard 2, with gradual diminishing in strength inbetween. The effect is such that from the onset children made virtually no errors on phonemes spelled with frequent-mappings. Their errors were on phonemes spelled with infrequent-mappings, and in terms of numerical modelling (Widrow and Stearns, 1985) the developmental spectrum conforms to a normal learning curve, such that the responses of Standard 2 children by the third quarter were sensitive neither to Ambiguity nor Mapping Frequency (see Figure 4.1). Interestingly, though, their errors are still predominantly phonological, indicating a strategy of assembled spelling.

If we are to think of the conversion mechanism as being like a signal processing filter this time-varying, nonlinear feature is indicative of an adaptive filter, meaning it has a self-learning algorithm. By *learning* I refer to a numerical process whereby balance in the option weightings is adapted over time according to feedback on performance, in such a way that the error value approaches zero (see Figure 4.2). Results, then, provide evidence of well established phoneme-grapheme correspondences in use by this stage. By *well established*, I refer to the status in the setting up of option weightings. So, for these categories of phonemes it would seem the frequent-mapping option is initially clearly founded and in the ensuing process of establishing option weightings it is ratified as such. Further, older children begin to implement address modifications, and so are able to assemble a correct spelling of infrequent-mapping phonemes.

While phonological spelling is important, its influence is moderated by word-specific infor-

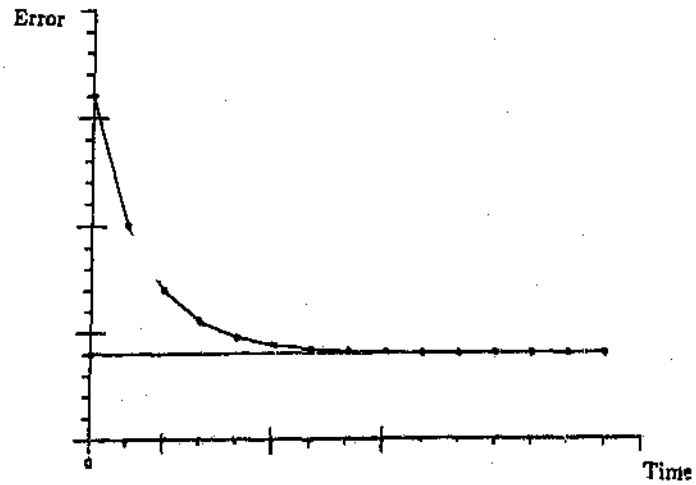


Figure 4.1: A normal learning curve

mation, which develops sooner for high-frequency words. This is evident in the four-way interaction with Development, Letter-Type, Word Frequency and Mapping Frequency. Firstly, there is a stronger Mapping Frequency effect with low- than with high-frequency words, so that most errors occurred on phonemes with infrequent correspondences in low-frequency words. This differential effect was significant in the responses of both Grade 2 and Standard 2 subjects, in such a way their performance on phonemes spelled with infrequent-mappings differs in terms of Word Frequency. In the performance of Standard 1 subjects, this trend did not attain significance. Perhaps this could be attributed to the influence of concurrent spelling instruction at school, which required rote memorisation of lists of words, categorised into sets of sound-families. Secondly, childrens' spelling of high-frequency words is no longer sensitive to Mapping Frequency by the third quarter of the Standard 1 year, while their spelling of low-frequency words continues to be effected by Mapping Frequency until the last quarter of the Standard 2 year.

Similarly, as shown in the four-way interaction with Development, Letter-Type, Ambigu-

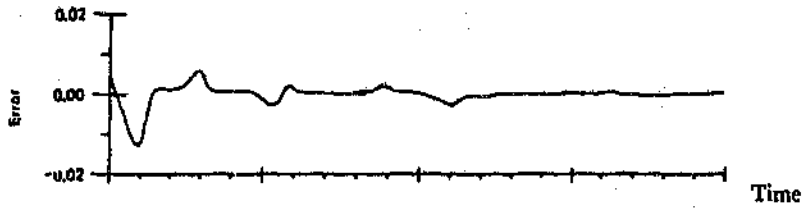


Figure 4.2: Signal from a data adaptive algorithm, showing "learning" by adjustment of a weighting until error = 0. Efficiency is demonstrated by there being few iterations before the signal steadies at zero.

ity and Word Frequency, the effect of Ambiguity is prevalent in childrens' spelling of low- but not in high-frequency words. This is because word-specific information is more available for high-frequency words. Further, the effect of Word Frequency is most evident in the responses by Standards 1 and 2 children to high-ambiguity phonemes.

Taken together, the evidence from these two interactions indicates that while children in Grade 2 rely totally on a strategy of assembling spelling, both for known as well as unknown words, a memory-before-rules strategy comes to be adopted by older children when ambiguity is high. Therefore,the spelling of high-frequency words with high-ambiguity phonemes are accessed. Since low-frequency words are less accessable in the lexicon, these are re-routed and their spelling assembled.

In comparison, mastery in the mapping of phonemes with low-ambiguity is acquired differently. Unexpectedly, an initial setting-up of the frequent-mapping option fails to occur. Hence, there were random Mapping Frequency effects in Grade 2 responses, and none in Standard 1. As indicated above, consonants were often doubled when they should have been single, and conversely, not doubled when they should have been. It is only in Standard 2 that the frequent-mappings are established as such. Evidence suggests word-specific knowledge or the awareness of conditional rules are necessary in order to spell these consonant sounds accurately.

4.2.2 Vowels

The sensitivity to childrens' spelling of high- and low- ambiguity phonemes to Mapping Frequency is time-dependent, as shown in the four-way interaction with Development, Letter-type, Ambiguity and Mapping Frequency (see Figure 3.9), with progressive weakening of the effect along the spectrum from being marked at the beginning of Grade 2 to absent in the spelling of low-ambiguity phonemes by the third quarter of the Standard 1 year and in the spelling of high-ambiguity phonemes by the third quarter of the Standard 2 year. The effect is such that, except for the first half of the Grade 2 year, phonemes spelled with frequent-mappings elicited few errors, while for those spelled with infrequent-mappings the developmental profile of performance on low-ambiguity phonemes conforms to a normal learning curve, as previously illustrated in Figure 4.1. For high-ambiguity phonemes, the

learning process appears protracted. If one thinks of the conversion mechanism as though it were an adaptive filter, the learning process of establishing weightings can be said to be complete, but address modifications take longer to come into operation. However, by the third quarter of the Standard 2 year, errors no longer show sensitivity to Mapping Frequency.

Because word-specific memory becomes available sooner for high-frequency words, Ambiguity ceased to effect childrens' spelling after the first quarter of the Standard 1 year, whereas their spelling of low-frequency words was effected by Ambiguity up to the third quarter of the Standard 1 year (see the four-way interaction with Development, Letter-Type, Ambiguity and Word Frequency). Specifically, there is a developmental shift from purely phonological spelling of high-ambiguity phonemes to an increasing use of word-specific memory. The four-way interaction with Development, Letter-Type, Ambiguity and Word Frequency shows the effect of Word Frequency has greater prevalence when target phonemes are of high-ambiguity, being a consistent influence in the childrens' spelling from the third quarter of Grade 2 onwards.

Details gained from the qualitative analysis serve to further inform. There were few errors in high-frequency words on phonemes of high-ambiguity that are spelled with frequent correspondences. Those that did occur were made by Grade 2 subjects, and consist of both types of phonological errors. Results are indicative of efficient learning with time. The pattern of errors on those spelled with infrequent correspondences can be interpreted to indicate the nature of this learning. Phonological regularisations were predominant in Grade 2 errors, but their proportion decreased with each Standard, in conjunction with an increase in lexical errors. This trend corresponds with the post-Grade 2 Word Frequency effect. An observation that adds further interest in this pattern of errors is that it was not the most-frequent mapping that was always used in the phonological regularisations of Grade 2 children. In terms of the mechanism being like an adaptive filter, this gives evidence to an early stage in the establishing of frequency weightings. Because spelling of highly ambiguious phonemes using conversion rules yields a high error-rate, older children adopt a memory-before-rules strategy. Low-frequency words are less accessible in the lexicon and they are re-routed and their spellings are assembled. Hence, most of their errors on phonemes with frequent correspondences are replacements, and with infrequent correspondences are

phonological regularisations. As with high-frequency words, it was not the most-frequent option that was always used in the phonological regularisations.

The spelling strategy that children develop with phonemes of low-ambiguity is different. While the spelling of high-ambiguity phonemes by older children is sensitive to Word Frequency, with low-ambiguity phonemes, it is the spelling of Grade 2 children which is sensitive to this factor, and the effect is in an inverse direction, with most errors occuring on high-frequency words. Again, details in the qualitative analysis are helpful towards informing an interpretation. Clearly, low-frequency words are processed phonologically. High-frequency words are not. Evidence suggests as soon as word-specific memory develops, a memory-before-rules strategy is favoured, and since word-specific information is more readily available for high-frequency words, their spellings are accessed. Thus, errors by Grade 2 children on phonemes with frequent correspondences in high-frequency words are of a random pattern, consisting of regularisations as well as replacements and also a fair proportion of idiosyncratic errors, while with phonemes spelled with infrequent correspondences, idiosyncratic, phonological regularisation and a variety of perturbation errors occur in equal proportions. In low-frequency words, evidence of efficient learning of the frequent-mapping options is demonstrated in their errors on infrequent correspondences, which are phonological regularisations, while almost all errors on frequent-mapping phonemes are in response to the word *clown*, and occur mainly as idiosyncratic and perturbation errors, the latter in the form of deletions and additions.

With older children, efficient learning of frequent correspondences is evident, in that they made few errors with low-frequency words, compared to Grade 2 children, and their error responses on infrequent correspondences are phonological regularisations. It is curious, then, that their errors on frequent-mapping phonemes in high-frequency words are mainly replacements. These cannot be arising from phonological processing. It could be that because they have access to partial representation only, they resort to a different stategy to achieve spelling of the high-frequency word. There is evidence of this alternative strategy in their spellings of moderate-ambiguity phonemes, too.

Mastery in the mapping of moderate-ambiguity phonemes takes a different course. Learning occurs, yet there is neither a Mapping Frequency effect nor, as the four-way interaction

with Development, Letter-Type, Ambiguity and Word Frequency shows, is there a Word Frequency effect in the response pattern. Also, the nature of childrens' errors is unlike those of the other ambiguity levels. The incidence of misinformation errors with low-frequency words suggests that mastery in mapping these phonemes may be delayed by a developmental lag in proficiency of auditory perception with regard to these sounds. Hence, the presence, too, of alphabetic errors, which indicates an immature strategy of assembling spellings used by children in the absence of appropriate elaboration in the phonographeme-to-letter conversion mechanism. In addition .. honemes themselves being difficult, the graphemic correspondences have a number of frequent-mapping options with similar weightings, so learning in terms of sorting out the weightings of these mapping options is confounded, and qualitatively there is little developmental change in the childrens' errors. Further, this indeterminateness of the frequent-mapping option weightings can be credited with increasing leverage of the moderating input that young children use from word-specific information. Thus the high proportion of idiosyncratic errors, particularly with high-frequency words. Approximately half the errors on frequent correspondences in high-frequency words were idiosyncratic and one quarter were regularisations. Perturbations occurred as mainly transpositions, and their proportion increased with Standard. The pattern of errors on low-frequency words was similar, in that they were idiosyncratic and regularisation errors, although the distribution of each type was more even than those in high-frequency words. Also, of the responses to phonemes with infrequent correspondences, phonological errors accounted for most of the errors made on low-frequency words by Grade 2 children, but for only half the total of both Standards. Many of the errors by Standard 1 children were substitutions, and by Standard 2 were lexical. Of interest, phonological errors were manifested as both regularisations and replacements, and those by Grade 2 and Standard 1 subjects were evenly distributed between the two types. In other words their phonological errors are of a random nature. With high-frequency words, the same pattern of random phonological errors accounted for two thirds of their errors. This random response pattern can be attributed to the confounding factor inherent in these phonemes.

The predominance overall of idiosyncratic errors, together with the presence of some transposition errors, can be viewed as symptomatic of another difficulty these phonemes present,

in that their graphemic representations are obscure. Because of this obstacle to achieving accurate accessed spelling of words that contain these phonemes, older children resort to using an alternative strategy. This is why the responses of Standard 2 children are not satisfactorily interpreted in terms of their using either an assembled or an accessed strategy. Thus, of their phonological errors on infrequent-mapping phonemes in low-frequency words, the proportion of replacements was, surprisingly, more than double that of regularisations. Perhaps this is because the weightings have yet to be correctly established, or it could be evidence of a *cognitive strategy* that signifies a preliminary stage in the development of conditional rules, for example, of local constraint. However, the pattern of their errors on infrequent-mapping phonemes in high-frequency words are also inconsistent with expectations. They consisted of idiosyncratic, substitution and regularisation errors, made in equal proportion. It is puzzling that there are no lexical errors on these high-frequency words, since they are expected to be more readily available from word-specific memory than are low-frequency words.

In this regard, the common incidence of perturbations in the form of deletions and substitutions is particularly interesting, on two accounts. Firstly, with one exception, they are prevalent in larger proportion in the Standards, particularly in Standard 2. (The exception was with low-frequency words with frequent-mappings of low ambiguity.) Taken in conjunction with the evidence of increasing use of the lexical strategy, it would seem the higher proportion of these type of errors in the older children speaks of their being associated with accessed rather than assembled spelling. (By corollary, are additions and transpositions then associated with assembled spelling?) Secondly, these type of perturbation errors are not expected to occur on short words. While the words in question are not long, if considered in terms of onset and rime, they do have long segments. For example, *house* → h-ouse, *mouse* → m-ouse, and *cause* → c-ause, compared to *clown* → cl-own and *stick* → st-ick. The longer rime could be giving rise to these type of perturbation errors. (In other words perturbation errors are indicative of the difficulty encountered by beginner spellers when accessing spellings from word-specific memory.) Accepting this is the case, then results support the idea that beginner spellers segment words into onset and rime (Treiman and Zukowski, 1988), and that the elementary structural organisation of the lexicon is established in these terms at this early stage.

This aspect of how *data* in the lexicon is processed becomes particularly pertinent when considering what happens when there are obstacles both to efficient learning in the phonographeme-to-letter conversion system, and also to successful access of word-specific information, as is the case with vowel phonemes of moderate- and low-ambiguity. Children resort to an alternative spelling strategy that gives rise to replacement errors by older children, the source of which is not phonological. These replacement errors can be explained by suggesting use of an analogy strategy, by which is meant a system of spelling where the onset of a word is assembled while the rime is accessed. Thus, in the absence of word-specific information, children may be forced to rely on what abstractions they do have in order to spell; a speller may address sound/structure-information (which is organised in terms of onset and rime) to access an analogous whole-word, then transform the onset of the *model* word to arrive at the spelling for the target word. This explanation is appealing because it also accounts for the anomaly in the original dataset, where erroneous responses to the moderate ambiguity phoneme, /s/ with frequent-mapping <s> in a high-frequency word, *base*, increased with age and the number was inordinately greater than those with the same stimulus in a low-frequency word. The error- type was consistently replacement of *b-ase* with *b- ace*.

4.2.3

Using the insights gained from this analysis of the strategies children use to acquire spelling proficiency, a developmental model of the processes children use to spell can be enumerated.

4.3 Model of How Children Learn to Spell

During the early stages of learning to spell, young children are taught the simplest sound-letter correspondences and this induces a nonlexical spelling stategy. Development of the phonographeme-to-letter conversion mechanism is autonomous, and to begin with it functions as the primary routine by which spelling is achieved. Phoneme-grapheme correspondences are taught by exposing the child to many examples from word families which share a target sound. The most common correspondences are taught first. As the child is exposed to more word families, the grapheme correspondence options for each phoneme are gradually abstracted. In so far as the phonographeme-to-letter conversion mechanism is like an adaptive

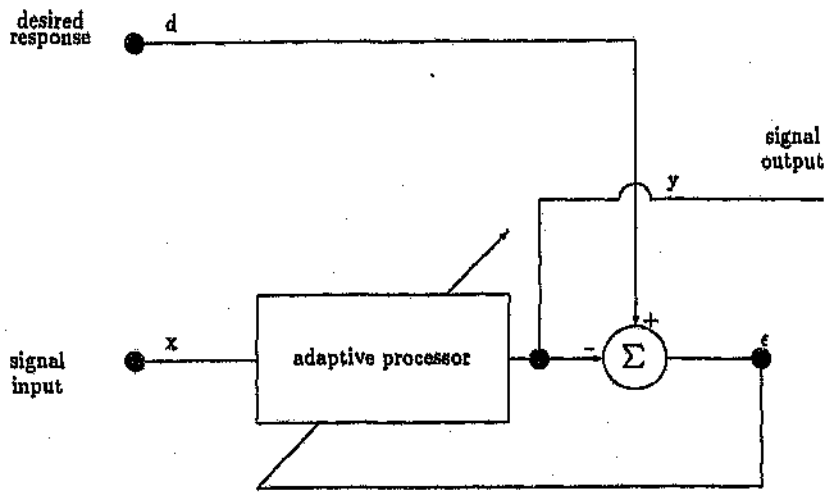


Figure 4.3: Conceptualised closed-loop adaptation in the conversion mechanism

processor, there is evidence of systematic compiling of options together with the setting up of their frequency/weightings. *Learning* consists of adaptation of the weightings according to feedback from the errors made such that, with time, errors are minimised. Elaboration of the conversion mechanism can be described in simple numerical modelling terms as being achieved by means of a closed-loop adaptation algorithm (Widrow and Stearns, 1985), as shown in Figure 4.3. . The figure represents the performance feedback process, and shows how the desired signal, d, being the correct grapheme representation of a phoneme, is approximated. The input signal is called phoneme x. The error signal, ε, is the difference between the desired output signal (the correct spelling) and the actual output signal (derived spelling), y of the conversion mechanism. Using the error signal, an adaptive algorithm adjusts the balance in the weightings of the grapheme option array, thus altering its response characterisitics by minimising some measure of the error.

As such, the conversion mechanism cannot be called a passive component, as Goodman-Schulman and Cararrazza (1987) have suggested. While with adults it may appear as passive,

DISTRIBUTION TYPE							
DISCONTINUOUS				EVEN			
Phoneme	Corr.	Grapheme	MOP	Phoneme	Corr.	Grapheme	MOP
/i:/	01	e	69.54	/ai/	01	i-e	37.48
	02	ee	9.81		02	i	37.41
	03	ea	9.65		03	y	14.25
	04	e-e	2.44		04	igh	5.94
	05	i-e	1.73		05	ie	1.76
	06	i	1.49		06	y-e	1.55
	07	ie	1.30		07	ey-e	0.47
	08	ea-e	1.18		08	ei	0.40
	09	ie-e	0.90		09	a	0.20
	10	ei	0.63		10	eigh	0.20
	11	ee-e	0.35		11	uy	0.20
	12	ei-e	0.23		12	ai-e	0.06
	13	ey	0.23		13	ae	0.06
	14	ae	0.19				
	15	oe	0.19				
	16	eo	0.07				

Table 4.1: Types of mapping option probability (MOP) frequency distributions.

it is simply that the learning process has been achieved; the adaptive filter, though dynamic, is stabilised. Further, it appears that in the absence of address modifications the mechanism is shown to operate as a simple non-deterministic algorithm, in that it always outputs the option with the heaviest weighting.

The essential feature in closed-loop adaptation is the feedback signal, in this instance being the desired correct spelling, the source of which is the orthographic lexicon for reading. Therefore, progress towards elaboration of the phonographeme-to-letter conversion mechanism depends on availability of an orthographic lexicon for reading. This assertion is in keeping with the developmental model put forward by Frith (1980) and by Seymour (1987) in which the orthographic stage for reading is shown as preceding, and leading to, an orthographic stage in spelling. Further, efficiency of learning in this mechanism depends on the distribution of the mapping option probability frequencies. Two types of distributions are shown in Table 4.1. When there is a discontinuous spread, as is found in most high-ambiguity consonant phonemes, the learning process is efficient because the weighting of the frequent mapping correspondence is clearly determinate. When the spread is so even that several

frequent-mapping options have similar probability weightings, the system is confounded, in that learning continues without achieving a balance of the weightings such that *error* = 0, because they are indeterminate.

While initially phonographeme-to-letter conversion is achieved by means of a simple type nondeterministic algorithm, its structure becomes elaborate, in that address modifications do come to be implemented. It is debatable as to whether or not these are lodged in the phonological output lexicon, as Seymour (1987) suggests, which would mean they enter the system as input with the desired response signal, *d* (see Figure 4.3). Modelled adaptive filters are shown by Widrow and Stearns (1985) to be capable of considerable sophistication, and it is just as likely that the address modifications become programmed into the structure of the adaptive processor itself.

Most of the words which beginners are taught to spell are already familiar to them aurally and through reading. During dictation, the phonological representation is retrieved from the phonological output lexicon and automatically stored in the phonological buffer. Beginners will parse the item into its individual phonemes and a grapheme will be assigned to each phoneme, the abstract representation of which is held in the graphemic buffer. Representations of words are entered into the grapheme output lexicon from the phonological output lexicon via the phonographeme-to-letter conversion mechanism and from the orthographic input lexicon, since children learn to spell from printed lists often without attention to meaning.

As expected, initial development in the processing capacity of the two routes is very rapid. At each quarter of the Grade 2 year and the first in Standard 1, there is a qualitative elaboration in skill as well as a quantitative improvement. A consolidation period follows until the middle of the Standard 2 year, afterwhich new developments occur. Elaboration of processing ability is also astoundingly systematic. In order to describe this growth of ability, the details of what children are able to do as they progress through from their second to fourth year at school is organised in a series of developmental models (see Figures 4.4 - 4.9).

Figure 4.4 shows the development status of children in the first quarter of their second year at school. By this stage, simple phoneme-grapheme correspondences have been set-up, being the frequent-mapping option for high- and moderate-ambiguity consonants and for

low-ambiguity vowels. A very small store of whole-words are in the grapheme output lexicon and the spelling of some high-frequency words with low-ambiguity consonant phonemes are accessable from memory. At this early stage of writing development, the buffer is a newly acquired specialisation of short-term memory, and possibly it only functions to hold the sequence of abstract representations in preparation for output processing. By the second quarter of the Grade 2 year (see Figure 4.6), children have also established frequent-mapping correspondences for high-ambiguity vowel phonemes. In addition, they are able to read out to the graphemic buffer from the grapheme output lexicon partial representations of high-frequency words, and because they can now use this partial lexical information in the buffer as moderating input to the assembled spelling, they are more likely to spell accurately high-frequency words that contain these type of phonemes. (In the Figures, this *moderating input* is indicated by the broken lines.) As shown in Figure 4.6, by the time children reach the third quarter of their Grade 2 year, frequent-mapping correspondences for low- ambiguity consonant phonemes are used in addition to those of moderate- and high-ambiguity. The correspondences for moderate-ambiguity vowels are not established, though. As a result of the partial word-specific information of high-frequency words that is read into the buffer and used as moderating input to the derived spelling, more high- than low-frequency words with infrequent-mapping options are spelled correctly. So, for example, children can assemble *stick* but not *stack*, which is a low-frequency word.

A pattern of progressive development in the phonographeme-to-letter conversion mechanism is apparent. Also, there is evidence of a systematic process of lexical abstraction which leads from and is subsequent to this sequential development of operational conversion procedures. With consonant phonemes, there is an ordered effect of Word Frequency on Ambiguity which is linked to a developmental progression. In the first half of the Grade 2 year the effect relates to low-ambiguity phonemes only; in the second quarter of the Grade 2 and the first of Standard 1 it relates to moderate-ambiguity phonemes only; while in the second quarter of the Standard 1 year and the first half of Standard 2 it relates to high-ambiguity phonemes only. This aspect of the results could be an artefact of the concurrent instruction programme at school. However, a similar pattern is replicated with vowel phonemes. In the first half of the Grade 2 year the effect relates to low-ambiguity phonemes only; in their third quarter

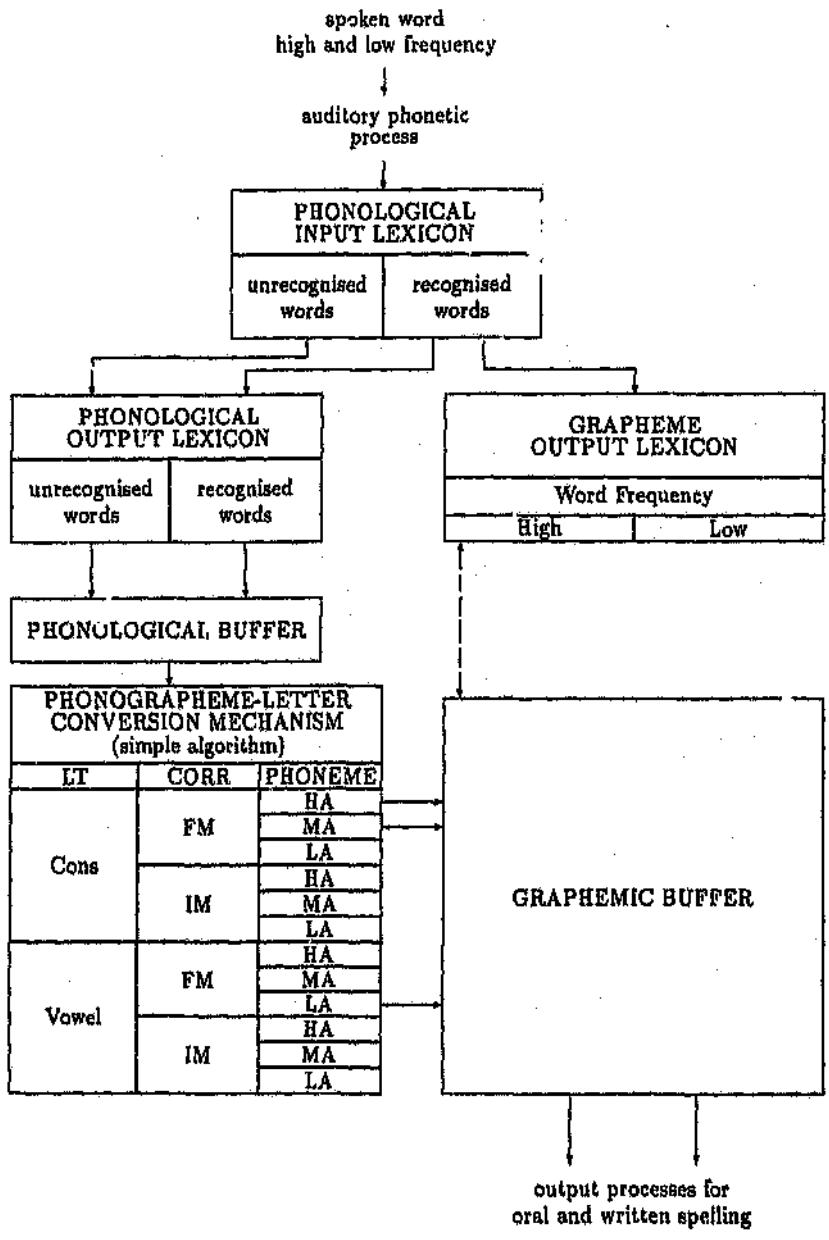


Figure 4.4: Model of spelling processes, showing development status of children in the first quarter of their Grade 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity)

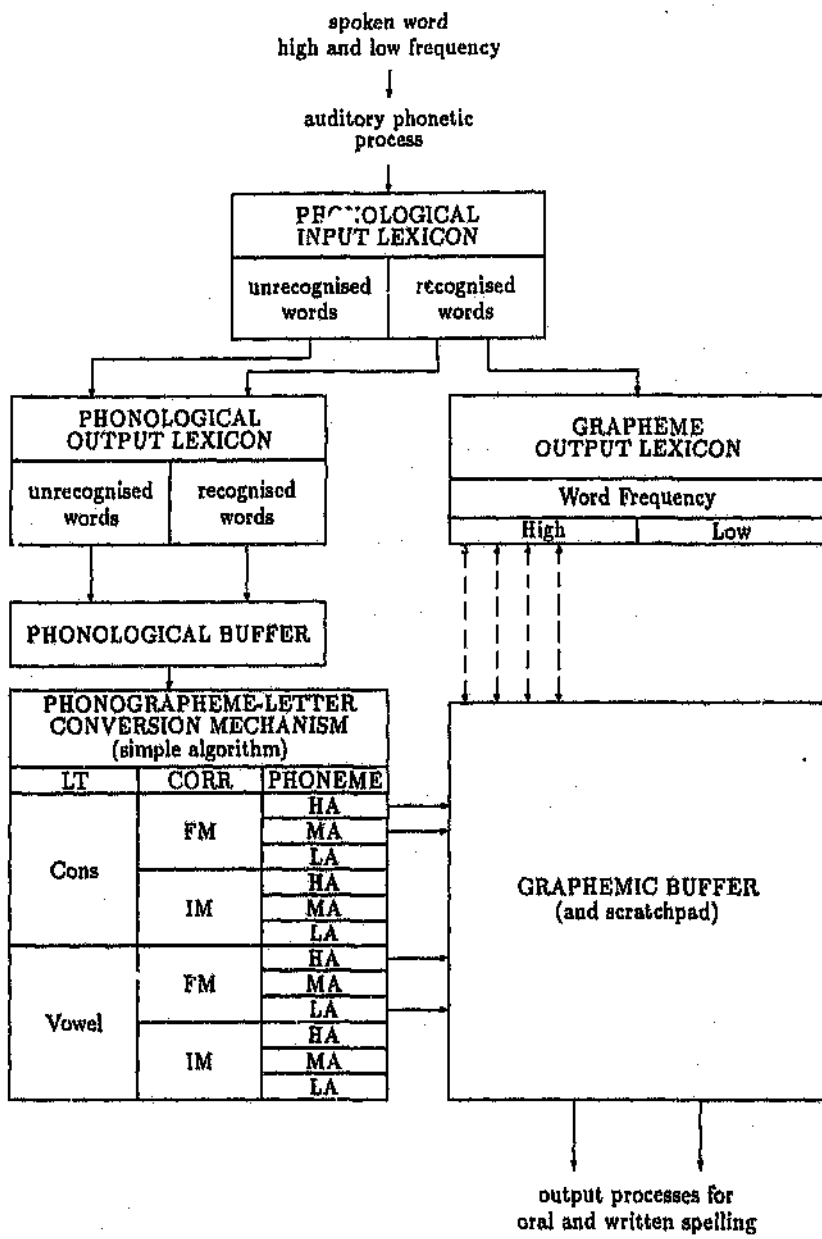


Figure 4.5: Model of spelling processes, showing development status of children in the second quarter of their Grade 2 year. (*LT* = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity)

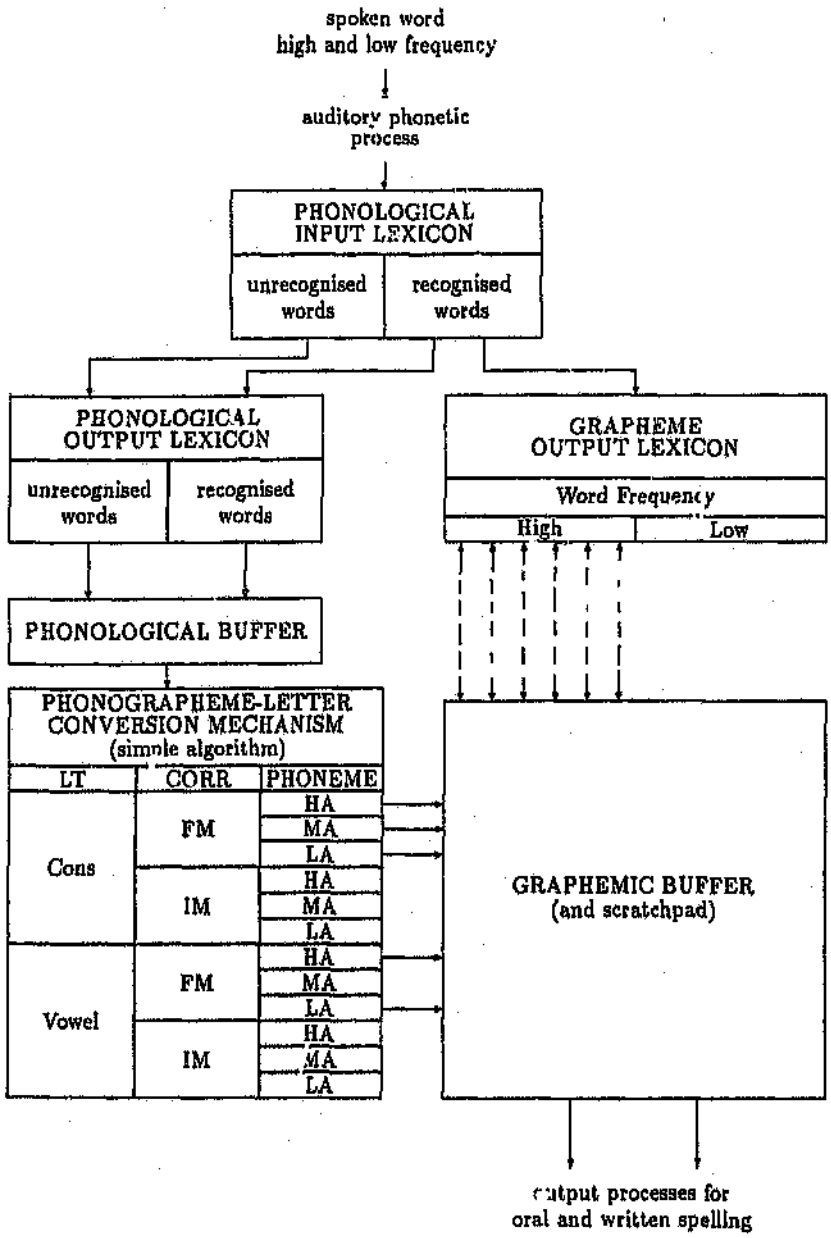


Figure 4.6: Model of spelling processes, showing development status of children in the third quarter of their Grade 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity)

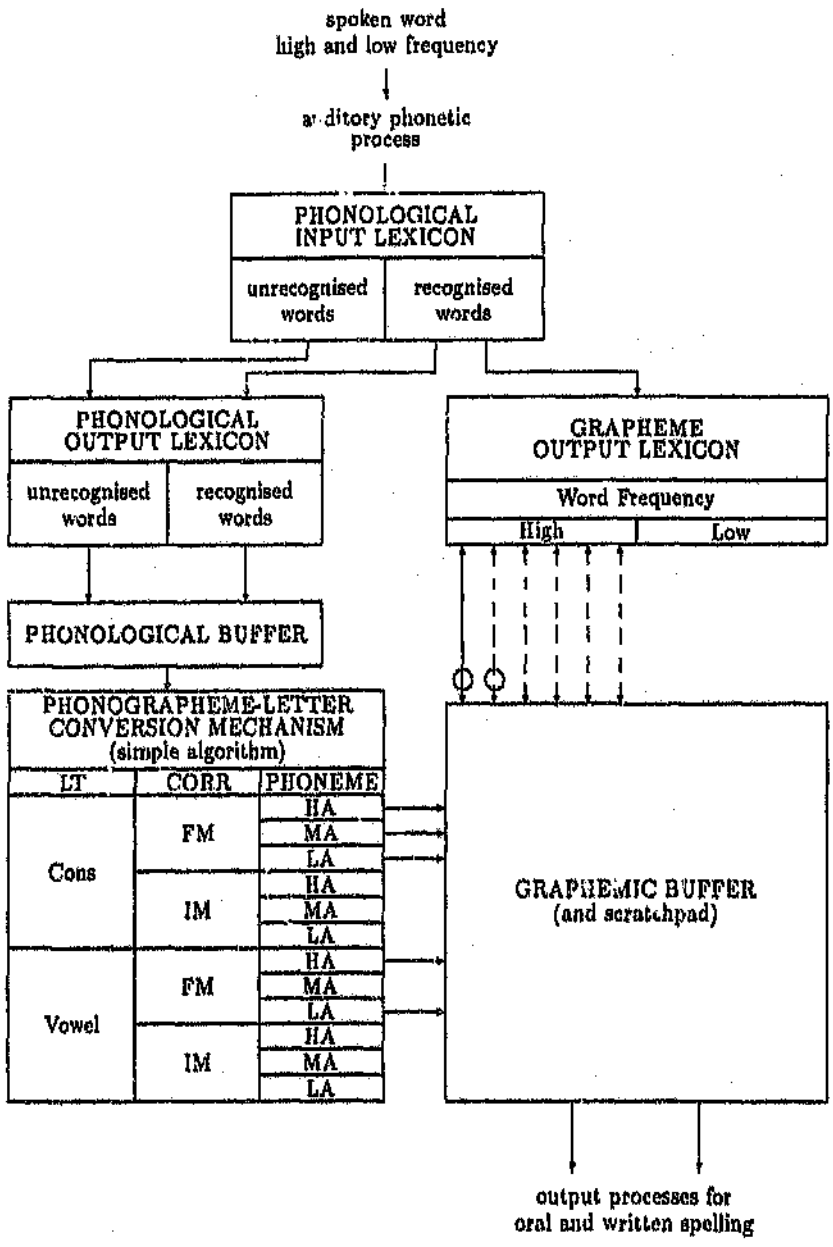


Figure 4.7: Model of spelling processes, showing development status of children in the first quarter of their Standard 1 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity, circle = model word)

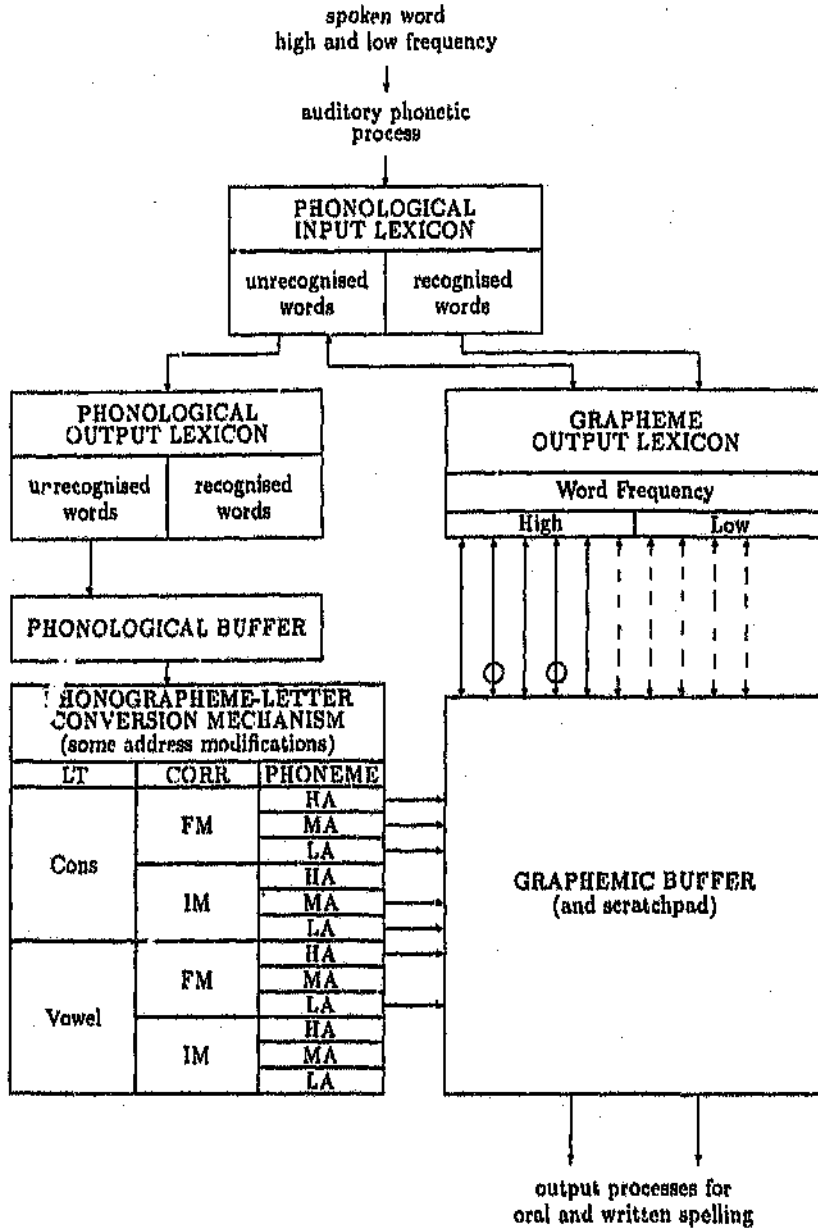


Figure 4.8: Model of spelling processes, showing development status of children from mid-year of Standard 1 to mid-year of Standard 2. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity LA = low-ambiguity, circle = model word)

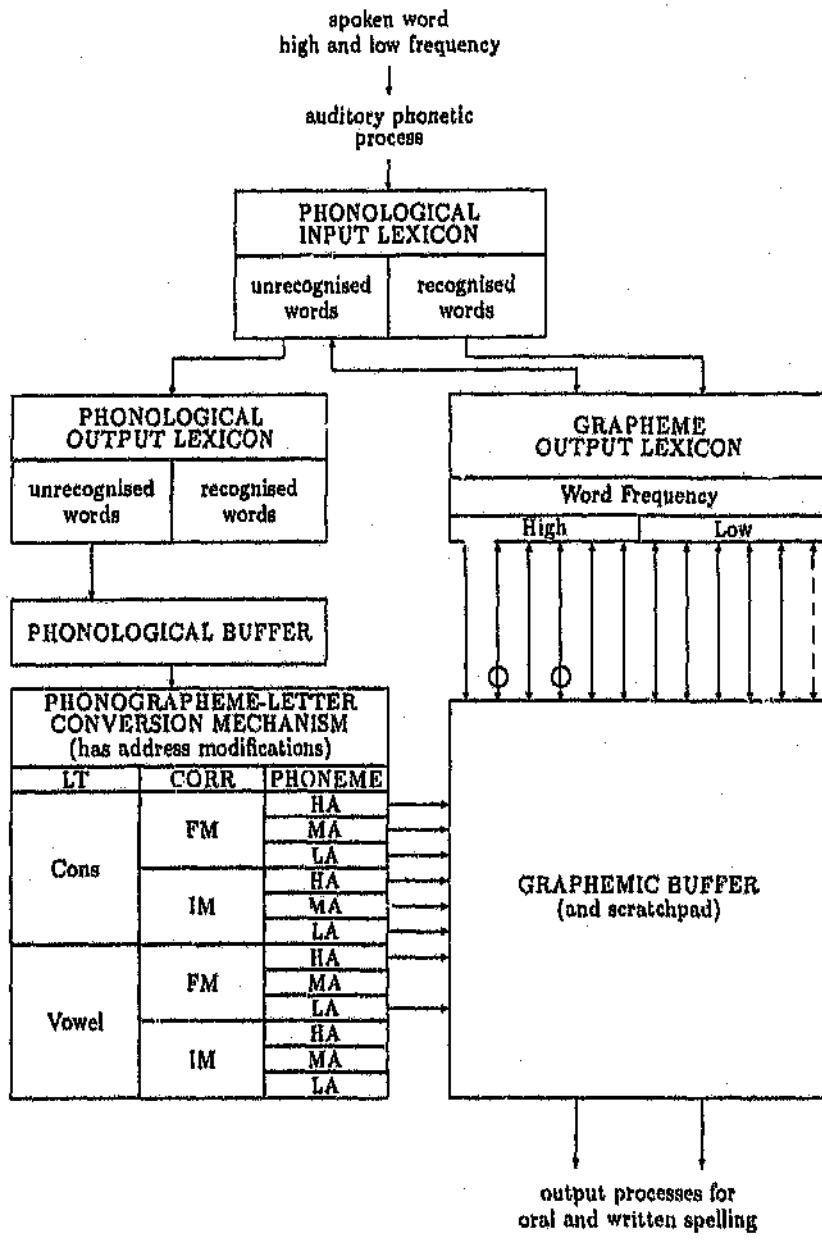


Figure 4.9: Model of spelling processes, showing development status of children in the third quarter of their Standard 2 year. (LT = Letter-Type, CORR = correspondence, Cons = consonants, FM = frequent-mapping, IM = infrequent-mapping, HA = high-ambiguity, MA = moderate-ambiguity, LA = low-ambiguity, circle = model word)

and the second of the Standard 1 year it relates to moderate-ambiguity phonemes; while from the third quarter of the Grade 2 year onwards, except for the second quarter of the Standard 2 year, it relates to high-ambiguity phonemes. Since this progression occurs with both consonants and vowels, it is unlikely that it is an artefact. Clearly phonographeme-to-letter conversion assists in consolidating the store of lexical representations in the grapheme output lexicon. Results then support the assertion by Frith (1980) and by Seymour (1987) that establishment of an orthographic lexicon for spelling production depends on the availability of a foundation of simple phoneme-grapheme associations as well as on the availability of an orthographic lexicon for reading. It could be that this systematic lexical abstraction reflects coding processes with word-specific information in the lexicon in terms of the developing structural organisation of onset and rime.

While beginner spelling reflects phonological knowledge, results do not support the idea that young childrens' spelling is achieved wholly by use of the assembled spelling strategy. If they did, this would suggest a model in which the routes operate independently in an on/off system. Instead, results are better accomodated by dual-process interactive models in which both lexical and non-lexical routines contribute (Nolan and Caramazza, 1983; Burden, 1989). Analysis in the foregoing section of the strategies children use reveals both Ambiguity and the character of mapping option probability distributions is fundamental to the dynamics of this interactive process in a developmental context: the cognitive response by children to the difficulties encountered in terms of these facors influences the relative contribution of each processing route.

The interaction that is set up by this *cognitive response* is difficult to capture in a diagrammatic format. To summarise, results provide evidence of the phonographeme-to-letter conversion mechanism becoming well established and effectively used for high- and moderate-ambiguity consonant phonemes, so that the phonological route is dominant despite simultaneous lexical processing which does yield a moderating input from the grapheme output lexicon (see Figures 4.4 - 4.7). With high-ambiguity phonemes, though, a memory-before-rules strategy comes to be adopted by children in Standard 2 because of the fallibility inherent in the early system of assembling spelling for words containing infrequent-mappings (see Figures 4.8 and 4.9). Spelling of high-ambiguity vowel phonemes also begins with the development of the

phonographeme-to-letter conversion mechanism, but it takes longer for th cy weightings to become correctly established because of the less determinate character of their mapping option probability distributions. As with consonant phonemes, though perhaps sooner, a memory-before-rules strategy comes to be adopted. Several features of vowel phonemes of moderate-ambiguity confound efficient learning in the phonographeme-to-letter conversion system and also make accurate accessed spelling difficult, and so an alternative strategy of spelling by analogy is developed by older children in response to these obstacles.

Of low-ambiguity phonemes, there is evidence that although the correspondence options for consonants have been compiled at the onset, their weightings do not become established, and word-specific knowledge or the awareness of conditional rules are demonstrated as necessary in order to spell these consonant sounds accurately. In the first quarter of Standard 1, word-specific information is used for the spelling by analogy of words containing low-ambiguity consonants. It could be that the analogy strategy provides the means by which address modifications, such as rules of local constraint, are developed in order to disambiguate frequency weightings of the mapping options for a *problem* phoneme, thereby effecting a more sophisticated non-deterministic algorithm. Progress shown in older children (see Figure 4 8) with regard to the correct spelling of high- and moderate-ambiguity consonant phonemes are indicative of this development. It seems when the weightings are clearly determinate this development proceeds early. It would be interesting to further explore this aspect in the spelling of children in higher primary school.

With vowel phonemes, the frequent-mapping correspondence options are shown to be compiled early in the learning process, and their relative weightings are quickly established. However, as soon as word-specific memory develops, a memory-before-rules strategy is favoured, and further development of the phonographeme-to-letter conversion mechanism, in terms of compiling a full list of the correspondence options, seems halted. Further, because word-specific memory is confounded by the complex rime some words with these phonemes have, older children resort to using an analogy strategy to derive the spelling of high-frequency words.

An implication of this interactive model is that it amplifies the central role in the spelling process of the graphemic buffer. More than the holding function for which it is so well

recognised, it clearly functions as the scratchpad that allows for interactive dual-processing. Perhaps, too, older children are more adept at using the buffer in this way. It could be that with development of structural organisation in the graphemic output lexicon, efficiency of the scratchpad function is enhanced. Certainly, during the period of consolidation, as illustrated in Figure 4.8, the grapheme ouput lexicon becomes sufficiently well elaborated, both in terms of quantity of information and quality of information (organised coding), for the spellings of high-frequency words to be spelled directly using whole-word information. (In the Figure, this direct access is indicated by the solid output lines from the grapheme output lexicon.) Low- frequency words still have to be assembled, though. As mentioned above, an analogy strategy is used to generate spelling of words with moderate- and low-ambiguity vowels. Some address modifications become implemented for low-and moderate-ambiguity consonant phonemes which result in infrequent-mapping phonemes being accurately assembled. The conversion mechanism is becoming more sophisticated.

By the time children are in the third quarter of their fourth year at school, word-specific information for low- as well as high-frequency words is accessible from the grapheme output lexicon, and spelling is achieved primarily by use of the lexical strategy. Low-frequency words containing high-ambiguity vowels, though, are assembled. In addition to those of low- and moderate-ambiguity, words with infrequent-mapping consonants of high-ambiguity, too, can be correctly assembled. The phonographeme-to-letter conversion mechanism is approaching optimum functionality. All that remains is for the correspondences of moderate-ambiguity vowels, to become established. It is interesting to note that the average age of children at this stage is 10 years old, by which age most children have moved into the fourth and final stage of reading development, being that of orthographic reading (Harris and Coltheart, 1986).

Chapter 5

Conclusion

This study set out to investigate the extent to which several psycholinguistic factors influence the spelling of young children, with a view firstly, to examine the strategies children use to acquire spelling proficiency and secondly, to consider the nature of the phonographeme-to-letter conversion mechanism in terms of how phoneme-grapheme correspondences become established. The following general conclusions are proposed.

1. The spelling of young children is achieved by interactive parallel processing. To begin with, the phonological route is dominant, although simultaneous lexical processing does yield a moderating input. However, children begin to favour word-specific memory and this strategy quickly becomes the default route in that its output to the grapheme buffer has higher leverage. An analogy strategy is resorted to as an alternative system for acquiring spelling proficiency when there are obstacles both to *learning* in the phonographeme-to-letter conversion mechanism and to accurate word-specific information. Mapping Frequency, Ambiguity and Word Frequency are fundamental influences to the dynamics of interplay between the two routes in their relative contribution to the spelling of a word.

2. Conceptualisation of the phonographeme-to-letter conversion mechanism as though it were a signal processing filter is very useful for describing how phoneme-grapheme correspondences are learned. The conversion mechanism can be said to contain an adaptive processor. An array of grapheme options are compiled for each phoneme and *learning* consists of setting-up and establishing frequency/weightings for the

options by means of a closed-loop adaptation algorithm, whereby the weightings are adjusted according to feedback from the errors made such that, with time, errors are minimised. Efficiency of learning in the phonographeme-to-letter conversion mechanism depends on the determinateness of the frequent-mapping options. When they are indeterminate, as is the case with many vowel phonemes of moderate ambiguity, the system is confounded and learning does not occur without the assistance of address modifications.

3. Ambiguity and Mapping Frequency are fundamental influences to the dynamics of interplay between the two routes in their relative contribution to acquisition of spelling proficiency. The interaction arises from the cognitive response by children to the limitations, in terms of these factors, of each processing route.

4. The spelling processes that children develop and use can be accomodated within the framework of models as developed from studies with brain-damaged subjects and with adults. It is evident, though, that the phonographeme-to-letter conversion mechanism is a dynamic component because it contains an *adaptive* (self-adjusting) facility. Also, this study of spelling which is achieved with the processing routes working in tandem, highlights the dynamic scratchpad function of the graphemic buffer.

Future research into this area of study is recommended, especially with regard to investigating the nature of the phonographeme-to-letter conversion mechansim in terms of being an adaptive signal processor, with a view to elaborating the architecture of the algorithm. It would be useful to replicate this study with children in higher primary school in order to assess the way in which address modifications come into operation in terms of such a system. Several questions arise that would be interesting to pursue. Does the analogy strategy operate to set up address modifications, such as rules of local constraint? Information from this study pertaining to these issues is limited because analysis of errors was of the target segment only. A separate additional analysis is required of errors on words where the target segment is incorrect and there is at least one other error in the word. In addition, it might become important to have a measure of spelling latencies.

It is worth noting that the within-Standard information of childrens' developing spelling ability gained from data sampling at three-monthly intervals adds valuable insight. If the analysis had been based on just one mid-year sample, it is possible that the spelling ability of Standard 1 children may misleadingly have appeared as not differing from that of Standard 2 children.

Results of this study suggest onset-rime segmentation would be beneficial in teaching chidren to spell at this stage, not simply because the elementary structural organisation of the grapheme output lexicon is in terms of onset-rime units, but also because these units facilitate use of the analogy strategy and thereby, perhaps, development too of address modifications. In addition, it is possible that coded information enhances efficiency in the graphemic buffer of the scratchpad function which is so essential to accomplishing spelling proficiency. A suggestion then, for example, is lists of *word families* that are organised in terms of targetted sounds could also be organised in terms of rime-onset units. Such teaching programmmes could also take cognisance of the influence mapping option probability distributions have, by ensuring that frequent-mapping options, especially those for vowels, are consolidated first. This would disambiguate phonographeme-to-letter conversion processes and thereby facilitate development of the mechanism.

This developmental analysis of how spelling processes are acquired will also assist in refining diagnosite features of a cognitive psycholinguistic assessment of spelling, because the aim of such an assessment is to evaluate not so much what the child knows as how he/she knows. For example, results of this study suggest use of an analogy strategy with some categories of words is appropriate by children in Standard 1 and 2. However, if use of this strategy were pervasive it would be indicative of obstacles to learning, and this could be evaluated. Of considerable practical value, results demonstrate it is possible to gain a wealth of insight into the spelling ability of a child by assessing performance on just a small sample of words. Use of the ambiguity index to categorise phonemes into three levels of Ambiguity is upheld as a valid basis for selective sampling of test stimuli.

In conclusion, this study is firmly rooted in a tradition of cognitive neurolinguistic studies, and makes a useful contribution to the established body of knowledge.

References

Allport, D.A. and Funnell, E. (1981) Components of the mental lexicon. *Philosophical Transactions of the Royal Society (London), B295*, 397-410.

Badecker, W. and Hillis, A. and Caramazza, A. (1990) Lexical morphology and its role in the writing process: evidence from a case of acquired dysgraphia. *Cognition, 35*, 205-243.

Barron, R.W. (1980) Visual and phonological strategies in reading and spelling. IN U. Frith (Ed.), *Cognitive processes in spelling*. London: Academic Press.

Barry, C. (1988) Modelling assembled spelling: convergence of data from normal subjectsand "surface" dysgraphia. *Cortex, 24*, 339- 345.

Barry, C. and Seymour, P.H.K. (1988) Lexical priming and sound-to-spelling contingency effects in nonword spelling. *Quarterly Journal of Experimental Psychology, 40A*, 5-40.

Baxter, D.N. and Warrington, E.K. (1987) Transcoding sound to spelling: single or multiple sound unit correspondances?. *Cortex, 23*, 11-28.

Baxter, D.N. and Warrington, E.K. (1988) The case for biphoneme processing: a rejoinder to Goodman- Schulman. *Cortex, 24*, 137-142.

Beauvois, M.F. and Dérousné, J. (1981) Lexical or orthographic dysgraphia. *Brain, 104*, 21-45.

Bradley, L. (1983) Dissociation of Reading and Spelling Behaviour. IN D.D. Duane and C.K. Leong (Eds.) *Understanding Learning Disabilities*. New York: Plenum Press.

Bradley, L. (1985) P Spellers, poor readers: understanding the problem. Paper presented to t' .K.R.A. Annual Conference, Reading University, July. 1985.

Bradley, L and Bryant, P.E. (1979) The Independence of reading and spelling in backward and normal readers. *Developmental Medicine and Child Neurology, 21*, 504-514.

Bub, D and Kertesz, A. (1982) Deep agraphia. *Brain and Language, 17*, 146-165.

Burden, V. (1989) A comparison of priming effects on the nonword spelling

performance of good and poor spellers. *Cognitive Neuropsychology, 6*, 43-66.

Carroll, J.B., Davies, P. and Richman, B. (1971) *Word Frequency Book.* New York: American Heritage Publishing Co., Inc.

Campbell, R. (1983) Writing nonwords to dictation. *Brain and Language, 19*, 153- 178.

Caramazza, A., Berndt, R.S. and Basili, A.G. (1983) The selective impairment of phonological processing: a case study. *Brain and Language, 18*, 128-174.

Caramazza, A., Miceli, G. and Villa, G. (1986) The role of the (output) phonological buffer in reading, writing and repetition. *Cognitive Neuropsychology, 3* (1), 37-76.

Caramazza, A., Miceli, G., Villa, G. and Romani, C. (1987) The role of the graphemic buffer in spelling: evidence from a case of acquired dysgraphia. *Cognition, 26*, 59-85.

Case, R.., Kurland, D.M. and Goldberg, J. (1982) Operational efficiency of short-term memory span. *Journal of Experimental Psychology, 33*, 386-404.

Chomsky, N. and Halle, M. (1968) *The Sound Pattern of English.* New York: Harper and Row.

Doctor, E.A., Antoine, W and Scholnick, J. (1989) Ambiguous Phoneme-Grapheme Correspondence and its Effect on Children's Spelling. Paper presented at the International Conference on Cognitive Neuropsycholgy, Harrogate, England, July 21-24.

Dodd, B. (1980) The spelling abilities of profoundly pre-lingually deaf children. IN U. Frith (Ed.), *Cognitive Processes in Spelling.* London: Academic Press.

Ellis, A.W. (1982) Spelling and writing (and reading and speaking), in A.W. Ellis (ed.) *Normality and Pathology in Cognitive Functions.* London: Academic Press.

Ellis, A.W. (1984) *Reading, Writing and Dyslexia: A Cognitive Analysis.* London: Lawrence Erlbaum.

Ellis, A.W. and Young, A.W. (1988) *Human Cognitive Neuropsychology.* Lawrence Erlbaum Associates: London.

Ellis, A.W., Miller, D. and Sin, G. (1983) Wernicke's aphasia and normal language processing: a case study in cognitive neuropsychology. *Cognition, 15*, 111-144.

Fischer, F.W., Shankweiler, D and Lieberman, I.Y. (1985) Spelling proficiency and sensitivity to word structure. *Journal of Memory and Language, 24*, 423-441.

Freeman, D.H. (1987) *Applied Categorical Data Analysis.* New York: Marcel Dekker, Inc.

Friendly, M., Franklin, P.E., Hoffman, D and Rubin, D.C. (1982) The Toronto Word Pool: norms for imagery, concreteness, orthographic variables, and grammatical usage for 1,080 words. *Behavior Research Methods and Instrumentation, 14,* 375-399.

U. Frith (Ed.), (1980) *Cognitive processes in spelling.* London: Academic Press.

Gelb, I.J. (1963) *A Study of Writing.* Chicago: Chicago University Press.

Gilhooly, K.J. and Logie, R.H. (1980) Age-of-acquisition, imagery, concreteness, familiarity, and ambiguity measures for 1,944 words. *Behavior Research Methods and Instrumentation, 12,* 395- 427.

Glushko, R.J. (1979) The organisation and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 674-691

Goodman, R.A. and Caramazza, A. (1986a) Aspects of the spelling process: evidence from a case of acquired dysgraphia. *Language and Cognitive Processes, 1,* 263-296.

Goodman, R.A. and Caramazza, A. (1986b) Dissociation of spelling errors in written and oral spelling: the role of the al-lographic conversio in writing. *Cognitive Neuropsychology, 3* (2), 179- 206.

Goodman-Schulman, R.A. (1988) Orthographic ambiguity: comment on Baxter and Warrington. *Cortex, 24,* 129-135.

Goodman-Schulman, R.A. and Caramazza, A. (1987) Patterns of dysgraphia and the nonlexical spelling process. *Cortex, 23,* 143-148.

Hanna, P.R., Hanna, J.S., Hodges, R.E. and Rudorf, E.H. (1966) Phoneme Grapheme Correspondences as Cues to Spelling Improvement. *US Dept of Health, Education and Welfare, Office of Education,* Washington, DC: U.S Government Printing Office.

Harris, M. and Coltheart, M. (1986) *Language Processing in Children and Adults: An Introduction.* London: Routledge and Kegan Paul.

Hatfield, F.M. and Patterson, K. (1983) Phonological spelling. *Quarterly Journal of Experimental Psychology, 3A,* 451-468.

Henderson, E.H. (1980) Developmental concepts of word. IN E.H. Hendersen and J.W. Beers (Eds), *Developmental and cognitive aspects of learning to spell.* Newark:IRA.

E.H. Hendersen and J.W. Beers (Eds), (1980) *Developmental and cognitive aspects of learning to spell.* Newark:IRA.

Hier, D.B. and Mohr, J.P. (1977) Incongruous oral and written naming: evidence for a subdivision of the syndrome of the syndrome of Wernicke's aphasia. *Brain and Language, 4*, 115-126.

Hillis, A.E. and Caramazza, A. (1989) The graphemic buffer and attentional mechanisms. *Brain and Language, 36*, 208-235.

Johnston, R.S. and Thompson, G.B. (1989) Is dependence on phonological information in children's reading a product of instructional approach? *Journal of Experimental Child Psychology, 48*, 131-145.

Lesser, R. (1989) Selective preservation of oral spelling without sematics in a case of multi-infarct dementia. *Cortex 25*, 239-250.

Lesser, R. (1990) Superior oral to written spelling: evidence for separate buffers? *Cognitive Neuropsychology, 7*(4), 347-366.

Levine, D.N., Calvanio, R. and Popovics, A. (1982) Language in the absence of inner speech. *Neuropsychology, 20*, 391-409.

Luria. A.R. (1970) *Traumatic Aphasia.* Mouton: The Hague.

Marcel, T. (1980) Surface dyslexia and beginning reading: a revised hypothesis of the pronunciation of print and its impairments. IN M. Coltheart, K.E. Patterson and J.C. Marshall (Eds), *Deep Dyslexia.* London: Routledge and Kegan Paul.

Margolin, D.I. (1984) The neuropsychology of writing and spelling: semantic, phonological, motor and perceptual processes. *Q.J. Exper. Psychology, 36A*, 459-489.

Marsh, G., Friedman, M., Welch, V. and Desberg, P. (1980) The development of strategies in spelling. IN U Frith (Ed.), *Cognitive Processes in Spelling.* London: Academic Press.

Marshall, J.C. (1977) Disorders in the expression of language. IN J. Morton and J.C. Marshall (Eds), *Psycholinguistics Series*, Vol. 1. London: Elek Science.

Miceli, G. and Caramazza, a. (1988) Dissociation of inflectional and derivational morphology. *Brain and Language, 35*, 24-65.

Miceli, G., Silveri, M.C. and Caramazza, A. (1985) Cognitive analysis of a case of pure agraphia. *Brain and Language, 25*, 187-212.

Morton, J. (1980) The logogen model and orthographic structure. IN U. Frith (Ed.), *Cognitive Processes in Spelling.* London: Academic Press.

Nolan, K.A. and Caramazza, A. (1983) An analysis of writing in a case of deep dyslexia. *Brain and Language, 20*, 305-328.

Patterson, K. (1986) Lexical but nonsemantic spelling? *Cognitive Neuropsy-*

chology, *9*(3), 341-367.

Pavio, A., Yuille, J and Madigan, S.A. (1968) Concreteness, imagery and meaningfulness values for 925 nouns. *Journal of Experimental Psychology*: Monograph Supplement, *76*.

Read, C. (1971) Pre-school children's knowledge of English phonology. *Harvard Educational Review*, *41*, 1-34.

Roeltgen, D.P. and Heilman. K.M. (1984) Lexical agraphia: further support for the two system hypothesis of linguistic agraphia. *Brain*, *107*, 811-827.

Roeltgen, D.P., Sevush, S. and Heilman, K.M. (1983). Phonological agraphia: Writing by the lexical-semantic route. *Neurology*, *33*, 755-765.

Rubin, H. (1988) Morphological knowledge and early writing ability. *Language and Speech*, *31*(4), 337-355.

SAS Institute Inc. (1985) *SAS User's Guide: Statistics*, Version 5 Edition. Cary, N.C.: SAS Institute.

Saussure, F de (1916) *Cours de Linguistique Generale*. Paris: Payot.

Scholnick, J. (1988) *The nature of the phoneme-grapheme conversion system*. Unpublished Honours dissertation. University of the Witwatersrand.

Schwartz, S. and Doehring, D.D.G. (1977) A developmental study of children's ability to acquire knowledge of spelling patterns. *Developmental Psychology*, *13*(4), 419-420.

Seymour, P.H.K. (1987) Developmental dyslexia: a cognitive experimental analysis. IN M. Coltheart, G. Sartori and R. Job (Eds), *The Cognitive Neuropsychology of Language*. London: Lawrence Erlbaum Associates Ltd.

Seymour, P.H.K. (1990) Developmental dyslexia. IN M.W Eysenck, (Ed.), *Cognitive Psychology: An International Review*. Chichester: John Wiley and Sons.

Shallice, T. (1981) Phonological agraphia and the lexical route in wrting. *Brain*, *104*, 413-429.

Siegel, L.S. and Ryan, E.B. (1989) The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development*, *60*, 973-980.

Simon, D.P. and Simon, H.A. (1977) Alternative uses of phonemic information in spelling. *Review of Educational Research*, *43*(1), 115-137.

Teale, W.N. and Sulzby, E. (Eds). (1986) *Emergent Literacy: Writing and Reading*. Norwood, NJ: Ablex.

Tenney, Y.J. (1980) Visual factors in spelling. IN U Frith, (Ed.), *Cognitive*

Processes in Spelling. London: Academic Press.

Treiman, R and Zukowski, A. (1988) Units in reading and spelling. *Journal of Memory and Language, 27*, 466-477.

Venezky, R.L. (1970) *The Structure of English Orthography*. The Hague: Mouton.

Waters, G.S., Bruck, M. and Malus- Abramowitz, M. (1988) The role of linguistic and visual information in spelling: a developmental study. *Journal of Experimental Child Psychology, 45*, 400-421.

Widrow, B and Stearns, S.D. (1985) *Adaptive Signal Processing*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Wing, A.M. and Baddeley, A.D. (1980) Spelling errors in handwriting: a corpus and a distribution analysis. IN U. Frith (Ed.), *Cognitive Processes in Spelling*. London: Academic Press.

APPENDIX A

TABLE OF PHONEME-GRAPHEME CORRESPONDENCES

CORR. = Correspondence.
FREQ. refers to the frequency with which the grapheme maps onto a particular phoneme in English. Hanna et al. frequencies were used primarily, and those of Lee have been incorporated when necessary.
MOP = Mapping Option Probability, and refers to the probability of occurrence of each correspondence. It is the distribution percentage of within-correspondance-category Frequencies (FREQ).

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/ə/	27	01	er	soldier	1969	23.61
		02	o	idiom	1611	19.34
		03	a	canvas	1438	17.27
		04	i	scissors	1340	17.27
		05	e	mineral	763	9.16
		06	ou	pious	336	4.04
		07	u	medium	297	3.57
		08	ar	anarchist	171	2.05
		09	or	scissors	163	1.96
		10	e-e	science	101	1.21
		11	y	syrup	23	0.28
		12	ie	mischievous	22	0.26
		13	o-e	welcome	21	0.15
		14	ur	Saturday	12	0.14
		15	eo	pigeon	10	0.12
		16	ai	certain	9	0.11
		17	eou	courageous	8	0.10
		18	i-e	engine	6	0.07
		19	u-e	capture	4	0.05
		20	a-e	pirate	4	0.05
		21	ea	sergeant	3	0.04
		22	ei	foreign	3	0.04
		23	ol-e	tortoise	2	0.02
		24	in	parliament	2	0.02
		25	au	epaulet	2	0.02
		26	ir	elixir	1	0.01
		27	re	manoeuvre	1	0.01

PHONEME	AMBIGUITY INDEX	CORRENC.	GRAPHEME	EXAMPLE	FREQ	MOP
/i/	20	01	i	wiggle	5346	68.42
		02	y	myth	1801	23.05
		03	i-e	give	339	4.33
		04	a-e	senate	187	2.39
		05	ey	donkey	40	0.51
		06	ie	mischief	29	0.37
		07	ui	build	16	0.21
		08	ai	captain	15	0.19
		09	ei	forfeit	11	0.14
		10	ee	been	6	0.08
		11	e	pretty	5	0.06
		12	a	spinach	4	0.05
		13	ia-e	marriage	3	0.04
		14	u	busy	3	0.04
		15	u-e	minute	3	0.04
		16	o-e	privelege	1	0.01
		17	ea	guinea	1	0.01
		18	ie-e	sieve	1	0.01
		19	o	women	1	0.01
		20	y-e	apocalypse	1	0.01
/ei/	18	01	a	angel	1002	44.53
		02	a-e	ape	790	35.11
		03	ai	daily	208	9.24
		04	ay	clay	131	5.82
		05	ai-e	praise	18	0.08
		06	eigh	weigh	18	0.08
		07	e	regime	16	0.71
		08	ea	break	14	0.62
		09	ei	vein	14	0.62
		10	ey	they	14	0.62
		11	et	beret	9	0.40
		12	e-e	fete	6	0.27
		13	aigh	straight	4	0.18
		14	ei-e	Seine	2	0.09
		15	ee	matinee	1	0.04
		16	au-e	gauge	1	0.04
		17	ay-e	aye	1	0.04
		18	ae	Israeli	1	0.04

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/i:/	16	01	e	enormous	1765	69.54
		02	ee	feed	249	9.81
		03	ea	beat	245	9.65
		04	e-e	scene	62	2.44
		05	i-e	naive	44	1.73
		06	i	ski	38	1.49
		07	ie	chief	33	1.30
		08	ea-e	please	30	1.18
		09	ie-e	piece	23	0.90
		10	ei	ceiling	16	0.63
		11	ee-e	geese	9	0.35
		12	ei-e	seize	6	0.23
		13	ey	key	6	0.23
		14	ae	algae	5	0.19
		15	oe	amoeba	5	0.19
		16	eo	people	2	0.07
/u:/	16	01	oo	school	173	38.27
		02	u	truth	93	20.58
		03	o	two	37	8.19
		04	u-e	rude	34	7.52
		05	ou	soup	29	6.42
		06	ew	threw	22	4.87
		07	ue	blue	16	3.54
		08	oo-e	choose	12	2.66
		09	o-e	lose	12	2.66
		10	ui	fruit	6	1.33
		11	eu	sleuth	4	0.89
		12	oe	shoe	4	0.89
		13	ui-e	juice	4	0.89
		14	ou-e	route	3	0.67
		15	ough	through	2	0.44
		16	oeu	manoeuvre	1	0.22

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/ou/	14	01	o	ghost	1876	77.65
		02	o-e	c^de	370	15.32
		03	oa	coat	126	5.22
		04	ow	own	124	5.13
		04	ow	bow	13	0.54
		05	oe	toe	8	0.33
		06	ough	dough	6	0.25
		07	eau	beau	4	0.17
		08	oh	oh	3	0.12
		09	au	hauteur	3	0.12
		10	ew	sew	3	0.12
		11	ou	shoulder	3	0.12
		12	au-e	mauve	2	0.08
		13	ow-e	owe	1	0.04
		14	oo	brooch	1	0.04
/ə:/	14	01	e	certain	313	39.62
		02	u	burn	203	25.70
		03	i	bird	104	13.17
		04	o	word	53	6.71
		05	e-e	verse	41	5.19
		06	ea	learn	29	3.67
		07	ou	journey	21	2.66
		08	u-e	curse	10	1.27
		09	eu	amateur	6	0.76
		10	ea-e	hearse	2	0.25
		11	y	myrtle	2	0.25
		12	i-e	dirge	1	0.13
		13	o-e	worse	1	0.13
		14	ou-e	scourge	1	0.13
/ai/	13	01	i-e	ice	555	37.48
		02	i	island	554	37.41
		03	y	typist	211	14.25
		04	igh	light	88	5.94
		05	ie	lie	26	1.76
		06	y-e	rhyme	23	1.55
		07	ey-e	eye	7	0.47
		08	ei	stein	6	0.40
		09	a	kayak	3	0.20
		10	eigh	height	3	0.20
		11	uy	buy	3	0.20
		12	ai-e	aisle	1	0.06
		13	ae	maestro	1	0.06

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/e/	13	01	e	beg	3316	90.94
		02	ea	head	139	3.81
		03	a	many	94	2.57
		04	e-e	ledge	79	2.16
		05	ai	said	4	0.10
		06	ie	friend	4	0.10
		07	eo	leopard	3	0.08
		08	u	bury	2	0.05
		09	a-e	orange	1	0.02
		10	ae	aerosol	1	0.02
		11	ay	says	1	0.02
		12	ea-e	cleanse	1	0.02
		13	ei	heifer	1	0.02
/ɔ:/	13	01	or	cork	312	40.47
		02	a	water	165	21.40
		03	au	autumn	146	18.94
		04	aw	dawn	75	9.73
		05	or-e	horse	17	2.21
		06	ough	thought	15	1.95
		07	augh	daughter	12	1.56
		08	oar	board	9	1.17
		09	au-e	cause	9	1.17
		10	ao	extraordinary	2	0.26
		11	aw-e	awe	2	0.26
		12	our	four	2	0.26
		13	oo	door	2	0.26
/ju/	11	01	u	fusion	814	68.51
		02	u-e	use	256	21.54
		03	ew	news	38	3.19
		04	eu	feud	28	2.35
		05	ue	value	27	2.27
		06	ui	suit	8	0.67
		07	iew	view	6	0.50
		08	eau	beauty	5	0.42
		09	ieu	lieu	4	0.33
		10	eu-e	deuce	1	0.08
		11	ew-e	ewe	1	0.08

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/ɛ/	09	01	a	vary	64	29.09
		02	a-e	care	50	22.72
		03	ai	hair	46	20.90
		04	e-e	where	34	15.45
		05	ea	bear	13	5.90
		06	ei	their	5	2.27
		07	e	bolero	4	1.81
		08	ai-e	millionaire	3	1.36
		09	ey	eyrie	1	0.45
/iː/	08	01	e	hero	64	32.32
		02	ea	near	49	24.74
		03	ee	deer	36	18.18
		04	e-e	here	27	13.63
		05	ie	cashier	14	7.07
		06	i	souvenir	3	1.51
		07	ie-e	fierce	3	1.51
		08	ei	weird	2	1.01
/ʌ/	07	01	u	cuff	1212	85.90
		02	o	mother	112	7.94
		03	ou	touch	30	2.13
		04	o-e	come	26	1.84
		05	u-e	budge	23	1.63
		06	oo	blood	7	0.50
		07	oe	does	1	0.07
/ɑː/	07	01	a	father	518	89.16
		02	a-e	large	31	5.34
		03	ea	heart	18	3.10
		04	e	encore	5	0.86
		05	ah	bah	4	0.69
		06	au	aunt	4	0.69
		07	aa	baa	1	0.17
/ɔ/	07	01	o	odd	1681	93.65
		02	a	yacht	80	44.57
		03	o-e	dodge	24	1.34
		04	ow	knowledge	4	0.22
		05	au	sausage	4	0.22
		06	ou	cough	1	0.06
		07	eau	bureaucracy	1	0.06

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/au/	06	01	ou	cloud	227	55.77
		02	ow	clown	119	29.24
		03	ou-e	house	54	13.27
		04	ough	drought	4	0.98
		05	ow-e	browse	2	0.49
		06	au	saurkraut	1	0.25
/ʊ/	06	01	u	put	200	75.19
		02	oo	good	114	42.86
		03	ou	could	25	9.40
		04	o	woman	17	6.40
		05	u-e	pure	9	3.38
		06	eu	pleurisy	1	0.38
/ɔi/	04	01	oi	oil	92	61.74
		02	oy	boy	48	32.21
		03	oi-e	voice	8	5.36
		04	oy-e	gargoyle	1	0.67
/əiə/	04	01	ire	fire		
		02	iar	liar		
		03	ier	drier		
		04	igher	higher		
/ɐ/	03	01	a	bag	4192	96.58
		02	a-e	have	147	3.38
		03	ai	plait	1	0.02
/uə/	03	01	ure	sure		
		02	oor	poor		
		03	our	tour		
/əuə/	02	01	our	hour		
		02	ower	cower		
/eiə/	02	01	ayer	layer		
		02	eyer	greyer		
/ouə/	01	01	ower	mower		

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/ʃ/	15	01	ti	auctioneer	820	53.35
		02	sh	shoe	398	25.89
		03	ci	social	81	5.27
		04	ssi	passion	51	3.31
		05	si	tension	38	2.47
		06	c	oceanic	38	2.47
		07	ch	charade	34	2.21
		08	t	negotiate	30	1.95
		09	s	sure	20	1.30
		10	ss	pressure	9	0.58
		11	sc	crescendo	6	0.39
		12	sci	luscious	5	0.32
		13	xi	anxious	3	0.23
		14	ce	ocean	2	0.13
		15	sch	schweppes	2	0.13
/k/	12	01	c	act	3452	73.25
		02	k	key	601	12.75
		03	ck	luck	290	6.15
		04	ch	school	142	3.01
		05	cc	tobacco	76	1.61
		06	qu	queue	27	0.57
		07	q	liquid	20	0.42
		08	lk	talk	14	0.29
		09	cq	acquiesce	3	0.06
		10	kh	khaki	3	0.06
		11	sc	viscount	3	0.06
		12	cch	saccharin	1	0.02
/s/	10	01	s	ask	4599	72.69
		02	c	acid	1067	16.86
		03	ss	bass	442	6.98
		04	sc	muscle	77	1.21
		05	st	hasten	33	0.52
		06	ps	psychology	19	0.30
		07	z	waltz	6	0.14
		08	sw	answer	4	0.06
		09	sch	schism	2	0.03
		10	sth	asthma	1	0.01

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/t/	09	01	t	towel	7528	96.59
		02	tt	pretty	216	2.77
		03	ed	paced	28	0.35
		05	tw	two	3	0.08
		06	pt	receipt	2	0.02
		07	ct	indict	2	0.02
		08	cht	yacht	2	0.02
		09	th	thyme	1	0.01
/dʒ/	07	01	g	gem	647	65.88
		02	j	juice	218	22.24
		03	dg	dodge	51	5.19
		04	dj	adjust	16	1.62
		05	gi	region	14	1.42
		06	gg	exaggerate	2	0.20
		07	di	soldier	2	0.20
/z/	06	01	s	busy	640	64.32
		02	z	zoo	229	23.01
		03	es	goes	44	4.42
		04	zz	puzzles	23	2.33
		05	ss	scissors	13	1.30
		06	cz	czar	1	0.10
/f/	06	01	f	fruit	1580	78.25
		02	ph	graphic	242	12.02
		03	ff	coffee	177	8.76
		04	lf	half	9	0.44
		05	gh	cough	8	0.39
		06	ft	often	3	0.14
/m/	06	01	m	medium	3302	94.31
		02	mm	immediate	140	3.99
		03	mb	lamb	27	0.77
		04	lm	calm	17	0.49
		05	mn	autumn	7	0.23
		06	gm	phlegm	8	0.22

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/n/	06	01	n	news	7452	97.33
		02	nn	inn	127	11.65
		03	kn	knowledge	41	0.53
		04	gn	gnat	32	0.41
		05	pn	pneumonia	3	0.07
		06	mn	mnemonic	1	0.01
/tʃ/	05	01	ch	choose	313	55.49
		02	t	capture	175	31.03
		03	tch	hatch	61	10.81
		04	ti	question	13	2.33
		05	c	cello	2	0.35
/l̩/	05	01	le	able	620	95.23
		02	el	angel	19	2.91
		03	il	pencil	7	1.07
		04	al	plural	4	0.61
		05	ol	aerosol	1	0.18
/ʒ/	04	01	si	fusion	50	49.01
		02	s	measure	34	33.33
		03	g	regime	15	14.70
		04	z	azure	2	1.98
/g/	04	01	g	geese	1178	90.96
		02	gg	wiggle	67	5.17
		03	gu	guinea	40	3.09
		04	gh	ghost	10	0.77
/j/	04	01	i	senior	66	55.00
		02	y	kayak	53	44.17
		03	e	azalea	1	0.83
		04	i	hallelujah	1	0.83

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/r/	04	01	r	rude	9119	97.11
		02	rr	marriage	207	2.20
		03	wr	wraught	48	0.52
		04	rh	rhyme	16	0.17
/d/	04	01	d	dye	3611	97.83
		02	dd	odd	74	2.00
		03	ld	could	6	0.17
		04	ed	appeared		
/l/	03	01	l	law	4894	90.81
		02	ll	villain	489	9.07
		03	sl	island	5	0.11
/ŋ/	03	01	ng	long	362	58.86
		02	n	anxious	251	40.81
		03	ngue	tongue	2	0.33
/n̩/	03	01	en	women	84	65.02
		02	on	passion	41	32.04
		03	in	basin	3	2.34
/v/	03	01	v	vein	1485	99.54
		02	lv	calves	4	0.26
		03	f	of	3	0.20
/w/	03	01	w	weigh	578	92.35
		02	u	liquid	47	7.50
		03	o	once	1	0.15

PHONEME	AMBIGUITY INDEX	CORR. NO.	GRAPHEME	EXAMPLE	FREQ	MOP
/kw/	03	01	qu	quartz	191	96.95
		02	equ	acquaint	5	2.54
		03	ch	choir	1	0.51
/h/	02	01	h	hot	762	97.94
		02	wh	whole	16	2.06
/ks/	02	01	x	axe	245	90.41
		02	cs	ethics	26	9.59
/b/	02	01	b	board	2239	97.22
		02	bb	ebb	63	2.78
/p/	02	01	p	plate	3296	95.56
		02	pp	apple	153	4.44
/hw/	01	01	wh	where	89	100.00
/ ϕ /	01	01	h	hour	41	100.00
/M/	01	01	m	chasm		
/θ/	01	01	th	myth	411	100.00
/ð/	01	01	th	mother	149	100.00

APPENDIX B
MAPPING FREQUENCIES

Frequent-Mapping		Infrequent-Mapping	
legs	90.96	eggs	6.17
lords	90.96	odds	2.00
tube	96.59	space	16.86
self	72.69	grace	16.86
ship	25.89	stick	6.15
shield	25.89	stack	6.15
hole	90.81	sell	9.07
hail	90.81	yell	9.07
base	72.69	dress	6.96
bites	96.59	kiss	6.96
fish	25.89	talk	6.15
hush	25.89	chalk	6.15
cloud	55.77	house	13.27
clown	29.24	mouse	13.27
tube	21.54	bear	5.90
cube	21.54	pear	5.90
moon	38.36	tail	9.24
boot	38.36	hail	9.24
plan	3.57	voice	5.36
flap	96.57	axe	3.39
talk	21.40	cause	1.17
chalk	21.40	draws	9.73
gave	35.11	grew	4.88
fade	35.11	chew	4.88
Total	1322.50	Total	183.78
$\bar{x}$	55.14	$\bar{x}$ =	7.66

APPENDIX C
CONCRETE AND ABSTRACT NOUNS

Concrete		Abstract	
legs		lords	4.18
eggs	6.17	tube	
ship	6.93	odds	
stick	6.57	space	4.00
hail	6.03	self	4.74
house	6.93	grace	3.10
clown		stack	
mouse	6.69	hush	4.03
cube	5.69	cloud	
bear		moon	
pear	6.80	tube	
tail			
boot	6.89		
Total	59.24	Total	20.05
$\bar{x}$	6.60	$\bar{x}$ =	4.20

APPENDIX D
THE WORD LIST

Words with targetted consonants	Words with targetted vowels
legs	cloud
eggs	house
lords	clown
odds	mouse
tube*	tube*
space	bear
self	cube
grace	boot
ship	pear
stick	moon
shield	tail
stack	hail*
hole	plan
sell	voice
hail*	flap
yell	axe
base	talk*
dress	cause
bites	chalk*
kiss	draws
fish	gave
talk*	grew
hush	fade
chalk*	chew

* duplicate word administered once only.

APPENDIX E
THE SPELLING TEST

SPELLING WORDLIST

3/19/90

ACC. NO.	WORD	SENTENCE	WORD
1	chalk	CHALK up the score	chalk
2	kiss	KISS Mom goodbye	kiss
3	stick	Take a STICK from the tree	stick
4	grew	I GREW taller	grew
5	self	I went all by my SELF	self
6	odds	ODDS and ends	odds
7	stack	A STACK of books	stack
8	shield	Sunglasses SHIELD our eyes	shield
9	plan	PLAN a holiday	plan
10	sell	We might SELL our house	sell
11	chew	CHEW before you swallow	chew
12	legs	We have two LEGS	legs
13	ship	A SHIP at sea	ship
14	clown	The CLOWN is funny	clown
15	cause	That will CAUSE an accident	cause
16	fish	We like to FISH	fish
17	bites	The puppy BITES us	bites
18	eggs	Eggs for breakfast	eggs
19	grace	Say GRACE before dinner	grace
20	draws	He DRAWS pictures	draws
21	flap	See the bird's wings FLAP	flap
22	dress	DRESS quickly for school	dress
23	cube	A CUBE of sugar	cube
24	pear	This PEAR is juicy	pear
25	tube	A TUBE of toothpaste	tube
26	cloud	A CLOUD in the sky	cloud
27	axe	AXE the tree down	axe
28	base	We BASE our decision on facts	base
29	yell	YELL for help	yell
30	talk	We TALK about holidays	talk
31	space	Make a SPACE for me	space
32	lords	LORDS and ladies	lords
33	voice	VOICE your ideas	voice
34	mouse	Cat and MOUSE	mouse
35	hush	A HUSH of quietness	hush
36	hail	Will this rain turn to HAIL?	hail
37	fade	Colour does FADE	fade
38	bear	A BEAR in the zoo	bear
39	house	The HOUSE we live in	house
40	boot	A soccer BOOT	boot
41	hole	Bears HOLE up for winter	hole
42	moon	The MOON shines at night	moon
43	gave	He GAVE me a sweet	gave
44	tail	The cat chases her TAIL	tail

SPELLING WORDLIST

6/25/90

ACC. NO.	WORD	SENTENCE	WORD
1	house	The HOUSE we live in	house
2	grace	Say GRACE before dinner	grace
3	moon	The MOON shines at night	moon
4	space	Make a SPACE for me	space
5	kiss	KISS Mom goodbye	kiss
6	clown	The CLOWN is funny	clown
7	lords	LORDS and ladies	lords
8	cube	A CUBE of sugar	cube
9	hail	Will this rain turn to HAIL?	hail
10	ship	A SHIP at sea	ship
11	gave	He GAVE me a sweet	gave
12	chalk	CHALK up the score	chalk
13	mouse	Cat and MOUSE	mouse
14	fade	Colour does FADE	fade
15	plan	PLAN a holiday	plan
16	draws	He DRAWS pictures	draws
17	voice	VOICE your ideas	voice
18	legs	We have two LEGS	legs
19	yell	YELL for help	yell
20	axe	AXE the tree down	axe
21	cloud	A CLOUD in the sky	cloud
22	flap	See the bird's wings FLAP	flap
23	hush	A HUSH of quietness	hush
24	talk	We TALK about holidays	talk
25	cause	That will CAUSE an accident	cause
26	base	We BASE our decision on facts	base
27	odds	ODDS and ends	odds
28	pear	This PEAR is juicy	pear
29	chew	CHEW before you swallow	chew
30	grow	I GREW taller	grew
31	tube	A TUBE of toothpaste	tube
32	dress	DRESS quickly for school	dress
33	stack	A STACK of books	stack
34	bites	The puppy BITES us	bites
35	fish	We like to FISH	fish
36	self	I went all by my SELF	self
37	stick	Take a STICK from the tree	stick
38	bear	A BEAR in the zoo	bear
39	tail	The cat chases her TAIL	tail
40	shield	Sunglasses SHIELD our eyes	shield
41	hole	Bears HOLE up for winter	hole
42	eggs	Eggs for breakfast	eggs
43	sell	We might SELL our house	sell
44	boot	A soccer BOOT	boot

SPELLING WORDLIST

9/15/90

ACC. NO.	WORD	SENTENCE	WORD
1	tail	The cat chases her TAIL	tail
2	tube	A TUBE of toothp ste	tube
3	grew	I GREW taller	grew
4	hail	Will this rain turn to HAIL?	hail
5	shield	Sunglasses SHIELD our eyes	shield
6	grace	Say GRACE before dinner	grace
7	legs	We have two LEGS	legs
8	odds	ODDS and ends	odds
9	clown	The CLOWN is funny	clown
10	cloud	A CLOUD in the sky	cloud
11	boot	A soccer BOOT	boot
12	eggs	Eggs for breakfast	eggs
13	space	Make a SPACE for me	space
14	base	We BASE our decision on facts	base
15	chalk	CHALK up the score	chalk
16	ship	A SHIP at sea	ship
17	talk	We TALK about holidays	talk
18	lords	LORDS and ladies	lords
19	gave	He GAVE me a sweet	gave
20	stick	Take a STICK from the tree	stick
21	fish	We like to FISH	fish
22	axe	AXE the tree down	axe
23	voice	VOICE your ideas	voice
24	house	The HOUSE we live in	house
25	hush	A HUSH of quietness	hush
26	flap	See the bird's wings FLAP	flap
27	cause	That will CAUSE an accident	cause
28	bear	A BEAR in the zoo	bear
29	cube	A CUBE of sugar	cube
30	hole	Bears HOLE up for winter	hole
31	mouse	Cat and MOUSE	mouse
32	yell	YELL for help	yell
33	kiss	KISS Mom goodbye	kiss
34	sell	We might SELL our house	sell
35	dress	DRESS quickly for school	dress
36	pear	This PEAR is juicy	pear
37	fade	Colour does FADE	fade
38	stack	A STACK of books	stack
39	mo	The MOON shines at night	moon
40	pla	PLAN a holiday	plan
41	b tes	The puppy BITES us	bites
42	chew	CHEW before you swallow	chew
43	self	I went all by my SELF	self
44	draws	He DRAWS pictures	draws

APPENDIX F
SAMPLE ANSWER SHEETS

Name: Std: Age: Sex:

1. _____ 16. _____ 31. _____

2. _____ 17. _____ 32. _____

3. _____ 18. _____ 33. _____

4. _____ 19. _____ 34. _____

5. _____ 20. _____ 35. _____

6. _____ 21. _____ 36. _____

7. _____ 22. _____ 37. _____

8. _____ 23. _____ 38. _____

9. _____ 24. _____ 39. _____

10. _____ 25. _____ 40. _____

11. _____ 26. _____ 41. _____

12. _____ 27. _____ 42. _____

13. _____ 28. _____ 43. _____

14. _____ 29. _____ 44. _____

15. _____ 30. _____

Example of the Response Sheet to be used for the Working Memory - Counting Task

DOT COUNTING SPAN
One card set:

____

____

____

Two card set:

____ ____

____ ____

____ ____

Three card set:

____ ____ ____

____ ____ ____

____ ____ ____

Four card set:

____ ____ ____ ____

____ ____ ____ ____

____ ____ ____ ____

Five card set:

____ ____ ____ ____ ____

____ ____ ____ ____ ____

____ ____ ____ ____ ____

APPENDIX G
INSTRUCTIONS FOR THE SPELLING TEST

NOTE TO TEACHERS

This spelling test has been devised for the purpose of examining cognitive aspects of how primary school children acquire spelling proficiency. In preparing the list, the words that have been selected are controlled on a number of psycholinguistic dimensions, such as word length and frequency of usage. In this way these words will be used to assess the variety of performance factors known to influence spelling accuracy.

INSTRUCTIONS

Please give a blank answer sheet to each child, and ask them to fill in the information requested at the top of the form.

Before beginning, note that this is not a tes' for marks, and mention that you will not be looking at their answers. Also mention some words will be very easy to write and others difficult. They must do their best and try every word. It is important that they do not leave any out.

PROCEDURE

Read each word you want them to spell. Use it in a sentence, as given, then repeat the word. Allow time to write the word.

THANK YOU FOR ADMINISTERING THIS TEST

APPENDIX H
REVISED STIMULI
Crosstabulation analysis of the revised selection of high-frequency words, showing they are counterbalanced for log normal Word Frequency across the dimensions of Grammatical Word Class (GWC), Mapping Frequency (MF) and Ambiguity.
(a) High-Frequency Words: Consonants.

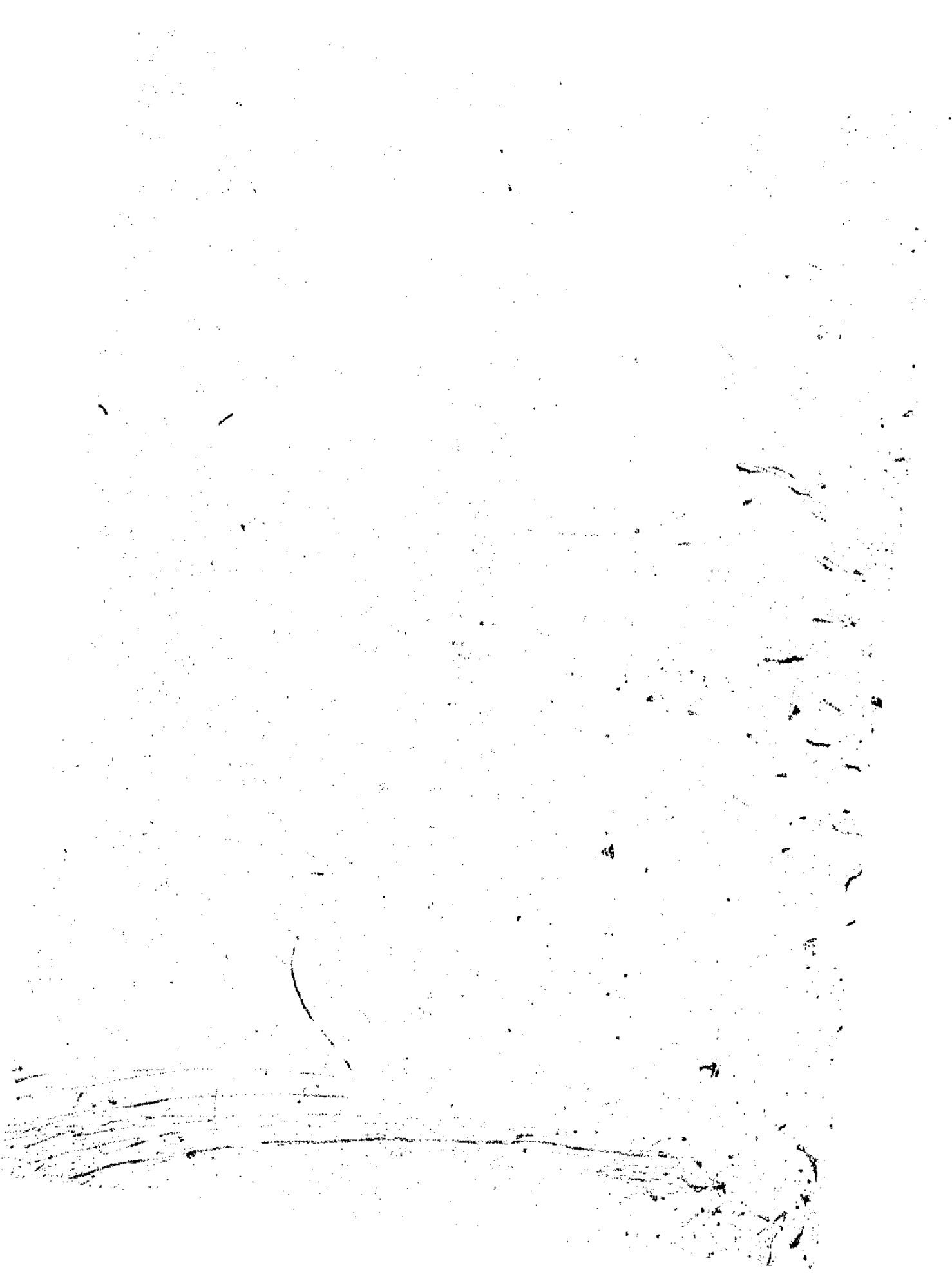
GWC	MF	AMBIGUITY						$\overline{x}$ log normal freq.
		High		Moderate		Low		
nouns	freq	ship	2.2	stick	2.0	legs	2.2	2.2
	infreq	stick	2.0	space	2.4	eggs	2.1	
verbs	freq	fish	2.4	sell	1.9	hole	1.9	2.0
	infreq	talk	2.3	dress	1.8	sell	1.9	
$\overline{x}$ log normal freq			2.2		2.0		2.0	total $\overline{x}$ = 2.1

median = 2.15; $SD = 0.22$.

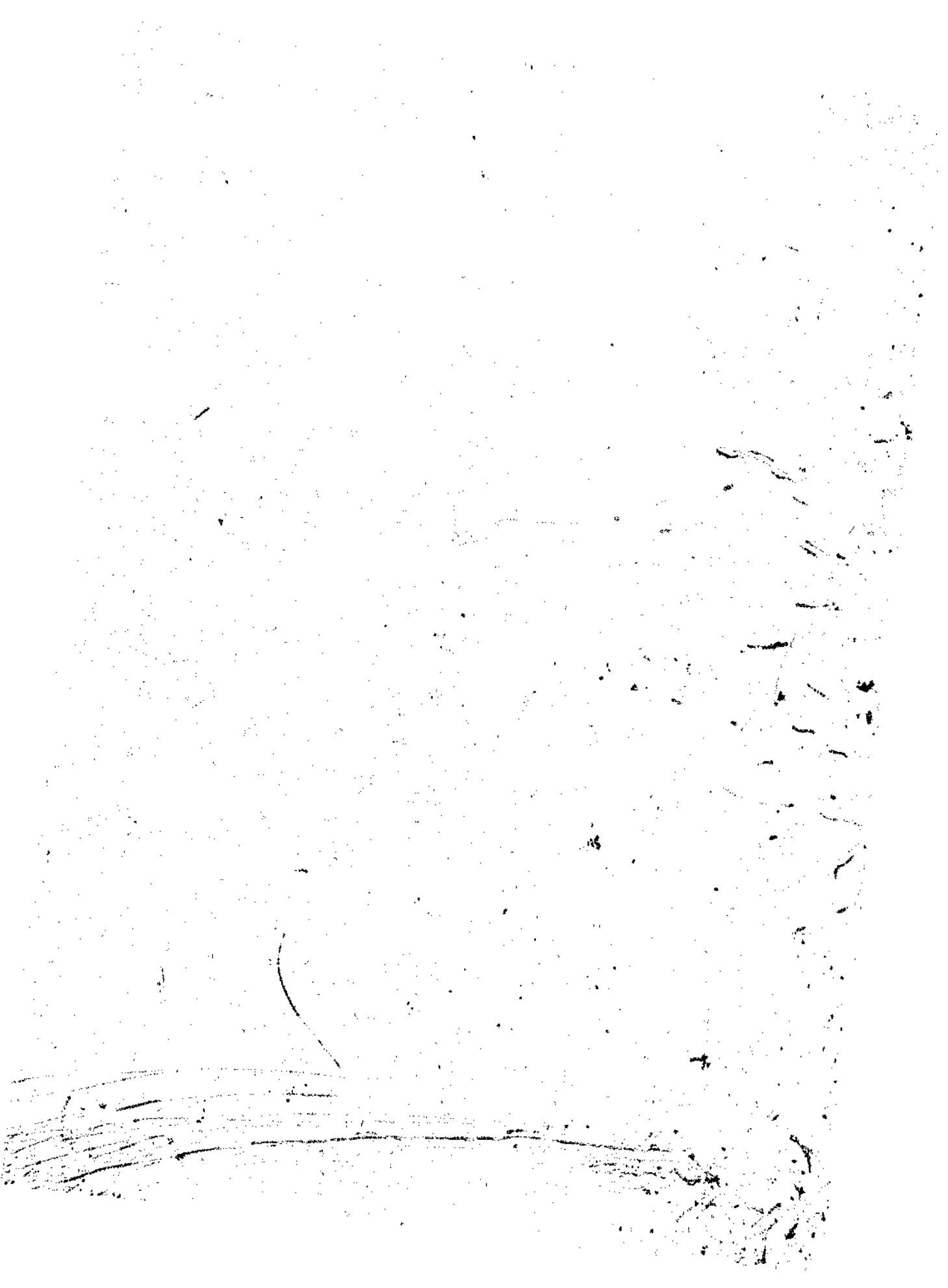
(b) High-Frequency Words: Vowels.

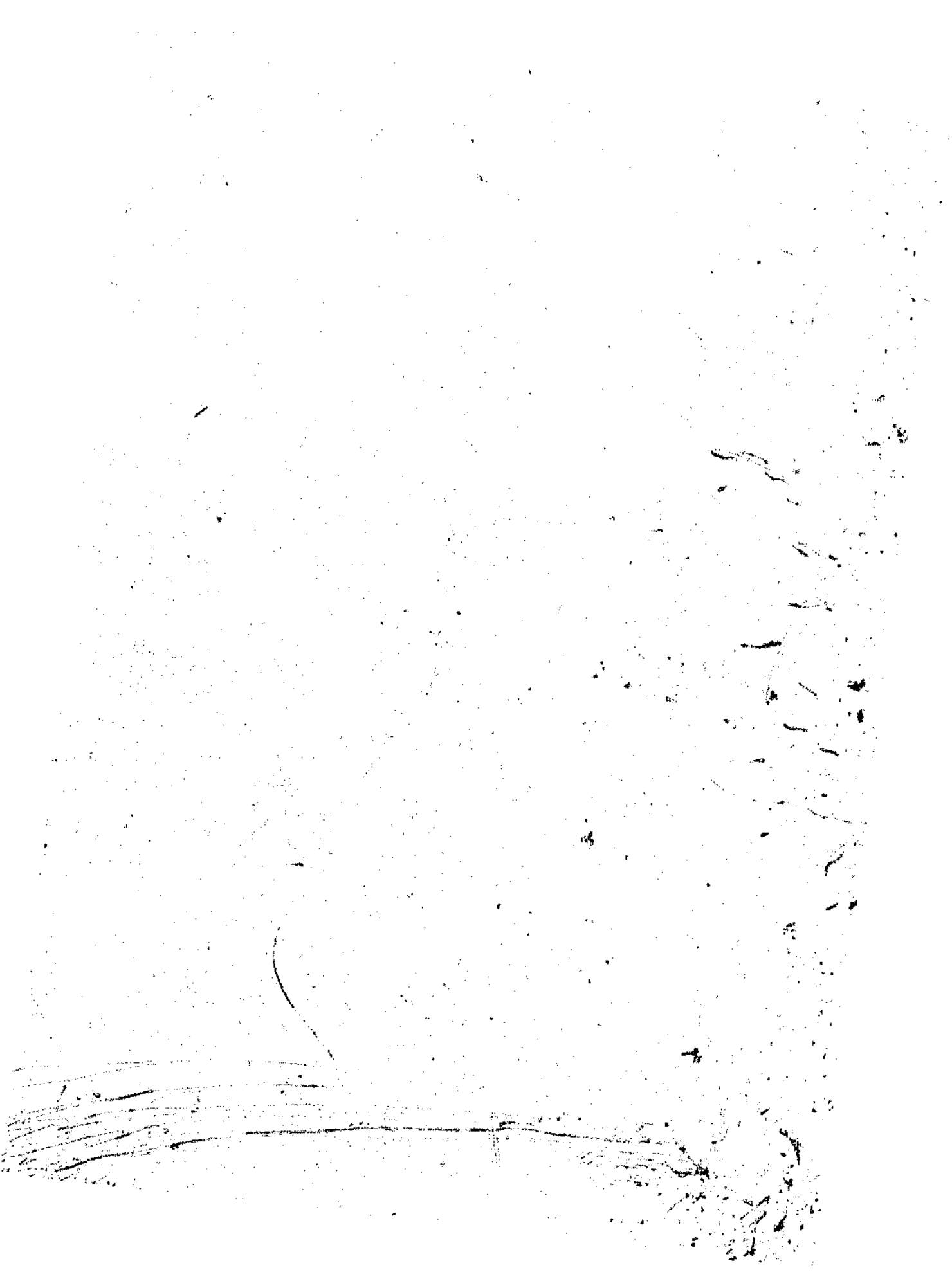
GWC	MF	AMBIGUITY						$\overline{x}$ log normal freq.
		High		Moderate		Low		
nouns	freq	moon	2.3	tube	1.8	cloud	1.7	2.1
	infreq	tail	2.0	bear	2.0	house	2.6	
verbs	freq	gave	2.4	talk	2.3	plan	2.1	2.2
	infreq	grew	2.2	cause	1.9	voice	2.3	
$\overline{x}$ log normal freq			2.2		2.0		2.2	total $\overline{x}$ = 2.1

median = 2.15; $SD = 0.26$.









Author: Antoine, Wendy.
Name of thesis: The modelling of spelling processes- a developmental perspective.

PUBLISHER:
University of the Witwatersrand, Johannesburg
©2015

LEGALNOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page)for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.