INFLECTIONAL MORPHOLOGY IN THE LITERACY OF DEAF CHILDREN

by

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ABSTRACT

Severe literacy impairments are well documented in the deaf population. Morphology provides a source of text-to-meaning associations that should be available to the deaf. In this thesis, different levels of morphological awareness necessary for literacy were tested. Deaf children demonstrated that they associated morphologically related words – the first level of awareness. This was evidenced in a short-term memory task in which words sharing morphological overlap were confused more often than words sharing orthographic or semantic overlap (although these associations may have involved the combined effects of orthographic and semantic overlap). Deaf children also demonstrated knowledge of morphological generalisation (the second level of awareness) by producing predicted plural nonword spellings and over-regularisations. Finally, they demonstrated morpho-syntactic awareness – in a self-paced reading task they revealed sensitivity to subject-verb number agreement. However, deaf children demonstrated limited knowledge of irregular plural nouns and of morpho-syntax. In the self-paced reading task, they were slow to perform syntactic integration and they failed to make explicit use of agreement in a judgement task. Furthermore, even reading-age appropriate morphological awareness represents a substantial chronological delay. The findings therefore suggest that deaf children could benefit from explicit education in morphographic rules and exceptions as well as training in morpho-syntax.

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Dedicated to Pamela Malcolm and Elizabeth Breadmore,

For helping journeys to begin.

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CHAPTER ONE

GENERAL INTRODUCTION

The present thesis examines deaf children's knowledge of English morphology within the context of literacy acquisition. Severe literacy impairments are well documented in the deaf population (Conrad, 1979; Gaustad, Kelly, Payne, & Lylak, 2002; Powers, Gregory, & Thoutenhoofd, 1998) and the received view is that these impairments are due to limited phonological awareness resulting in a focus on inefficient visual-orthographic strategies (Aaron, Keetay, Boyd, Palmatier, & Wacks, 1998; Musselman, 2000; Sterne & Goswami, 2000). Morphology may provide an alternative source of text-to-meaning associations that could be utilised to aid literacy acquisition.

Chapter Two provides a review of background information relevant to the present thesis. The demographics of the British deaf population are described and the different modes of communication and education prevalent within the UK are summarised. Models of literacy acquisition for hearing children are considered and discussed with reference to the implications for the literacy of deaf children. The received view that literacy impairments within the deaf population are due to limited access to the phonological route will be highlighted. Morphology will then be presented as an alternative source of text-to-meaning mappings which, like phonology, provides a means of segmenting text into smaller units and which is highly productive. Morphology is also more likely to be available to the deaf, since it is visible in the orthography as well as in spoken language. Hearing children have pre-existing knowledge of morphology from speech which they can apply when they learn to read and write. However, the rules for morpheme combination in spoken and written language do not always correspond and therefore hearing children must also acquire understanding of morphology that is specific to literacy. Having argued for the importance of morphological awareness for literacy development, research relating to morphological awareness in spoken language and the existent research relating to morphology and literacy in deaf and hearing children will be discussed. Finally, a testable model will be presented providing levels of morphological awareness that must be achieved in order for the child to use morphology in their growing understanding of orthography. This model will then form the basis of the remainder of this thesis, with each level of the model tested in a series of experiments presented in a separate chapter.

Chapters Three and Four present a novel short-term memory (STM) probe task which is developed to assess awareness of the relationships between morphologically related words and which can distinguish awareness of morphological overlap from orthographic and semantic overlap. Experiments 1a and 1b (Chapter Three) establish the validity of the experimental paradigm for measuring these relationships within a sample of hearing adults. Experiment 2a and 2b (Chapter Four) apply the STM probe task to a sample of deaf and hearing children to assess whether deaf children can demonstrate an awareness of morphological relationships that is comparable to reading-age matched hearing children.

Having explored deaf children's awareness of morphological relationships, Chapter Five examines whether deaf children can use morphographic correspondences productively in a series of plural noun and nonword spelling tasks. Experiments 3a and 3c assessed deaf children's accuracy at spelling English plural nouns varying in regularity. Productive use of morphology predicts that morphographically regular words will be easier to spell than irregular words and that errors on irregular words will result from over-generalisation of morphological rules (e.g., **foots* for *feet*). However, mature understanding of plural formation requires that the speller also learns the exceptions. Experiment 3b examines spellings of nonword plurals to assess whether deaf children are able to extend their understanding of plural formation to novel words.

Chapter Six investigates whether deaf children use morphological knowledge when comprehending sentences. It examines awareness of subject-verb number agreement, which operates at the sentence level by coordinating number marked nouns with number marked verbs. Therefore, awareness of subject-verb agreement involves applying understanding of morphology at the single-word to the sentence level, through understanding morpho-syntax. At this point, inflectional morphology must operate not only to relate words within the lexicon but extend to syntactic processing. Not only must the reader understand the respective rules for inflecting nouns and verbs for number but they must also keep these number markers in mind and learn to check that they match during syntactic integration.

Experiment 4a assesses deaf children's knowledge of plural nouns as a pre-test to the main experiments of Chapter Six. Experiment 4b examines implicit awareness of subject-verb number agreement within the context of a self-paced reading task. Deaf children, reading-age matched hearing children and hearing adults read sentences containing agreeing or disagreeing number markers on the subject and verb (e.g., *the* ***bubbles float*** *over the fence* vs. *the* ***bubbles floats*** *over the fence*). Awareness of agreement is demonstrated in this task by increased reading times for sentences that contain disagreeing subject-verb number markers. The final experiment, Experiment 4c, tests participants' explicit use of their knowledge of agreement. Participants completed a pencil-and-paper judgement task in which they read sentences containing agreeing or disagreeing number markers and had to state whether the sentence contained an error. If they thought the sentence contained an error, they then had to correct the sentence, thereby explicitly manipulating the number markers on the subject or verb. This level of morphological awareness represents the final level that is necessary in order to use morphology to assist literacy. Once the child has acquired this level of understanding, they should be able to notice errors in their own writing and correct them appropriately.

Finally, Chapter Seven reviews the findings from all experiments within the context of the levels of morphological awareness described in Chapter Two, before presenting conclusions regarding the level of morphological awareness achieved in the deaf samples examined in the present thesis. Areas where the deaf children appeared to be deficient in morphological understanding will be highlighted and the implications for education discussed. Finally, limitations of the present research and ideas for future research will be described.

CHAPTER TWO

LITERATURE REVIEW

The present chapter reviews the current literature regarding the role of morphology in the literacy acquisition of deaf children. The degree of literacy impairment typically observed within the deaf population will be described before presenting some demographics of the British deaf population, including levels of hearing loss, preferred modes of communication and education. Having provided background information regarding the deaf population, models of literacy development will be discussed with reference to the implications for the deaf, highlighting the received view that literacy impairments are the result of limited access to the phonological route. Morphology will be presented as an alternative source of regularity that may provide a means of obtaining meaning from text without necessarily relying on phonology. Morphology is visible in the orthography and therefore available to the deaf chid. It will be argued that hearing children learn about morphology from their experience with speech prior to acquiring literacy but, because morphological rules in speech and spelling do not always correspond, they must also acquire knowledge of morphology that is specific to text. Research into to the development of morphological awareness in speech and literacy will be discussed. Finally, a testable model will be presented that provides levels of morphological awareness that must be achieved so that morphology can be used to assist literacy acquisition.

2.1 Literacy impairments in the deaf population

In an extensive investigation of the reading abilities of 468 deaf and hearing-impaired British school leavers (aged 15–16;6 years), Conrad (1979) demonstrated that their median reading-age was equivalent to a 9-year-old hearing child. More recent reviews of deaf children living in Britain and abroad consistently demonstrate a similar degree of literacy impairment at this age (e.g., Gaustad et al., 2002; Powers et al., 1998). The socioeconomic implications of impaired literacy are profound, impacting on education, employment, recreational opportunities and even health (Bowe, 2002; Luckner, Sebald, Cooney, Young, & Muir, 2005). Considering that deaf individuals often have difficulty accessing spoken language, the implications of impaired literacy are further compounded within this population. The ability to read and write effectively would provide a deaf child with an important means of accessing the hearing world, whilst impairment presents an even larger hurdle to overcome.

It has been argued that deaf adolescents reach a plateau, rarely acquiring literacy beyond the equivalent of an 8 to 9-year-old hearing child (Allen, 1986; Musselman & Szanto, 1998). Although the average reading delay appears to increase at adolescence (Allen, 1986), there is a great deal of individual variation in literacy skill, with some deaf children apparently developing age appropriately and becoming highly literate deaf adults (Geers & Moog, 1989; Kelly, 1993; Volterra & Bates, 1989; Waters & Doehring, 1990). Nevertheless, these literate individuals form the minority of the deaf population (Marschark & Harris, 2006). Amongst the 205 profoundly deaf school leavers examined by Conrad (1979), only five were reading-age appropriately whereas almost 50% failed to provide *any* correct responses on the reading measure (representing a reading-age less than 7;0 years). In a report to the DfEE in the UK, Powers et al. (1998, p8) stated that there was '*no evidence to demonstrate an overall significant improvement in the education of deaf children since Conrad's study*'.

2.2 Demographics of the British deaf population

In the UK there are around 8,945,000 deaf and hard of hearing people. 1:1000 children are deaf by the age of 3 and there are around 20,000 children (aged 0–15 years) who are moderately-to-profoundly deaf (RNID, 2007). The deaf population is heterogeneous and many of the variations may impact on literacy acquisition. Deaf people differ in terms of cause and degree of deafness, use (and effectiveness) of hearing aids, cochlear implants and whether they became deaf before or after initiating language acquisition. They differ in their preferred mode of receptive and expressive communication, relative competence in different languages, the age at which they acquired these languages and their educational experiences. The impact that these individual differences have on literacy acquisition will be discussed further below.

Proponents of the *simple view* of literacy development argue that reading acquisition builds on pre-existing language skills, that is, speech (Juel, 1988; Juel, Griffith, & Gough, 1986) and therefore literacy skill is necessarily tied to proficiency in spoken language. To date, the majority of research into literacy impairments within the deaf population has focused on the relationship between speech and literacy. It is for this reason that, when describing the heterogeneity of the deaf population below, an emphasis is placed on the effects on English language competence. There is no intention for the present thesis to imply superiority of particular modes of communication or education. These are complex issues and any such discussion should consider the broader ability of the individual child to communicate generally as well as the implications for their sense of identity, community and general well-being. This is clearly outside of the remit of the present thesis.

2.2.1 Levels of deafness

The amount of auditory speech reception a deaf individual has experienced is dependent not only on their degree of deafness but also the age they became deaf and the use of hearing aids and/or cochlear implants. Level of deafness is defined by the quietest audible sounds in decibels. Better ear average (henceforth BEA) refers to the average hearing loss at the frequencies 500 Hz, 1000 Hz and 2000 Hz and this measurement is used to classify levels of deafness (Leybaert, 2005). The categories and descriptions presented in Table 2.1 are taken from the website of the Royal National Institute for Deaf and Hard of Hearing People (RNID, 2007). In the present thesis, the sample of deaf children was restricted to those with severe to profound hearing loss on this scale (i.e., those with the least access to the sounds of spoken language).

Table 2.1: Levels of deafness defined by the quietest audible sound in dB (RNID, 2007)

Degree of deafness	Quietest audible sounds	Quality of speech perception
Mild	25-39 dB	Some difficulty understanding speech, mainly in noisy environments.
Moderate	40-69 dB	Difficulty understanding speech without a hearing aid.
Severe	70-94 dB	Speech perception is highly reliant on lipreading, even with hearing aids.
Profound	95+ dB	

In some cases, hearing aids enable people to access more speech sounds. However, the effectiveness of hearing aids varies between individuals and many deaf people prefer not to wear them. In addition, a growing number of children are receiving cochlear implants. When successful, this can result in a BEA improvement of around 28dB (Blamey et al., 2001) and, particularly when implanted from a young age, may significantly improve educational outcomes (Thoutenhoofd, 2006).

2.2.2 Communication and education

Deaf people communicate using sign language, speech, or combinations of the two modes. Naturally, the preferred mode of communication will impact on their experience with spoken language, as will the individual's speech-reading ability.

The education of deaf children is typically described with reference to the communication philosophy of the school. Within the UK there is a growing trend to educate deaf children in a mainstream setting. There will usually be a qualified Teacher of the Deaf and/or Teaching Assistants who are fluent in BSL to support deaf children within mainstream classes. In addition, there are many schools and colleges that solely educate deaf children. These schools typically have very small class sizes and employ a large number of specialist Teachers of the Deaf, Teaching Assistants and Support Workers, many of whom are deaf themselves (and therefore also provide positive Deaf[1] role models). The most common teaching practices within both mainstream and specialist schools for the Deaf are the Oral/Aural approach, Sign Bilingualism or Total Communication, which I will describe below. Most of the children sampled in the present thesis attended dedicated schools for the deaf, with a few children in each study drawn from mainstream schools with Units for the Hearing Impaired (further description of the participants is provided in the Method section of each experiment).

Some deaf individuals are able to communicate effectively using speech. Speech-reading entails the use of lip-reading, residual hearing and any other available clues to understand the oral productions of others. Oralism or the Oral/Aural approach to education involves intensive training in speech-reading and speech production to enable deaf children to use spoken English alone for communication (for a review see Watson, 1998).

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[1] Some deaf people who are part of the British Deaf Community describe themselves as Deaf with a capital D to emphasis their Deaf identity (Marschark, 1997).

Sign Bilingualism refers to an educational setting that encourages the use of spoken English and British Sign Language (BSL) as two distinct languages, with the aim of developing bilingual and bicultural competence (for further discussion see Pickersgill, 1998). In Sign Language, hand shapes, facial expressions and body movements are used for communication instead of speech. Deaf communities in most countries have developed their own, unique sign language (Kyle & Woll, 1988; Rodda & Grove, 1987) and evidence from an emergent sign language in Nicaragua suggests that this development is spontaneous (Senghas, Kita, & Ozyurek, 2004; Senghas, Ozyurek, & Kita, 2005). In the UK, there are estimated to be around 50,000 British Sign Language (BSL) users (RNID, 2007). BSL is a natural language which has evolved in the British Deaf Community over hundreds of years. It has lexemes and grammar which are distinct from English (Kyle & Woll, 1988; Rodda & Grove, 1987). A person is typically only described as a native signer if they were born to deaf signing parents and have been exposed to a full and rich Sign Language from birth (Kyle & Woll, 1988; Rodda & Grove, 1987) although this does not preclude the possibility of non-native signers having BSL as their first or preferred language. Indeed, there are many deaf children born to hearing parents who do not acquire a functional level of spoken English and can only communicate effectively using BSL.

Sign Bilingualism should be distinguished from Total Communication. In Total Communication, speech, signs, finger-spelling, reading, writing and other techniques are all used in combination (reviewed in Baker & Knight, 1998) rather than maintaining the hands and lips as separate modes for different languages. There are also various synthesised combinations of signed and spoken communication, the umbrella term for which is Manually Coded English (MCE). In MCE, the grammatical and syntactic structure of sentences is consistent with English and signs are borrowed from BSL to support understanding (see Goldin-Meadow & Mayberry, 2001). Cued Speech is an MCE approach which emphasises orality. Visually confusable phonemes are disambiguated using a series of hand shapes (representing consonants) and positions (representing vowels). Unlike other forms of manually coded speech (and sign languages), in Cued Speech the hand shapes are used to disambiguate confusable phonemes (e.g., /b~p~m/) rather than representing lexemes. Despite evidence for the utility of Cued Speech in other languages (particularly French), it is rarely used in the UK (Harris & Moreno, 2006) and there are reasons to believe that Cued Speech would be less effective in English than in other languages (Alegria & Lechat, 2005).

Finger-spelling is a means of representing the alphabet on the hands. In Britain this is achieved using both hands but finger-spelling varies between cultures (e.g., Americans use one hand). Whilst some proper nouns and borrowed words are finger-spelled in BSL, this is not a mode of communication in its own right.

In the present thesis, the majority of deaf children communicated both at home and at school using BSL, although the use of spoken English was also encouraged in either Bilingual or Total Communication environments within the schools. Nonetheless, the deaf children sampled in the present thesis are likely to have limited experience with spoken English compared to their hearing peers, in terms of both reception and production.

2.3 Literacy acquisition for hearing children

Before considering the nature of literacy impairment within the deaf population, it is important to first understand models of skilled literacy and the nature of development in unimpaired populations. Literacy typically develops after spoken language and therefore is considered to be parasitic on speech. In accordance with this view, models of skilled literacy argue that there are dual routes for obtaining meaning from text (Coltheart, 1978; 1980; Morton & Patterson, 1980; Perfetti, 1999). Translation may occur directly through semantics (referred to as the *direct, visual-orthographic* or *lexical route*) or via conversion from letters to sounds (referred to as the *indirect, phonological* or *nonlexical route*). The second, indirect, route involves the use of phoneme-grapheme correspondences to translate text into speech and then accessing the speech vocabulary to obtain meaning (for reviews see Coltheart, 2005 and Ellis, 1993). The direct and indirect routes are accessed concurrently, with the fastest system winning the race. For the skilled reader, meaning will be obtained directly for most words but low frequency or novel words will be read using the phonological route (Forster & Chambers, 1973).

The simple view of reading suggests that hearing children acquire literacy by adding the orthographic information to their pre-existing spoken language skills (Juel, 1988; Juel et al., 1986). The problem of literacy acquisition for the hearing child is therefore viewed as a matter of matching the written form to its spoken form. This has resulted in models of literacy acquisition focusing on conversion of text-to-speech rather than text-to-meaning. Not only has this resulted in a large body of developmental research that ignores the very purpose of reading–to obtain meaning (Snowling, 2000)–but there has also been a tendency to focus solely on phonology and the indirect route (Derwing, Smith, & Wiebe, 1995).

Traditional stage models of literacy acquisition claim that successful development involves progression through specific phases, characterised by the dominant strategy in use (e.g., Ehri, 1995; Frith, 1985). Early in development, children have a very small sight vocabulary and focus on salient visual cues in reading. During this *logographic* or *pre-alphabetic* stage of development, children have a tendency to misread words as one of the few words in their sight vocabulary that has similar visual characteristics (Ehri, 1995; Frith, 1985). For example, the Scottish prereaders (4;6 to 5;6-year-olds) studied by

Seymour and Elder (1986) read *SMALLER* as **yellow*[2] "because it has two sticks" (<ll>) and *POLICEMAN* as **children* "because it's a long one". As vocabulary increases, visual strategies rapidly become inefficient and grapheme-phoneme correspondences (letter-to-sound rules) become central for deciphering novel words (Gough, Juel, & Griffith, 1992). This phase is referred to as the *alphabetic stage*. Initially, children are able to use grapheme-phoneme correspondences to decode a few parts of the word and to provide hints, until eventually they can apply complex grapheme-phoneme correspondences (such as the vowel lengthening effect of silent e) and the entire word is decoded (Ehri, 1995; Frith, 1985). Each time a child encounters an unknown word and is able to successfully decode it, they learn something about the orthography (Share, 1995). Eventually, it becomes clear that many words cannot be decoded through the use of grapheme-phoneme correspondences alone. Following sufficient experience with text, the child acquires understanding of orthographic regularities, morphological spellings and grammatical conventions, and they enter the final, *orthographic stage* of development (Frith, 1985). Contemporary models of literacy acquisition focus on the fluid expansion of skills and the use of multiple strategies throughout development (Cassar & Treiman, 1997; Rittle-Johnson & Siegler, 1999; Stuart & Coltheart, 1988; Treiman & Bourassa, 2000).

Phonological awareness refers to the ability to segment words into their constituent sounds (Read, 1986) and plays an integral role in both traditional and contemporary models of literacy development. Hearing children are initially able to segment words into syllables (e.g., /kär//pət/[3]), then onset and rime (e.g., /p//ət/) and finally into phonemes (e.g., /ə//t/) (Treiman & Zukowski, 1991). As phonological awareness develops, children

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[2] Throughout this thesis, misspellings/misreadings are in italics and proceeded by an asterisk.

[3] Throughout the present thesis, phonetic transcriptions are enclosed within forward slash marks (//), orthographic transcriptions within angular brackets (<>) and abstract morphemes within square brackets ([]). Phonetic notation is taken from the International Phonetic Alphabet (International Phonetic Association, 1996).

represent each segment (as they understand it) with a grapheme (Treiman, 1994). Research into literacy acquisition places great importance specifically on the role of *phonemic awareness* (the ability to segment sound into the smallest unit, phonemes), as this is essential for phoneme-grapheme correspondence (Gough et al., 1992; Tunmer & Hoover, 1992). However, whilst phoneme-grapheme conversion is central to literacy development, it is viewed as only one root to meaning for skilled readers (Gaustad, 2000).

2.4 Literacy acquisition for deaf children

The assumption that literacy acquisition is a problem of matching the written form to a pre-existing spoken form persists in the received view of literacy development in hearing populations. Deaf children have limited experience with both receptive and productive spoken English and therefore literacy acquisition poses quite a different problem to them. For the deaf child, literacy development may be more comparable to language acquisition (or even second language acquisition in the case of the native deaf signer). Thus, to improve deaf children's literacy one must either improve their access to spoken language and phonology (to enable the progression through the same developmental stages as hearing children) or to find alternative sources of regularity to enable them to obtain meaning from text with minimal reliance on phonology. To date, the vast majority of research has focused on the former solution and very little has examined alternatives. Before discussing alternative decoding mechanisms, highlights from the existing research relating to phonology will be discussed.

2.4.1 Phonology

Given the importance of the phonological route in theories of skilled literacy and literacy development in unimpaired populations, the cause of deaf children's literacy impairments from this perspective seems clear–they result from limited access to the phonological route. Since deaf children typically have limited experience with spoken

English prior to embarking on literacy acquisition, they are (at best) assumed to have underrepresented phonological awareness. Much phonemic information is not available from lipreading. For example, whilst canonical vowels are equally audibly and visually distinct, consonants are not–both manner and place of articulation (except for front of mouth) are indistinguishable (Kyle & Woll, 1988; Rodda & Grove, 1987). Furthermore, perceptual difficulties with individual phonemes are compounded when lipreading words, since larger homophone families will be created (Auer Jr & Bernstein, 1997). At the sentence level it seems likely that more information is lost and even skilled lipreaders are believed to miss over one third of spoken words (Leybaert, 2000).

According to stage theories of literacy acquisition in hearing populations, knowledge of orthographic and morphological conventions are not integrated into the child's growing literacy skill until understanding of phoneme-grapheme conversion is complete. Thus, children with incomplete phonological awareness are unable to develop literacy beyond a basic level and difficulties are predicted due to a focus on inefficient visual-orthographic strategies. In non-stage theories, phonological impairment similarly predicts an increased use of visual-orthographic strategies because underspecified knowledge in one linguistic domain leads to compensatory usage of unimpaired skills (Carpenter & Just, 1981; Just & Carpenter, 1992; Stanovich, 1980). Numerous investigators have supported the claim that a phonological deficit is the root of a vast range of literacy impairments in hearing populations. Furthermore, impaired phonology does result in reliance on unimpaired skills such as visual-orthographic strategies (Brady, 1997; Frith, 1985; Goswami & Bryant, 1990; Stanovich, 1992). For the deaf, limited access to phonological information makes the use of letter-to-sound conversion difficult, whilst limited speech vocabulary may make this fruitless even when phoneme-grapheme decoding is possible (Waters & Doehring, 1990). Thus, it is commonly argued that deaf children are constrained to using inefficient, visual-orthographic strategies to process text (Aaron et al., 1998; Musselman, 2000; Sterne & Goswami, 2000).

A growing body of evidence suggests that at least some deaf individuals are capable of acquiring a degree of phonological awareness. Several studies have demonstrated above chance performance on pseudohomophone tasks, although performance is typically below that of hearing peers (Hanson & Fowler, 1987; Sterne & Goswami, 2000). Sterne and Goswami (2000) found that deaf children demonstrated equivalent syllable awareness to hearing peers, making word length judgements based on phonology when phonological and orthographic length were incongruent. However, tasks that do not *force* phonological mediation are typically less successful at demonstrating phonological skill. For example, Waters and Doehring (1990) failed to show a phoneme-grapheme regularity effect in a lexical decision task with orally trained deaf children (7 to 20-years-old). Dodd (1980) found no significant difference in deaf children's spelling errors for phonographically regular and irregular words (although the sample was small and refusals common). Nonetheless, Dodd found that it was possible to manipulate both hearing and deaf children's relative reliance on visual and phonological strategies.

The spelling errors made by deaf students support the claim that underspecified phonology results in poor literacy. Not only are phonetically plausible misspellings relatively uncommon (accounting for 50% of substitutions compared with 80% of substitutions in a hearing population) but misspellings often violate the phonetic structure of the target words through insertion, omission and re-ordering of phonological segments. Nonetheless, misspellings are rarely unpronounceable (although this could be due to orthographic rather than phonological awareness) and more substitutions are made on vowels than consonants, just as seen in the hearing population (Hanson, Shankweiler, & Fischer, 1983).

Although limited access to the phonological route clearly accounts for part of the literacy impairment observed in the deaf population, current measures of phonological awareness and alternatives such as degree of deafness, speech comprehension and production are insufficient to explain the wide variation in literacy achievement observed within the deaf population (Hanson et al., 1983; Olson & Caramazza, 2004; Wakefield, 2006). Clearly, other literacy skills are also important.

2.4.2 Orthography

In order to recognise phoneme-grapheme correspondences, knowledge of both phonology and stored graphemic (visual) representations are necessary (Dodd, 1980; Venezky, 1967). English has a relatively opaque orthography and therefore grapheme-phoneme correspondences are rarely one-to-one; many phonemes correspond to more than one grapheme and vice versa (e.g., the phoneme /s/ corresponds to the graphemes <s~c~ss~sc~x~st~ps~z~sw~sch>–Hanna, Hanna, Hodges, & Rudorf, 1966). Orthographic awareness has two components–knowledge of legal and frequent letter strings (graphemes) and use of this information in reading and writing (use of a visual-orthographic strategy). Some grapheme constellations occur more frequently in particular positions. For example, <c~ck~k> all correspond to the phoneme /k/ but <ck> cannot occur in word-initial positions. Similarly, a limited number of letters can form doublets (two identical letters in consecutive positions, e.g., <gg>) and doublets do not occur in word-initial positions (Solso, Juel, & Rubin, 1982; see Venezky, 1970 for further discussion). These orthographic regularities are rarely formally taught and yet hearing children demonstrate awareness of orthographic patterns from an early age (Treiman, 1993). For example, knowledge about doublets (both the letters that can be doubled and the positions they can occur) is prevalent by 5 or 6-years-old and has been demonstrated in children as young as 4 (Cassar & Treiman, 1997; Treiman, 1993). Similarly, knowledge that the grapheme <ck>

can only represent /k/ in medial and final positions is present by 6 or 7 years old (Treiman, 1993).

Unlike phonological awareness, there is no intuitive reason to expect an orthographic impairment in the deaf population and indeed, no such impairment has been reported. Deaf children demonstrate an understanding of positional frequency and orthographic constraints such as doubling and legal word-initial consonant clusters from a young age. For example, Padden (1993) demonstrated that deaf 4 to 9-year-olds never produced illegal doublets or doublets in illegal positions and very rarely (7/185 attempts) produced illegal word-initial consonant clusters. Furthermore, deaf college students produce misspellings that are typically both pronounceable and orthographically legal and they recall orthographically regular nonwords more accurately than irregular nonwords (Gibson, Shurcliff, & Yonas, 1970; Hanson, 1982b; Hanson et al., 1983; Olson & Caramazza, 2004).

Following the argument that limited access to the phonological route results in a focus on unimpaired strategies, deaf children are typically believed to rely on visual-orthographic strategies to read. The use of a visual-spatial language system (i.e., Sign Languages) is argued to further increase attention on visual strategies. Deaf adults certainly seem to make greater use of visual processes to code information, for example remembering in sign (Bellugi, Klima, & Siple, 1975; Campbell & Wright, 1988). Furthermore, deaf children have been found to confuse visually similar words and letter-strings, whereas hearing children’s confusions are usually based on acoustic similarity (Conrad, 1964, 1972; Conrad & Rush, 1965). Although visual processing is considered to be advantageous for the skilled reader (providing a direct route of obtaining meaning from text), an over-reliance on visual-orthographic strategies is inefficient for the developing deaf child, because they are not able to obtain meaning for words that are not in the sight vocabulary (for hearing children, the use of phoneme-grapheme correspondence enables them to access the larger speech vocabulary when a written word is unknown). A focus on visual-orthographic strategies makes it difficult to self-teach the meaning of new words and therefore the acquisition of new words is more difficult. For these reasons, the over-use of visual-orthographic strategies due to underspecified phonology is believed to be the cause of deaf children's literacy impairments (Aaron et al., 1998; Musselman, 2000; Sterne & Goswami, 2000).

2.4.3 Alternative decoding strategies

The major advantage of phonological awareness for the hearing child is that they can use phoneme-grapheme correspondences to decode unknown written words and then access their pre-existing speech vocabulary to obtain meaning. By comparison, phoneme-grapheme conversion is likely to be an arduous endeavour for the deaf child. Even if phoneme-grapheme conversion is successful, a restricted speech vocabulary due to limited experience with spoken English is also likely to prevent the deaf child from accessing meaning via phonology. The tacit implication of a focus on phonology is that the deaf child is condemned to a life without functional literacy until they have more experience with spoken English and a better understanding of sound. As Derwing, Smith and Wiebe (1995) point out, there has been an overwhelming tendency for linguists (and psycholinguists) to focus on phonology. Scinto (1986, p2) refers to this as the *phonocentric canon*;"*...the voice is somehow primary and central to language, and, by implication, other instantiations of language are only secondary reflections of the voice...*". Rodda, Cumming and Fewer (1993, p340) stated that this"*...presupposes a biological determinism in which the human organism is preprogrammed to use one sensory system and code to the exclusion of others...*". However, is this assertion appropriate when considering a population whose experience with the auditory sense and, more specifically, speech is so limited? If one assumes that a deaf child is typically unable to decode the meaning of a written word by phoneme-grapheme correspondence but accept that skilled literacy can be attained, one must assume an alternative route to literacy is employed (Leybaert, 2005). It is for this reason that the use and effectiveness of alternative strategies must be examined.

2.4.3.1 Sign Language

For the bilingual deaf child, one must also consider the impact of L1 (BSL) on L2 (English). The native BSL user may recode written words into signs rather than using their relatively limited speech vocabulary (Leybaert, 2005). Deaf children born to deaf parents (who use a Sign Language) typically attain higher levels of literacy and academic achievement than their peers born to hearing parents, although the causes of this relationship remain unclear (Chamberlain & Mayberry, 2000; Strong & Prinz, 1997, 2000). It has been claimed that superior parent-child communication leads to increased world knowledge, vocabulary and morpho-syntax, enabling the child to infer the meaning of novel words, meanwhile adjusted parental expectations enables better mother-child interactions during reading activities (Leybaert, 2005; Strong & Prinz, 2000). However, good Sign Language abilities correlate with good literacy skill independently of parental hearing status (Strong & Prinz, 1997). In response, some authors have argued that the development of a natural language, whatever that language may be, enables the development of higher cognitive skills (Chamberlain & Mayberry, 2000; Rodda, Cumming, & Fewer, 1993). An alternative argument is that the deaf signer is able to utilise explicit links between Sign Language and English. There is evidence that the ability to write down finger-spellings and to translate initialised signs (signs where the hand shape corresponds with the finger-spelled initial letter) correlates with reading ability (Padden & Hanson, 1999; Padden & Ramsey, 2000). However, because English and BSL are independent natural languages, it is not always possible to directly translate from one language to another, particularly as there are many features of English morpho-syntax that differ or are not represented in BSL (see Kyle & Woll, 1988 for further discussion of the morphology of BSL). Thus, although lexical representations of written words and signs may be linked, knowledge of BSL is likely to offer little help with syntax or morphology. At the sentence level, conversion into BSL becomes highly inefficient. BSL provides the deaf child with an effective means of communication but, in terms of using this information to aid English literacy, BSL does not provide a direct substitute for speech. Finally, around 90% of deaf children are born to hearing parents (Chamberlain & Mayberry, 2000; Marschark, 1997), meaning that they do not grow up engulfed in a natural Sign Language from birth. Most children learn to sign when they start school and so seem unlikely to be able to apply pre-existing knowledge of BSL to English literacy acquisition, at least not during the earliest stages of literacy acquisition. Therefore, although pre-existing sign vocabulary may aid the acquisition of literacy for some deaf children, there will always be children who have insufficient sign vocabulary to do so.

2.4.3.2 Morphology

Just as a phoneme is the smallest unit of sound, a morpheme is the smallest unit of meaning. For example, *dogs* contains two morphemes, the root noun [dog] and the plural suffix +[s]. Morphology may enable the child to segment words into meaningful chunks that are smaller than the whole word but larger than the grapheme (or phoneme), thereby providing a more efficient means of obtaining meaning from text. English is considered to be a morphologically transparent language (i.e., morphemes are consistently represented in the orthography) and therefore morphology offers an alternative source of regularity that may be utilised during literacy acquisition. Because morphology is visible in the orthography, it should be available through experience with written English alone and therefore available to deaf children with the least experience with speech. Nonetheless, the role of morphology in the literacy development of both hearing and deaf children has received very little research. For these reasons, morphology is the focus of the present thesis.

The nature of English orthography suggests that knowledge of morphology is important in order to read and write effectively. English has a deep orthography and often, although the majority of a word is decipherable through phoneme-grapheme conversion, there is a small ambiguous segment. Morphographic correspondence is typically reliable and consistent, even if phoneme-grapheme correspondence is not (Bourassa & Treiman, 2001; Elbro & Arnbak, 1996; Gaustad & Kelly, 2004; Treiman & Cassar, 1996). Indeed, because morphologically related words typically share spellings (regardless of pronunciation) low phoneme-grapheme regularity commonly co-occurs with high morphographic regularity (Gaustad, 2000; Gaustad et al., 2002; Venezky, 1967, 1970; Verhoeven & Perfetti, 2003). For example, plural nouns are typically marked with the suffix +<s> in the orthography, yet in speech the suffix can be /s~z~əz/ (e.g., *cat-CATS, dog-DOGS, horse-HORSES.* This will be discussed further in Section 2.6.2.1 on p31). Thus plurals are often more regular in orthography than phonology. Morphographic correspondence can also aid pronunciation. For example, based on phoneme-grapheme correspondence alone, <ea> in *reading* affords the pronunciations /eI~ɛ~e~ɑ~i~I~ɚ/ (Hanna et al., 1966). Analogy to orthographically similar but morphologically unrelated words (e.g., *react*) may further compound the problem. However, knowing that *reading* is related to the root morpheme [read] disambiguates pronunciation (assuming you already know how to pronounce *read*). Thus, the printed form of English involves a triad of regularities in phonology, orthography and morphology.

From their earliest attempts at writing, hearing children seem to have an inherent desire to represent meaning. Initially, this is expressed by an expectation for direct relationships between meaning and spelling. For example, young children commonly believe that large objects should have long spellings (Levin & Tolchinsky-Landsmann, 1989; Lundberg & Torneus, 1978). Byrne (1996) specifically argues that the level of meaning that hearing children expect to be represented is that of the morpheme. If children initially seek to make direct text-to-meaning associations, particularly at the unit of the morpheme, it is possible that they will continue to make these associations throughout development. However, the focus on the roles of phonology and orthography has resulted in a lack of research into morphology (Mann, 2000; Verhoeven & Perfetti, 2003).

English morphological relationships include inflections, derivations and compounds. Compound words are two or more free morphemes that have been concatenated, probably due to the frequency of co-occurrence (e.g., *blackboard*). Over time, compounds take on their own identity and meaning (Sterling, 1983). Derivation and inflection involve the combination of bound and free morphemes. Derivation involves generating words with different shades of meaning from a base/root morpheme (e.g., *drink-drinkable*) and may involve changing the grammatical category of the word (Verhoeven & Perfetti, 2003). In inflection, changes in meaning are consistent between inflections (e.g., both *car-cars* and *dog-dogs* differ in number only) and the morphological change serves a primarily grammatical role. For example, syntactic demands may require that a verb be marked for tense, aspect, mood, voice or number (Verhoeven & Perfetti, 2003). Although inflectional morphology is described as primarily grammatical, there are also semantic reasons for the use of different forms (e.g., plural marking on noun serves a semantic purpose but number marking on the verb is due more to grammatical factors). Grammar consists not only of morphology but also syntax (Nunes, Bryant, & Bindman, 1997b). Morphology refers to meaning at the subword level, while syntax refers to how words are combined into the larger context of sentences and prose. Syntax involves grammatical agreement and word order. For example, in the phrase "*the keys to the cabinet are on the table in the hall*" the plural *keys* leads to the plural verb *are*. Contrast this to the meanings of "*the key to the cabinets is on the table in the hall*" or "*the keys to the cabinet on the table are in the hall*". The present thesis focuses primarily on inflectional morphology at the single-word level, although morpho-syntax will be considered in Chapter Six.

Because English morphology typically involves adding a suffix or prefix to a base morpheme, morphologically related words are usually similar in terms of orthography, phonology and semantics (Feldman & Andjelkovic, 1992). The degree of overlap differs for different types of morphological relationships. Compared with inflection, derivational morphology tends to be less regular in terms of both semantic and orthographic overlap (Feldman & Andjelkovic, 1992; Verhoeven & Perfetti, 2003). For example, compare the semantic overlap in the inflectionally related pairs *cat-cats* and *walk-walked* to the derivationally related pairs *slow-slowly* and *apart-apartment*. The present thesis focuses on inflectional morphology because the relationships between words are more transparent, more readily available, and therefore inflection is typically viewed as being "easier" than derivation. Furthermore, the interaction between inflectional morphology at the word level and morpho-syntax at the sentence level makes it particularly interesting for examining the child's developing awareness of morphology within the context of literacy acquisition.

There are a range of morphological skills that may have a direct impact on literacy development, including knowledge of morphemic structure (e.g., [mis]+[spell] must contain two <s>s), morphographic conventions (e.g., [thin]+[ed] requires a double <n>) and derivational relationships (e.g., relating *grammar* to *grammatical* disambiguates spelling of the reduced vowel in *grammar*) (Fischer, Shankweiler, & Liberman, 1985).

Furthermore, morphological decomposition enables segmentation into meaningful units. The use of morphological generalisation (the extension of morphological rules) enables the generation of plausible, novel spellings and interpretation of unknown words when reading, even if these words do not exist in the sight or speech vocabularies. This is because the reader can use knowledge of morphographic relationships and morpheme combination productively. For example, once a child is able to read the word *rain*, it takes little for them to read *rains*, *rained*, *raining* and *rainy* if (s)he knows the meaning of the suffixes. The text that children experience seems to encourage the use of morphological generalisation. For example, Nagy, Osborn, Winsor and O'Flahavan (1994) noted that during Fifth Grade (10 to 11-years-old), the average hearing reader encounters around 1 million words of text. These include 10,000 new words that are only seen once. Of these novel words, many are related to previously known words. For example, 1300 are inflections and 4000 are derivations of known words. Only 1000 words are truly novel. Thus, morphological generalisation would enable the child to infer (or self-teach) the meaning of a large proportion of the novel words that they encounter.

Interestingly, the point at which deaf readers apparently fail to progress (from around 9-years-old) is the same point at which hearing readers are believed to rely more heavily on morphological generalisation and context to expand their sight vocabulary and read independently. Many deaf children (even the orally educated) have a highly restricted vocabulary and there is a well established link between vocabulary and reading comprehension (Kyle & Harris, 2006; LaSasso & Davey, 1987; Paul, 1996; Waters & Doehring, 1990). If deaf children are constrained to using visual-orthographic strategies to process text, then they must learn each word individually and process words as wholes. Knowledge of morphology, on the other hand, not only provides a means of segmentation but is also highly productive, with the potential for reading, spelling and vocabulary advancement.

2.5 The role of morphology for skilled readers

Before considering models of morphological development, it is important to outline research relating to the lexical role of morphology for skilled readers. There is, however, much disagreement about the specific nature of morphological representations and whether morphology is involved in lexical storage or access (Drews & Zwitserlood, 1995; Giraudo & Grainger, 2000, 2001; Marslen-Wilson, Tyler, Waksler, & Older, 1994). Models also differ in terms of the nature of morphological representations. Full-listing models propose that morphologically complex words are stored independently and alongside morphologically related words. In these models, activation spreads between morphologically related words because of their close proximity (Kempley & Morton, 1982; Lukatela, Gligorijevic, Kostic, & Turvey, 1980). Full-parsing models assume that morphologically complex words are decomposed and the stem used for lexical search. Lexical representations of the stem contain information regarding legal morpheme combinations (Taft & Forster, 1975; Verhoeven & Perfetti, 2003). Full-listing and full-parsing models are not mutually exclusive and today the majority of theories are dual route, proposing that both full-listing and full-parsing plays a role in the processing of morphologically complex words. Some suggest that representations differ for lexical access and lexical storage (e.g., Caramazza, Miceli, Silveri, & Laudanna, 1985) whilst others argue that word specific factors influence the likelihood of decomposition, factors such as frequency, semantic transparency or morphological class. Words are more likely to be decomposed when they are low frequency (Laudanna and Burani, 1985; Luzzatti, Mondini, & Semenza, 2001, Schreuder & Baayaen, 1995), semantically transparent (Marslen-Wilson et al., 1994) regular inflections (Jackendoff, 1975; Stanners, Neiser, Hernon, & Hall, 1979). If morphological processing is part of skilled reading, one has to ask at what point this develops. In the following passages I will present the received view of the development of morphological awareness within the context of literacy acquisition.

2.6 Morphological development

Traditional theories of literacy acquisition for hearing children claimed that knowledge of morphology is integrated into the child's growing understanding of text during the final stages of development (Ehri, 1993; Frith, 1985)–around the age of 8-10 (Gentry, 1982; Henderson, 1985). However, the dominant models presently suggest that multiple strategies (specifically phonology, orthography and morphology) are applied throughout development (Cassar & Treiman, 1997; Rittle-Johnson & Siegler, 1999; Treiman & Bourassa, 2000; Varnhagen, McCallum, & Burstow, 1997). Therefore, if children have morphological awareness prior to literacy acquisition, they should apply this knowledge to literacy from the beginning of development. The following discussion will present evidence for a relationship between morphological awareness and literacy acquisition before discussing morphological development in speech and literacy.

2.6.1 Morphological awareness and literacy

Research into the relationship between morphology and literacy acquisition has largely examined the relationship between global measures of morphological awareness and literacy ability, rather than examining the development of specific morphological skills. In this context, morphological awareness is an umbrella term referring to the conscious understanding of the meaning and structure of morphemes and the ability to manipulate them (Carlisle, 1995; McBride-Chang, Wagner, Muse, Chow, & Shu, 2005). A growing body of evidence suggests that morphological awareness is related to literacy achievement for both deaf (Gaustad & Kelly, 2004; Waters & Doehring, 1990) and hearing readers (Carlisle, 1995, 2000; Deacon & Bryant, 2006b; Fowler & Liberman, 1995;

Mahony, Singson, & Mann, 2000; Shankweiler et al., 1995; Singson, Mahony, & Mann, 2000). For example, Brittain (1970) demonstrated that 7 to 8-year-old hearing children's ability to inflect pseudowords in speech (using a revision of Berko's *'wug'* test–Berko, 1958) correlated with general reading achievement. Freyd and Baron (1982) found that good hearing readers (10 to 11-years-old) are better than older average readers (13 to 14-years-old) at providing meanings for morphologically complex words and learning new meanings for morphologically related pseudowords, whereas there were no differences in performance on morphologically simple words. Awareness of the syntactic category of derivational suffixes is related to reading achievement in Grades 3-8 (age 8-14) and even amongst University students (Mahony, 1994; Mahony et al., 2000). Furthermore, performance on the Morphological Relatedness Test (a derivational judgement task involving determining whether word pairs are morphologically related or not) predicts reading achievement in adolescents, single word and pseudoword reading and word identification for 8 to 12-year-old hearing children and 7 to 9-year-old poor readers (Fowler & Liberman, 1995; Mahony, 1994; Mahony et al., 2000).

The relationship between morphological awareness and literacy achievement has typically been tested using metalinguistic tasks that focus on specific morphological skills such as segmentation (e.g., Gaustad & Kelly, 2004), relatedness (e.g., Fowler & Liberman, 1995) or describing the meaning of morphemes (e.g., Freyd & Baron, 1982). Therefore, the specific aspect of morphology assessed varies between studies. Carlisle (2000) examined the general contribution of morphology by using three different measures of morphological awareness (derivation and decomposition, definition, and reading morphologically complex words) and found that this accounted for 41-55% of the variance in reading vocabulary and comprehension in Third (8 to 9-years-old) and Fifth (10 to 11-

years-old) Grade hearing children. Furthermore, the contribution of morphological awareness increased with age (vis. Deacon & Kirby, 2004; Mahony et al., 2000).

Although previous studies imply a relationship between morphological awareness and literacy achievement, the correlational nature of this research makes it impossible to distinguish cause and effect. Furthermore, correlational studies do not explain *how* children make use of morphology during reading and spelling tasks.

2.6.2 The acquisition of morphology in speech and literacy

The acquisition of morphology is likely to be very different for deaf and hearing children. For hearing children, awareness of inflectional morphology develops through spoken communication prior to literacy acquisition (Gaustad et al., 2002). Although the development of morphology in speech may not yet be complete when the child embarks on literacy acquisition (Brittain, 1970), it is reasonable to expect hearing children to have a good level of understanding, particularly of the most simple structures. Plural formation is typically argued to be one of the first morphological markers to be acquired in speech (Cazden, 1968; De Villiers & De Villiers, 1973; Mervis & Johnson, 1991) and is often assumed to be very simple. However, in terms of literacy acquisition, understanding of number marking may not be as simple as it seems, because morphographic and morpho-phonological regularity sometimes differ (as will be discussed below). Before discussing evidence regarding the developmental path of plural acquisition, it is first necessary to describe some features of English plural noun formation in terms of morphographic and morpho-phonological regularity.

Deacon and Bryant (2006a) argued that in order to make productive use of morphology in spelling, children must know that morphologically complex words are made up of several morphemes and recognise that morphologically related words share root spelling. If the child has both of these forms of morphological awareness then being provided with the root morpheme should improve their spelling of the root. However, in order to spell the whole word accurately, the child must also have knowledge of suffix morphology. The development of root morpheme spelling is argued to occur relatively early (5 to 8-year-olds retain root spellings in related words–Treiman, Cassar, & Zukowski, 1994, Deacon & Bryant, 2006a) whilst understanding of suffixes develops relatively late (at around 8 to 10-years-old–Nunes et al., 1997b). Nonetheless, children at least begin to know something about the spelling of both roots and suffixes by the age of 7. For example, Deacon and Bryant (2005, 2006a, 2006b) demonstrated that 6 to 10-year-olds have knowledge of root morphology. Their spelling of the root of two-morpheme words was more accurate than the same letters embedded within one-morpheme words (e.g., *rock* in *ROCKED* vs. *ROCKET*) (Deacon & Bryant, 2006b) and presentation of the root word improved performance on morphologically complex words (e.g., *We had to turn the car around before TURNING into the lane*) (Deacon & Bryant, 2006a). Furthermore, 6 to 8-year-olds were more accurate at spelling inflectional suffixes (+<ing>, +<er>, +<est>) than the same word-final letters occurring in one-morpheme words (e.g., *er* in *CALMER* vs. *CORNER*) (Deacon & Bryant, 2005).

2.6.2.1 English plural noun formation

In English orthography, plural noun formation is mostly regular. The vast majority of plurals are formed by adding the suffix +<s> to the root (e.g., CAT-*CATS*). Exceptions to the morphographic rule root+<s> come in various forms. In the present research, a distinction is drawn between *irregular* and *semi-regular* plurals. Irregular plurals are particularly unusual transformations which cannot be described with reference to a rule. This transformation is either unique (e.g., CHILD-*CHILDREN*), has global (but not specific) similarity to a small subgroup of nouns (e.g., FOOT-*FEET*, MOUSE-*MICE*), or singular and plural forms are identical (e.g., SCISSORS-*SCISSORS*). Irregular plurals account for around 2% of noun types and 3% of noun tokens (Marcus, 1995).

Intermediate between the extremes of irregular and regular nouns are several subgroups of rule-based forms referred to here as semi-regular plurals. Semi-regular morphographic rules include:

Final <ch~x~s~sh~ss~z> becomes root+<es> (e.g., *fox-foxes*).

Final <y> preceded by a consonant becomes <ies> (e.g., *baby-babies*).

Final <f~fe> becomes <ves> (e.g., *knife-knives*).

While the orthographic representation of root+<s> plural is regular, in speech these plurals are formed using one of three morpho-phonological rules[4], dependent on the final phoneme of the root (Berko, 1958; Kopcke, 1998; Venezky, 1967):

Final /s~z~ʃ~ʒ~tʒ~dʒ/ becomes root+/əz/ (e.g., *horse-horses*).

Final voiceless consonant (/p~t~k~f~θ/) becomes root+/s/ (e.g., *cat-cats*).

Final voiced sound (/b~d~g~v~ð~m~n~ŋ~r~l/, vowels and semi-vowels) becomes root+/z/ (e.g., *dog-dogs*).

Knowledge of plural formation within one domain can directly inform the other. For example, by combining knowledge of plural formation in speech and spelling, the writer can learn that /əz/ signals a plural suffix spelled <es>, not <s> or <iz>. Thus, knowledge of stem pronunciation can enable productive use of morphology in spelling. For example, whenever the final phoneme of a noun stem is /s~z~ʃ~ʒ~tʒ~dʒ/ the plural spelling ends with <es>. However, although these nuances of morpho-phonology may be

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[4] Some authors (e.g., Anderson, 1974; Anderson & Lightfoot, 2002) argue that there is only one underlying representation for the morpheme /s~z~əz/ which is realised in different ways due to basic principles of English phonology including adding /ə/ between two adjacent sibilants or devoicing voiced obstruents following voiceless obstruents. Nonetheless, there remains inconsistency in the phoneme-grapheme correspondence between each phonological realisation of the plural morpheme and the corresponding graphemic realisation.

helpful to hearing children, they seem unlikely to be available to the deaf. For this reason, the present thesis focuses on morphographic rather than morpho-phonological regularity.

2.6.2.2 The acquisition of plural nouns

A U-shaped learning path is typically observed in morphological development in speech. Initially, children produce highly accurate inflections of just a few words, which are argued to be produced because each word is memorised individually. Over time, children generalise and begin to use rules such as +<s> for plural or +<ed> for past-tense. Berko (1958) famously demonstrated that 4 to 7-year-olds were able to use generalisation to form various novel inflections, derivations and compounds in speech. Therefore, 4-year-olds are already able to generalise simple plural formation rules in speech. However, not all plurals are regular and, therefore, over-regularisation errors are observed on irregular forms (e.g., **mouses* for *MICE*). Marcus (1995) demonstrated that in speech, hearing children produce accurate irregular plurals until around two-and-a-half to three-years-old and then begin to produce over-regularised forms of the very same words. Over-regularisations are rare by the time the children were around 5-years-old. In a single case study, Mervis and Johnson (1991) observed over-regularisations of irregular plurals even earlier, from age 1;7.15 and this type of error ceased aged 1;11.29. In the final stage of plural noun acquisition, children learn the exceptions (i.e., the irregular plurals) and performance on all inflections becomes highly accurate (e.g., Marcus, 1995; Mervis & Johnson, 1991). Clearly, plural acquisition occurs in speech at a very early age but is nonetheless not a trivial process. However, little research has examined plural acquisition within the context of literacy development.

As previously discussed, plural spelling is more complex than simply using phoneme-grapheme conversion from speech, since morphographic relationships often contradict or complicate phoneme-grapheme correspondences (e.g., / s~z~əz/ → <s>).

Although hearing children may begin spelling plural nouns through phoneme-grapheme correspondences from the spoken form, they must learn that morphographic correspondence supersedes phoneme-grapheme correspondence and acquire these rules. Therefore, one may expect to see a similar developmental path in spelling to that observed in speech simply occurring somewhat later. Children might start off by using phoneme-grapheme correspondences to spell both regular (e.g., *balls*) and irregular words (e.g., *feet*). When children begin to learn morphographic rules (e.g., add +<s> to the stem to form a plural noun) they might apply them indiscriminately to both regular and irregular forms, leading to over-generalisation errors (e.g., *foots*). Finally, they should learn the exceptions and performance across all forms should become highly accurate. Consistent with this, over-generalisation errors have been observed in spelling at an age when one would no longer expect children to make these errors in speech. For example, Nunes, Bryant and Bindman (1997a) demonstrated that 27% of 8-year-olds produced over-regularisation errors on irregular past-tense verbs (e.g., <slep>+<ed>), increasing to 38% of 10-year-olds' spellings. Meanwhile, inaccurate phonetic spellings of the suffix reduced from 20% of 8-year-olds' spellings to 7% of 10-year-olds'. Nunes et al. (1997b) presented a stage model of the acquisition of the past-tense spelling, suggesting that children begin to spell the endings of words phonetically at around 7;2-years, produce over-generalisation errors between around 8;6 and 9;7-years, by which point they have learned to apply morphographic rules to regular past-tenses and rely on phonetic spellings for irregular past-tense. However, because this model was based on evidence from past-tense formation it cannot necessarily be assumed to correspond with the development of other inflectional forms such as plural noun formation.

Very little research has examined over-generalisation of morphological rules within the context of plural spelling. One example is a study conducted by Beers and Beers

(1992), who used a written version of Berko's (1958) test of morphology (with new stimuli) to demonstrate that even first graders (6-year-olds) are highly competent at spelling root+<s> (+/s~z/) plural noun nonwords, with 83% correctly spelling plurals ending in /s/ and 85% correctly spelling plurals ending in /z/. Performance on the semi-regular root+<es> and final <y> → <ies> plurals was far lower and developed later. Only 31% of first graders spelled root+<es> (+/ez/) correctly, increasing to 88% by second grade (7-years-old). None of the first graders spelled final <y> → <ies> (final /əz/) correctly and even fifth graders (9-years-old) produced only 71% of these spellings correctly. Nonetheless, plural spellings were acquired at a substantially younger age than the morphological markers for the past-tense and progressive (+<ed> and +<ing>), which did not appear to be acquired confidently until around sixth grade (11-years-old). Beers and Beers (1992) noted that unexpected plural spellings were rarely phonological and were more often due to the use of the wrong morphological rule (e.g., *LAT+S* spelled **lat+es*), which still indicates a type of morphological generalisation (just of the less frequent plural rules).

Plural noun acquisition may be somewhat different for deaf children compared to their hearing peers. Plural markers are often invisible in terms of lip-patterns in English and therefore, without the contradictory evidence from phonology, deaf children may actually have an advantage in learning the plural morphographic rule root+<s>. Consistent with this argument, Totereau, Barrouillet and Fayol (1998) examined the development of number marking in French-speaking hearing children, where number markings on the noun and verb are typically inaudible but are spelled differently (verb +<nt>, noun +<s>). Children initially (aged 7) applied the noun number marking indiscriminately to their spellings of both nouns and verbs. They then learned the verb number marker and over-generalised this morphographic rule to nouns. Finally (aged 10) they learned the circumstances under which they should apply both types of marker. In English noun and verb number marking, hearing children have contradictory evidence from phonology that they have to learn to override but the situation for deaf children is very similar to French-speaking hearing children because they do not have the contradictory evidence from phonology.

2.6.3 A model for morphological awareness and literacy acquisition

The present thesis is concerned with the development of inflectional morphology and its relationship to literacy skills for both deaf and hearing children. In order for morphology to aid literacy, there are several levels of morphological awareness that must have been achieved. Firstly, morphologically related words must be stored in such a way as to enable the similarity between forms to be recognised. For the purpose of the present thesis, it is not important whether this is in accordance with full-listing or full-parsing models of morphological representation; it is only important that morphologically related words can be associated, enabling the development of morphological awareness. Gradually, children must begin to notice the co-occurrence of systematic changes in form and meaning (e.g., noun plurals <cat>**+<s>**, <dog>**+<s>**, <horse>**+<s>**). Verhoeven and Perfetti (2003) described this as acquisition of the *isomorphism principle* (words related in meaning tend to be related in form). In the present thesis, this will be referred to as awareness of morphological relationships. The next level of morphological awareness involves the generalisation of this understanding (either through the use of explicit rules or through analogy) to enable the productive use of morphology to assist spelling and interpretation of new words. In the present thesis this level of awareness will be referred to as productive morphology and/or morphological generalisation. As well as generalising rules for morphologically regular words, the child must also learn the exceptions (e.g., <foot>-<feet>). Finally, children must apply their understanding of morphology at the single-word level to the sentence level, in accordance with rules of morpho-syntax. For example, in English, the subject and verb of a phrase must have agreeing number markers. Thus the child must not only learn the respective morphological rules for inflecting the noun (plural +<s>) and verb (singular +<s>) but must also learn to check that these number markers match within a phrase. This is not a trivial matter, since there may be many other morphological markers in the same sentence that need not agree and associating the wrong noun and verb can lead to vast variation in meaning (e.g., as described previously with the phrase *the key(s) to the cabinet(s) is/are on the table*). The present thesis tests whether deaf children achieve each of these three levels of morphological awareness; morphological relationships, productive morphology and morpho-syntax.

2.6.4 The development of morphological awareness in the deaf population

Very little previous research has examined deaf children's knowledge of grammar and the existent literature has largely focused on knowledge of syntax rather than morphology. Deaf children's syntactic abilities are significantly impaired when compared to hearing children. For example, in an extensive review of the syntactic abilities of several hundred deaf children from America, Canada and Australia, Quigley and King (1980) argued that although deaf children (10 to 18-years-old) and younger hearing children (8 to 10-years-old) demonstrated the same pattern of difficulty across different syntactic structures, deaf children were substantially delayed. Indeed, 18-year-old deaf children performed significantly worst than 8-year-old hearing children on every type of syntactic structure. Furthermore, it has been argued that deaf children's syntactic abilities are more severely impaired than their semantic abilities (Yoshinaga-Itano, Snyder, & Mayberry, 1996) and that this may in fact be the main cause of their reading comprehension problems (Robbins & Hatcher, 1981). Some support for this view is provided by the finding that deaf children's reading abilities correlate with syntactic awareness (Waters & Doehring, 1990). However, correlational studies do not disentangle cause from effect. Furthermore, understanding of syntax must be the final stage of morphological development, necessarily preceded by extensive understanding of morphology at the single-word level. Therefore, before we can hope to improve the syntactic awareness of deaf children, we must establish that they have the morphological awareness which is necessary for morpho-syntactic understanding. Otherwise, we are asking the deaf child to run before he can walk.

Although research appears to agree that deaf children have difficulty with syntax, deaf children's understanding of morphology has received little attention. In a series of studies, Gaustad and colleagues have examined the relationship between morphology and literacy achievement for deaf children and students, repeatedly highlighting the importance of including morphographic analysis in deaf education (Gaustad, 2000; Gaustad et al., 2002, data re-examined in Gaustad & Kelly, 2004; Kelly & Gaustad, 2007). General measures of morphological awareness at the word level also correlate with literacy achievement for deaf children and college students, just as is observed for hearing children (Gaustad & Kelly, 2004; Gaustad et al., 2002; Hanson, 1995). Gaustad demonstrated that deaf college students (19 to 34-years-old) had morphological awareness equivalent to approximately reading-age matched middle-school hearing children (11 to 12-years-old), whilst middle-school deaf children's morphological abilities were much worst (particularly on the Meaningful Parts test, described below). Deaf students were particularly competent with inflection and simple, transparent derivation but were poor at understanding complex derivational relationships and multi-morphemic words (Gaustad & Kelly, 2004; Gaustad et al., 2002). Therefore, whilst deaf individuals develop some understanding of morphology from mere print exposure, this is insufficient and additional education is necessary. Furthermore, although deaf college students' inflectional awareness appeared to be approximately reading-age appropriate, it is important to recognise that this still represents a chronological delay of around 11 years compared to their hearing peers!

Is it possible that Gaustad's tasks might have underestimated morphological awareness? Gaustad used the Split Decisions and Meaningful Parts tests, both of which are explicit, metalinguistic tasks. The Split Decisions test involves dividing morphologically complex words into constituent morphemes (e.g., "*draw a vertical line between the letters in such a way that will break the word into its meaningful parts, for example, MIS/UNDERSTAND/ING*"). The Meaningful Parts test involves providing explicit definitions of bound morphemes (e.g., "*Choose the best meaning from the four choices:* ***re-*** *as in* re<u>write</u>, <u>re</u>turn*, a) important, b) again, back, c) moving, d) after*"). These metalinguistic tasks are not naturalistic and seem particularly difficult. Furthermore, they both involve morphological decomposition, which is not necessarily psychologically valid for all words (see previous discussion of full-listing versus fall-parsing models of morphological representation, Section 2.5, p26). The occurrence of allomorphs (e.g., plural /s/, /z/, /əz/) and bound morphemes with multiple meanings (e.g., *–ment* in *commandment, enjoyment, retirement*) seems to suggest that explicit morpheme definition may not always be straightforward. Similarly, morphographically irregular forms are often difficult to segment (e.g., where is *foot* in *feet*?). Therefore, the ability to associate morphologically related forms (relevant for both full-listing and full-parsing models of morphological representation) may be of greater importance than the ability to decompose the meaning and/or form of morphologically complex words (relevant to full-parsing models only). Furthermore, explicit knowledge of morphology as measured by a metalinguistic task does not necessarily imply the use of that knowledge during literacy tasks. A more important question is whether deaf children *use* morphology when reading and writing.

Less explicit measures of morphological awareness are inconclusive as to whether deaf people use morphology in literacy. At the single word level, Hanson and colleagues demonstrated that deaf college students who are good readers have access to and use morphology in word reading, since lexical decisions of target words could be primed using irregular inflections and derivationally related words (Hanson & Wilkenfeld, 1985). Furthermore, Hanson (1993) used a paired-associate learning task to demonstrate that deaf students were able to use derivational morphology productively, since they were more successful at learning the meaning of pseudowords that were morphologically related to a real English word than those that were not. Leybaert and Alegria (1995) demonstrated that Belgian deaf children (second half of elementary/ secondary school, aged 10;4–16;8) and younger hearing children (aged 6;10–8;5) use morphology in spelling, since they were more accurate at spelling phonographically irregular words when the irregularity was morphographically regular. However, younger deaf children (first half of elementary school, aged 8;7–13;4) did not show sensitivity to morphographic relationships.

Evidence from Hebrew and Italian-speaking deaf populations examining the use of morphology in written prose is less encouraging. Tur-Kaspa and Dromi (2001) found that although Hebrew-speaking orally trained deaf children (10;9–13;2 years) made fewer grammatical errors in their speech than in their writing, they always made more of these errors than hearing children (11;2–12;5 years). Grammatical errors were most commonly omissions of morphemes and failures to obey the rules of grammatical agreement (both subject-verb and noun-adjective agreement). Amongst the naturalistic and experimental writing samples of highly literate deaf Italian adults, a large number of grammatical errors have also been exposed (Fabbretti, Volterra, & Pontecorvo, 1998; Volterra & Bates, 1989). Furthermore, as observed in Hebrew, these grammatical errors most typically take the form of omissions and substitutions of free-standing function morphemes. Although errors on bound morphemes were relatively rare, the exception to this was long-distance agreement errors, which were common (Fabbretti et al., 1998; Volterra & Bates, 1989). Omission of morphological markers suggests a lack of morphological awareness, while failure to obey agreement indicates a lack of morpho-syntactic understanding/skills. Note that, in contrast to Gaustad's claims based on explicit tests of morphological awareness, these studies suggest that deaf people may have a particular problem with inflectional rather than derivational morphology (Fabbretti et al., 1998; Volterra & Bates, 1989). One needs to point out, though, that inflectional morphology (agreement marking in particular) is more complex in both Hebrew and Italian (where verbs must be marked for number, gender and tense) than in English (where verbs are marked for number and tense only). Furthermore, these studies examine morphology during sentence processing and therefore difficulties may have more to do with syntactic knowledge and/or the additional cognitive demands of sentence level processing than pure morphology. It is possible that deaf individuals develop awareness at the word-level but that this does not extend to understanding of morpho-syntax at the sentence level, since this is a more advanced stage of morphological awareness.

2.7 Conclusion

Severe literacy impairments have been well-documented in deaf populations. It is typically argued that these impairments result from a focus on visual-orthographic strategies because the phonological route to literacy is not available. Firstly, underspecified phonology hinders deaf children's use of phoneme-grapheme correspondences and secondly, vocabulary limitations reduce the likelihood of obtaining meaning even if the appropriate phoneme-grapheme decoding takes place. Morphology appears to offer an alternative source of text-to-meaning conversion that is visible in the orthography. Morphographic relationships are typically regular and transparent (particularly inflection), thereby enabling decoding of novel words in addition to more efficient processing of known words. Deaf people seem to have difficulty with syntax (Quigley & King, 1980; Yoshinaga-Itano et al., 1996), however, very little research has examined deaf children's knowledge of inflectional morphology and the use of this knowledge during reading and spelling, particularly at the single-word level. Knowledge of morphology should precede syntax and therefore it is essential to understand whether deaf children have morphological awareness, which can then act as the basis for syntactic awareness. The evidence of morphological awareness in deaf adults is conflicting; in Hebrew and Italian inflectional morphology appears to be particularly difficult (Fabbretti et al., 1998; Volterra & Bates, 1989), whereas explicit measures of morphological awareness in English suggest that American deaf college students know more about inflectional morphology than derivation (Gaustad & Kelly, 2004). Although these differences might be due to grammatical differences between the languages, it is unclear whether English deaf children use inflectional morphology during reading and writing.

In the following chapters I will present a series of studies investigating whether deaf children use inflectional morphology in reading and writing, testing each of the three levels of morphological awareness–awareness of morphological relationships, productive morphology and morpho-syntax. The first set of studies (Chapters Three and Four) used a short-term memory (STM) probe task to test awareness of morphological relationships. The second series of studies (Chapter Five) examined spelling of known plural nouns and nonwords varying in morphographic regularity in order to examine productive morphology. Finally, the third series of studies (Chapter Six) examined subject-verb number agreement in reading comprehension to assess awareness of morpho-syntactic relationships.

Before acquiring the first level of morphological awareness, children will use visual-orthographic strategies to store/process morphologically related words. At this point, words would be associated on the basis of orthographic features rather than morphological relationships. Therefore, in the STM probe tasks (Chapters Three and Four) confusions would be equally common for words sharing orthographic and morphological overlap. Plurals would be learned as individual words, stored independently from the singular. Therefore, in the plural spelling tasks (Chapter Five) spellings will be equally accurate regardless of regularity, plural accuracy will be independent of singular accuracy and children will not be able to produce plausible nonword plurals, as they will only be able to spell plurals that exist within their orthographic vocabulary.

To achieve the first level of morphological awareness, children must demonstrate that they have associated morphologically related words. In the STM probe tasks (Chapters Three and Four) this would be confirmed by confusing probe and list items more often for morphologically related probes than for orthographically or semantically related probes. In the spelling tasks (Chapter Five) this would be demonstrated by plural accuracy being dependent on singular accuracy.

The second level of morphological awareness is likely to have several stages, each of which is tested by an experiment in Chapter Five. In the first, children must demonstrate that they have recognised and generalised the co-occurrence of systematic changes in form and meaning. This would be demonstrated in the spelling tasks through superior performance on regular plurals (which have systematic changes in form and meaning) than irregular plurals (which do not). In the second stage these morphographic rules should be generalised (whether through the use of explicit rules or through analogy to similar words), enabling the production of plausible nonword plural spellings. Finally, the exceptions must be learned, enabling accurate spelling of irregular plurals.

The present thesis examines subject-verb number agreement (Chapter Six) as the third and final level of morphological awareness. A precondition of this level of awareness is that number markings on the noun and verb are processed. Nonetheless, it would be possible for a child to have understanding of plural morphology at the single-word level without understanding subject-verb number agreement, since this is a morpho-syntactic constraint. To achieve the level of morphological awareness where subject-verb agreement is understood, the child must have developed syntactic parsing to check that the number markers agree. At first, this knowledge may be implicit (demonstrated by longer reading times in the self-paced reading task) but later, children should become consciously aware of the error in sentences containing disagreeing subject-verb number markers (demonstrated by being able to correct disagreeing sentences in the agreement judgement task).

CHAPTER THREE

ESTABLISHING A MEASURE OF AWARENESS OF MORPHOLOGICAL RELATIONSHIPS

The first question addressed in this thesis is whether deaf children show awareness of morphological relationships. Are associations between morphologically related words based on more than simply overlapping orthography and/or semantics? Within the hearing adult population this distinction has largely been demonstrated through the use of lexical priming. However, for reasons that will shortly become clear, this type of task is inappropriate for use with deaf adolescents and therefore it was necessary to design a novel experimental paradigm. In the present chapter, a novel short-term memory (STM) probe task was tested with hearing adults. In this task, awareness of morphological relationships is demonstrated by inducing confusion errors on morphologically related words. Although morphologically related words overlap in terms of both orthography and semantics, models of morphological processing and storage assume that morphology is independently represented in the mental lexicon (e.g., Drews & Zwitserlood, 1995; Marslen-Wilson et al., 1994; Schreuder and Baayen, 1995; Taft & Forster, 1975). In accordance with this assumption, studies using lexical priming have found effects of morphological relatedness that can be distinguished from orthographic and semantic relatedness (e.g., Deutsch, Frost & Forster, 1998; Drews & Zwitserlood, 1995; Stolz & Besner, 1998; see further discussion below). If the effect of morphology is distinct from overlapping orthography and semantics, then morphological confusions in a STM task should occur more frequently than orthographic and semantic confusions. This is because, words in the morphological overlap condition share morphology in addition to orthographic and semantic overlap. Experiment 1a aims to distinguish morphological effects from those of orthographic overlap, while Experiment 1b attempts to distinguish morphological effects from both orthographic and semantic overlap. In Chapter Four, the STM probe task will be applied to deaf adolescents to ascertain whether they too demonstrate an effect of morphology that is distinct from orthography and semantics (i.e., demonstrating an awareness of inflectional relationships).

3.1 Evidence that morphological effects are not simply due to the combined effects of orthographic and semantic overlap

In concatenating languages such as English, morphologically related words typically share semantic, orthographic and phonological structure (Feldman, 2000; Feldman & Andjelkovic, 1992; Stolz & Feldman, 1995). To provide evidence for morphological awareness (or knowledge of morphological relationships), effects of morphological overlap must be distinguished from overlapping form (orthography and phonology) and semantics. The majority of studies examining morphological relatedness in adult readers make use of priming and lexical decision paradigms.

Differences in the time course and duration of morphological, orthographic and semantic priming effects are typically used to support the claim that all three sources of information are involved in word recognition and that their effects can be distinguished from one another. Priming studies consistently demonstrate that morphologically related prime-target pairs facilitate lexical decision latencies[1] on the target word (Forster, Davis, Schoknecht, & Carter, 1987; Stanners, Neiser, & Painton, 1979; Stolz & Feldman, 1995). These effects are both rapid and long lasting, having been observed in contiguous

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[1] In the classic lexical decision task participants view a string of text and provide a button-press response to state whether they think each item is a real word or a nonword. Priming occurs when related words are present prior to the target for lexical decision.

(immediate) priming with SOAs (stimulus onset asynchronies) of 42–4000ms (Deutsch et al., 1998; Drews & Zwitserlood, 1995; Henderson, Wallis, & Knight, 1984; Rastle, Davis, & New, 2004) and with at least 48 items between prime and target (Fowler, Napps, & Feldman, 1985). Moreover, morphological effects have been observed in a range of experimental paradigms (e.g., semantic categorisation–Bowers, Davis, & Hanley, 2005; naming–Murrell & Morton, 1974).

In comparison with morphological priming effects, both orthographic and semantic priming are weaker, more variable and task-dependent. Orthographic overlap can result in facilitation, inhibition or a null effect depending on SOA, the number of intervening items and the task (Drews & Zwitserlood, 1995; Feldman, 2000; Napps & Fowler, 1987; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997; Stolz & Feldman, 1995). For example, the same orthographically related prime-target pairs result in inhibition of lexical decisions but facilitation of naming latencies, whereas morphological effects are facilitatory in both tasks (Deutsch et al., 1998; Drews & Zwitserlood, 1995). Similarly, semantic overlap effects are generally weaker than morphological effects and are influenced by the temporal location of the prime (SOA and lag) as well as the nature of the task. For example, a letter search on the prime drastically reduces semantic priming (e.g., Friedrich, Napps, & Feldman, 1991; Stolz & Besner, 1996) but not morphological facilitation (Stolz & Besner, 1998). At long lags, both semantic and orthographic priming effects are short lived. Semantic effects reach insignificance with as few as one or two intervening items (Dannenbring & Briand, 1982; Gough, Alford, & Holley-Wilcox, 1981) and, although orthographic primes can result in a mild facilitation of target responses (e.g., with 10 intervening items), this is rarely significant (Drews & Zwitserlood, 1995; Feldman, 2000; Feldman & Moskovljevic, 1987; Stolz & Feldman, 1995). SOA manipulations have opposite effects on orthographic and semantic priming. Orthographic priming is facilitatory at very short SOAs (e.g., 32ms) and non-existent or inhibitory at longer SOAs (e.g., 42-300ms–Drews & Zwitserlood, 1995; Feldman, 2000; Grainger, Cole, & Segui, 1991; Rastle et al., 2004; Stolz & Feldman, 1995). In contrast, semantic facilitation increases with SOA (De Groot, 1984; Feldman, 2000; Joordens & Becker, 1997; Lorch, 1982; McNamara, 1992; Ratcliff, Hockley, & McKoon, 1985).

Although the effects of morphological, orthographic and semantic overlap are distinct from one another, morphologically complex words vary in terms of all three characteristics and therefore processing is likely to be simultaneously influenced by all three factors. Once again, it is priming studies that provide evidence for combinatory effects. For example, morphological priming effects are stronger when prime-target pairs are orthographically similar (i.e., regular morphographic relationships) than when they are dissimilar (Fowler et al., 1985; Rueckl et al., 1997; Stanners et al., 1979). However, only a handful of studies have considered morphological, semantic and orthographic overlap within a single experiment–two studies in Hebrew (Bentin & Feldman, 1990; Frost, Forster, & Deutsch, 1997) and two in English (Feldman, 2000; Stolz & Besner, 1998).

Stolz and Besner (1998) demonstrated that a letter-search on the prime resulted in a null effect of semantic overlap on lexical decision performance, whereas morphological facilitation remained significant even after partialling out the effect of orthographic overlap. Feldman (2000) conducted an extensive investigation into the relative contribution of orthographic, semantic and morphological effects in lexical decisions. The findings demonstrated clear differences in time courses. At short SOAs (32ms) morphological facilitation was not clearly different from semantic priming but over longer SOAs (300ms) and at long lags (an average of 10 intervening items) morphological facilitation exceeded the summative effects of orthographic and semantic priming. As morphological effects are longer lasting, they become more apparent as semantic effects fade and orthographic effects become inhibitory. These results have led to the conclusion that morphology is independently represented in the mental lexical, in addition to orthographic and semantic representations.

Unfortunately, the tasks used in previous research to investigate morphological relatedness are inappropriate for use with deaf adolescents and young hearing children. Effect sizes in priming studies are typically small, demanding large numbers of participants and items. Given the difficulties inherent in recruiting and working with the deaf population, it was necessary to find an alternative experimental task that would demonstrate strong effects with a small sample (in terms of both participants and items). The duration of the experimental task had to be limited because of children's relatively short attention spans. In addition, the relevant priming effects are typically observed mainly (if not solely) in reaction times rather than error rates. The wide range of reading abilities anticipated in the deaf population is likely to result in large variation in reaction times. An experimental task was required in which the morphological effect would survive this individual variation. Finally, the information used by hearing adults to make lexical decisions can change according to experimental context (Pugh, Rexer, & Katz, 1994; Stone & Van Orden, 1993) and episodic and strategic confounds are common (Forster & Davis, 1984). These confounds combined with the vocabulary limitations that are so common in the deaf population (Kyle & Harris, 2006; Paul, 1996; Waters & Doehring, 1990), led to the concern that deaf children might not be able to provide accurate lexical decisions.

Many of the alternatives to lexical decision that are typically used to examine lexical access are inappropriate for the study of morphology. For example, naming and stem completion may be confounded by a response bias, such that morphologically related primes are produced as errors (Rueckl et al., 1997). Furthermore, naming tasks are simply not appropriate for use with deaf adolescents, as speech intelligibility issues are likely to confound results. For these reasons, it was necessary to establish a novel paradigm to provide evidence of morphological effects in excess of those pertaining to semantic and orthographic overlap with young deaf readers.

Within the STM literature, the role of similarity amongst items on the STM list has been extensively studied. To my knowledge, no research to date has investigated the role of morphology in STM. The majority of research has focused on phonological similarity, which results in a powerful reduction in recall accuracy (see Baddeley & Hitch, 1994 for a review; Conrad & Hull, 1964; Kintsch & Buschke, 1969). Baddeley (1970, 1966) has demonstrated that the effects of orthographic and semantic similarity are, if present at all, substantially weaker than those of phonological similarity. Orthographic similarity on its own has received less attention (Baddeley, 1970) but appears to result in reduced accuracy, at least in circumstances where phonological recoding is unlikely, such as during articulatory suppression (Hitch, Woodin, & Baker, 1989; Walker, Hitch, & Duroe, 1993). In the present task, phonological and orthographic effects are not distinguished and therefore the expectation is that overlapping form will result in confusion errors. In terms of semantic overlap, errors on recall are common for lists of synonyms but, on the basis of position effects, it has traditionally been argued that semantic effects truly belong in the domain of long-term memory (LTM) rather than STM (e.g., Atkinson & Shiffrin, 1968; Baddeley, 1970; Kintsch & Buschke, 1969). However, more recent evidence suggests that semantic processes are involved in both STM and LTM (Martin, Shelton, & Yaffee, 1994; Romani & Martin, 1999). For the purposes of the present thesis, it does not matter whether semantic effects belong in the domain of STM or LTM. What is important is that an STM paradigm offers an opportunity to observe both orthographic and semantic effects and potentially to distinguish these effects from those of morphology.

Unfortunately, the way similarity is manipulated in most STM studies limits the relevance of previous findings to the present research. Typically, relatedness has been manipulated between list items whereas in the present task relatedness was manipulated between list and probe words. Within-list similarity encourages participants to use information that distinguishes words strategically, in order to prevent confusion between items. Errors may result from the use of the similar information and/or the effectiveness of alternative strategies. For example, confusion errors will occur on orthographically related lists if orthographic information is used. However, if instead of relying on confusing orthographic information, a participant strategically applied semantic coding but this was ineffective, errors will also occur. In the present research the list items were dissimilar to one another and relatedness was manipulated between a list word and a probe word. Previous evidence suggests that semantically and orthographically related list and probe words can indeed be confused in STM, at least when the use of such strategies is a task demand (Crosson et al., 1999, 1972; Shulman, 1970), but it has not been established whether the same is true of morphologically related pairs.

The task dependent nature of orthographic and semantic effects demands further attention and as little research has examined the role of morphology in STM (Rueckl et al., 1997) this domain presents an interesting opportunity to attempt to distinguish these three factors. However, effects observed in priming studies cannot be logically assumed to be observed in an STM probe task. The present studies examine the influence of morphological, orthographic and semantic overlap on the processing of regular, suffixed inflections within the context of a novel STM probe paradigm. In Experiment 1a, morphological and orthographic overlap will be compared. Experiment 1b includes the additional factor of semantics, to test whether morphology is distinguishable from the combined effects of orthographic and semantic similarity.

3.2 Experiment 1a: Morphological and orthographic overlap in short-term memory

The aim of the present experiment is to distinguish morphological and orthographic effects in STM to measure awareness of morphological relationships. Hearing adults viewed lists of seven words and then determined whether a subsequent probe word had been present on the list. When the probe did not appear on the list it was paired with one of the list words. The relationship between probe and list words was manipulated to test the impact of orthographic and morphological relatedness on accuracy. List and probe words were either completely unrelated (e.g., SIGH-*TRIPS*), shared orthographic features (e.g., BEE-*BEEF*) or had morphological overlap (e.g., BEE-*BEES*). The same root words (henceforth *substring*) were used in the morphological and orthographic overlap conditions (e.g., BEE) and were embedded within two longer (henceforth *superstring*) words to form the related words (e.g., <u>BEE</u>S, <u>BEE</u>F).

When the probe was absent from the list (i.e., list and probe word were unrelated), performance was expected to be most accurate (e.g., SIGH-*TRIPS*). If the mental lexicon contains an independent level of morphological representation, then false-positives should be most common when there is morphological overlap between list and probe words (e.g., BEES-*BEE*), since the words share the same root. The crucial comparison is between performance on morphologically related words and orthographically related words–pairs which share the same number of letters but are not morphologically related (e.g., BEEF-*BEE*). Since orthographic features are used in STM coding, false-positives should also occur in this condition. However, morphologically related words share both orthographic and morphological overlap and therefore, if these effects are independent and additive, performance on the orthographic overlap condition should be intermediate between unrelated and morphological overlap conditions.

In addition to the nature of overlap, the effect of relative probe length (substring vs. superstring) was examined. For substring probes the prediction is simple. A morphologically related superstring word on the list (e.g., BEES) activates its root (a substring probe, e.g., *BEE*) because it is fully specified in terms of both morphology and orthography. This hypothesis is also supported by the finding that suffixes can be lost in STM (Van der Molen & Morton, 1979). An orthographically related superstring word (BEEF) activates the substring probe (*BEE*) because it is fully specified at the orthographic level only, sharing letters but not morphemes. Therefore, it is expected that false-positives will be relatively more common when the probe is a morphologically related substring than when it is an orthographically related substring word. What will happen for substring-superstring list-probe pairs is less clear. Here, confusions would involve extension of the memory trace. Previous evidence suggests that roots prime suffixed derived words to the same, if not greater extent as derived words prime roots (Marslen-Wilson et al., 1994) but this has not been considered for inflections. Bowers et al. (2005) suggested that orthographic substring-superstring activations are just as likely as superstring-substring activations in a semantic categorisation task. Following their argument, a substring list word (BEE) activates related superstring probes (*BEES /BEEF*) because the whole morphological and/or orthographic neighbourhood is activated in just the same way as this neighbour is activated by superstring list words. Therefore, it is expected that false positives will once again be more common when the probe is a morphologically related superstring than when it is an orthographically related superstring word.

3.2.1 Method

3.2.1.1 Participants

Thirty-three monolingual native English speakers (26 female) were recruited from the student population of the University of Birmingham and received partial course credit or £6 for participation. Participants were aged 18 to 23-years, had normal or corrected to normal vision and no known literacy or language impairments.

3.2.1.2 Design

Overlap between list-probe pairs (morphological, orthographic and unrelated) was tested within-participants. Embedded within the morphological and orthographic overlap conditions was the additional factor of probe type (substring, superstring). In these conditions, probe and list words were systematically manipulated so that in half of the trials the substring word occurred on the list and the probe was the superstring word (henceforth *superstring probe* trials) and in half of the trials the superstring word occurred on the list and the substring word was the probe (henceforth *substring probe* trials). Each substring word was, therefore, involved in 10 trials–five trials with the probe word matching a list word (*probe present* on the list) and five where the probe and list words differed (*probe absent*, see Table 3.1 for examples). The dependent variable was accuracy of judging whether the probe had been on the list (henceforth *sensitivity*).

Table 3.1: Overlap conditions and example trials in Experiment 1a

Probe present on the list?	Overlap		
	Morphology	Orthography	Unrelated
Present	BEES-*BEES* BEE-*BEE*	BEEF-*BEEF* BEE-*BEE*	SIGH-*SIGH*
Absent	BEE-*BEES* BEES-*BEE*	BEE-*BEEF* BEEF-*BEE*	SIGH-*TRIPS*

Note. CAPS: Critical list word. *ITALICISED CAPS*: Probe word.

3.2.1.3 Materials

Twenty-seven sets of experimental words were selected, resulting in 270 total trials. A full list of stimuli can be found in Appendix 1a. The same substring words were used in morphological and orthographic overlap conditions (e.g., BEE-<u>BEE</u>S and BEE-<u>BEE</u>F). Morphological superstring words were regular inflections of the substring (noun plurals or past-tense verbs). Orthographic superstring words contained the substring word embedded at the beginning of a longer morphologically unrelated word (e.g., BEE-BEEF). Both morphological and orthographic superstring words shared orthographic and phonological overlap with their substring counterparts (i.e., there was neither phonological nor orthographic root adjustment). Morphological and orthographic superstring words were matched for word frequency (based on 17.9 million token text corpus taken from the CELEX Database–Baayen, Piepenbrock, & Rijn, 1993), number of letters and number of phonemes (independent samples *t* tests, $p > 0.8$). In addition, mindful that the experiment would be replicated with deaf adolescents and hearing children, words were selected which were likely to be in the vocabulary of these children. The unrelated probe words were matched to the morphological and orthographic overlap probes for frequency, number of letters and number of phonemes (independent samples *t* tests, $p > 0.2$). Morphological superstrings included 12 regular past-tense verbs and 15 regular plural nouns. See Table 3.2 for descriptive statistics.

Table 3.2: Descriptive statistics for each word type in Experiment 1a

Word type	Frequency *M (SD)*	LEN *M (SD)*	PhN *M (SD)*
Substring	1751 (2130)	3 (1)	3 (1)
Orthographic superstring	324 (392)	5 (1)	4 (1)
Morphological superstring	306 (549)	5 (1)	4 (1)
Unrelated probe present	800 (1040)	5 (1)	4 (1)
Unrelated probe absent	799 (921)	5 (1)	4 (1)

Note. LEN: Number of letters. PhN: Number of phonemes.

Each trial list consisted of seven words, around the limit of the average STM capacity (Miller, 1956). This length was chosen to maximise errors without making the task too difficult. The location of the critical word was counterbalanced in positions two-to-six of the list. Fillers were matched to experimental words for length, frequency and number of root/inflected words. To balance the presentation frequency of each word, experimental words occurred as fillers for other trials. To control for repetition effects due to orthographic overlap among experimental items, the presentation frequency of unrelated probe words was similar to the summed presentation frequency of substring, morphological superstring and orthographic superstring words. For example, the orthographic sequence CAR occurred on 10 lists (4x CAR, 3x CARS, and 3x CARD), while the unrelated probes WALL and IDEA each occurred on eight lists.

3.2.1.4 Procedure

Participants received written and verbal instruction prior to commencing two practice trials. They were asked to memorise lists of words and then provide a keyboard response to indicate whether a probe word occurred on the preceding list. The response keys were 'N' and 'C', with the dominant hand providing the positive response.

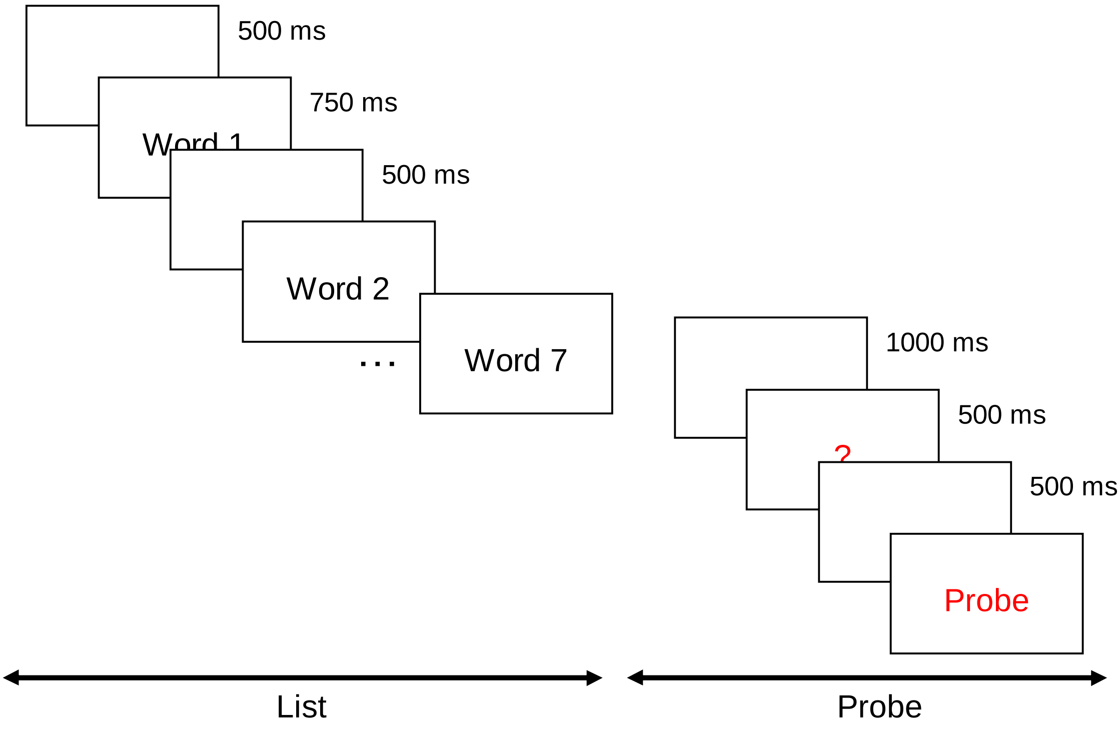

Figure 3.1: Graphical representation of a trial in the STM probe paradigm

An HP Pavilion dv1000 notebook computer was used to run the experiment using e-prime^{TM} (version 1.1.4.4 SP3, 2002) to control stimulus presentation and record responses. Words were presented in lower case in the centre of the screen, black on white, in 18pt bold Courier New font. For each trial, the seven list words were presented consecutively (750ms each) with a blank screen preceding each word (500ms). After the final word on the list there was a blank screen (1000ms), a red question mark (500ms) and another blank screen (500ms). Finally, the probe was displayed in red letters until a keyboard response was produced (see Figure 3.1). Trial order was randomised between participants and breaks were offered every 27 trials.

3.2.1.5 Categorisation task

Many words can occur in more than one part-of-speech and the degree of morphological overlap will be reduced if participants assigned the root and inflected words to different parts-of-speech. The limited choice of suitable substring words embedded within both morphological and orthographic superstring words made it impossible to use words belonging unambiguously to a single part-of-speech. Therefore, many of the substring words could occur in more than one part-of-speech (e.g., *top* can be a noun, verb or adjective). After completing the experimental task, participants performed a pencil-and-paper categorisation task in which they categorised morphological substring and superstring words as nouns, verbs or adjectives. Instructions explicitly stated that although words may occur in more than one part-of-speech, participants must classify them into only one–the form that came to mind first. For half of the words the inflected form occurred first on the list, for half the root occurred first. The check box order of noun and verb was counterbalanced between participants. The categorisation results allowed comparison of the morphological effect when related words were perceived to be in the same part-of-speech to when they differed.

3.2.2 Results

Because accuracy in the STM probe task can be influenced by response bias, *d'* values were calculated for each participant from counts of "yes" and "no" responses (adding 0.5 to each cell to prevent infinite *d'* when cell counts are 0). *D'* is a measure from signal detection theory which separates sensitivity to the presence of the probe word from response bias. If participants are unable to discriminate whether or not the probe was on the list, *d'* = 0. Perfect accuracy results in infinite *d'*, while 1.35 represents 75% accuracy (in hits and correct rejections). In addition to the measure of sensitivity (*d'*), *C* (criterion) is a measure of response bias–the tendency for a participant to respond "yes" regardless of the presence/absence of the probe on the list. Positive bias values indicate a tendency to say no and negative values represent a tendency to say yes. Zero reflects no response bias (see Macmillan & Creelman, 2005 for further discussion).

After calculating *d'* for the unrelated condition, one participant was removed from the analysis because they failed to show sensitivity to the presence of the probe on the list (*d'* = 0). The remaining 32 participants demonstrated good sensitivity and a slight bias to say "no" in the unrelated condition; mean *d'* = 2.63 (*SD* 0.72, mean bias 0.25).

3.2.2.1 The effect of overlap

Mean *d'* values for the experimental conditions (see Figure 3.2) suggest that sensitivity was high when the probe and list words were unrelated (mean *d'* 2.63, *SD* 0.72, mean bias 0.25), poor when they were morphologically related (mean *d'* 1.09, *SD* 0.43, mean bias -0.20) and intermediate when there was orthographic overlap (mean *d'* 1.80, *SD* 0.53, mean bias 0.16). Statistical significance was tested using hierarchical log-linear analysis with the factors of overlap (morphological, orthographic, unrelated), probe presence (present, absent) and response (yes, no). In these analyses, sensitivity is indexed by the interaction between probe presence and response (i.e., the tendency for the presence

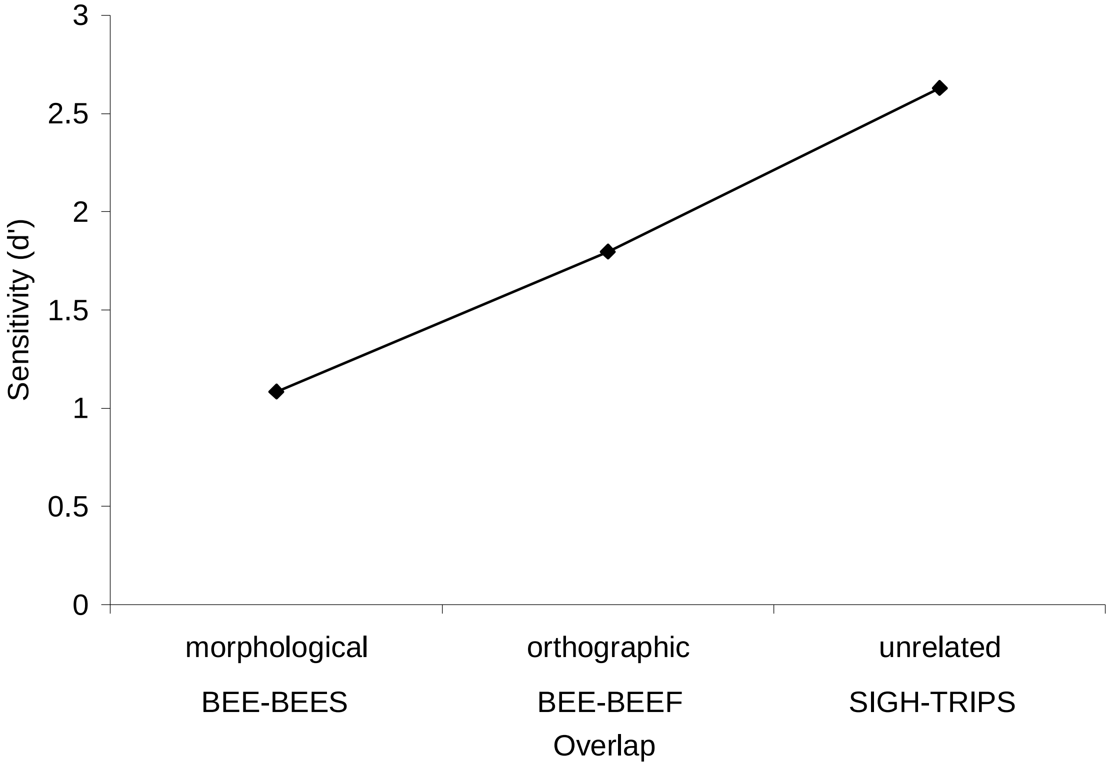

Figure 3.2: The effect of overlap on sensitivity (mean d') in the morphological, orthographic and unrelated conditions in Experiment 1a

of the probe on the list to modify responses) and bias is indexed by the main effect of response (i.e., the tendency to respond "yes" or "no" regardless of the probe's presence). The interaction between overlap and sensitivity was significant; Overlap*Probe presence* Response, $G^2(2) = 284.24$, $p < 0.0001$. To investigate which individual conditions differed from one another, three follow-up analyses were conducted, comparing a) orthographic and morphological overlap, b) orthographic overlap and unrelated and c) morphological overlap and unrelated conditions. The interaction between overlap and sensitivity was highly significant in all three analyses; Overlap*Probe presence*Response, $G^2(1) = 104.04$, $p < 0.0001$; $G^2(1) = 69.88$, $p < 0.0001$; and $G^2(1) = 263.53$, $p < 0.0001$ respectively. Thus, sensitivity was significantly lower in the morphological overlap condition than in the orthographic overlap condition, which in turn, was significantly less than in the unrelated condition (see Figure 3.2).

3.2.2.2 The effect of probe type

A second analysis investigated whether the effect of overlap differed when the probe was a substring word compared to when it was a superstring word–was BEE confused with *BEES* as often as BEES with *BEE*? Figure 3.3 illustrates the mean *d'* values for the orthographic and morphological overlap conditions as a function of probe type. The effect of probe type differed in the two overlap conditions. Hierarchical log-linear analysis with the factors overlap (morphological, orthographic), probe type (substring, superstring), probe presence (present, absent) and response (yes, no) indicated a significant interaction between probe type, overlap and sensitivity; Overlap*Probe type*Probe presence*Response, $G^2(1) = 35.40$, $p < 0.0001$. Follow-up analyses on each overlap condition indicated that probe type had a significant effect on sensitivity in the orthographic overlap condition but not in the morphological overlap condition; Probe type*Probe presence*Response, $G^2(1) = 68.52$, $p < 0.0001$ and $G^2(1) = 0.25$, $p = 0.6$

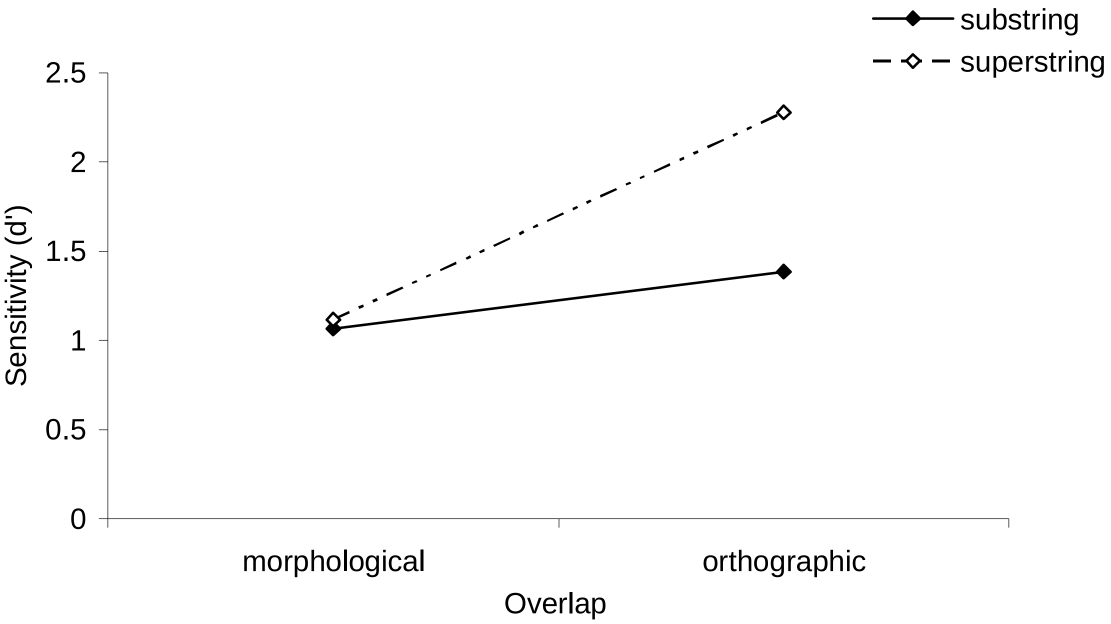

Figure 3.3: Sensitivity (mean d') in morphological and orthographic overlap condition of Experiment 1a as a function of probe type (e.g., substring probe BEES/BEEF-*BEE, superstring probe* BEE-*BEES/BEEF)*

respectively. Thus, participants were less likely to make errors on orthographically related words when the probe was a superstring word (i.e., the probe had been fully contained within the list word, e.g., BEE-*BEEF*) than when it was substring (i.e., the probe had to be extended to form the list word, e.g., BEEF-*BEE*). In contrast, participants were equally likely to make errors whether the probe was substring or superstring in the morphological overlap condition (Figure 3.3).

A final pair of log-linear analyses tested whether sensitivity to morphological and orthographic overlap conditions differed for each of the probe types (substring and superstring). These analyses confirmed that even when the probe was substring the difference between morphological and orthographic overlap conditions remained significant; Overlap*Probe presence* Response, substring $G^2(1) = 12.54$, $p < 0.0005$ and superstring $G^2(1) = 124.21$, $p < 0.0001$.

3.2.2.3 Categorisation task

Averaging across participants, there was an overwhelming bias to categorise substring words as nouns. Using a criterion of 75%, participants agreed on the part-of-speech for 41/54 words. Only 15/27 morphologically related pairs were consistently perceived to be in the same part-of-speech (matching pairs). The remaining 12 pairs (mismatching pairs) were either judged to belong to different parts-of-speech (e.g., 85% of participants categorised PET as a noun but 82% categorised PETTED as a verb) or participants failed to reach agreement on one or more of the words (e.g., 42% of participants categorised BLANKS as a noun, 21% as a verb and 36% as an adjective). The effect of match/mismatch part-of-speech on sensitivity in the morphological overlap condition was assessed in an items analysis. Sensitivity was lower when the categorisations matched (mean *d'* 0.84, *SD* 0.39, bias 0.07) than when they differed (mean *d'* 1.31, *SD* 0.05, bias 0.51). Hierarchical log-linear analysis confirmed that the match in substring-superstring categorisations significantly influenced sensitivity; Match/mismatch*Probe presence*Response, $G^2(1) = 23.24$, $p < 0.0001$. In other words, the morphological effect was stronger when the probe and list word were perceived to be the same part-of-speech.

3.2.3 Discussion

The present findings suggest that both orthographic and morphological overlap influenced performance in the STM probe task. These findings demonstrate that root and inflections are related by more than just shared letters. Given the particularly high degree of orthographic overlap in the present study (with substring-superstring words differing by only a few letters) the size of the morphological effect is particularly impressive.

Probe type moderated the effect of orthographic (but not morphological) overlap. Participants were less sensitive to substring probes than superstring probes–they were more likely to erroneously believe that they had seen *BEE* on the list when they had in fact seen BEEF than to believe they had seen *BEEF* when they had actually seen BEE. This suggests that for orthographically related words, embedded words are identified more often than words are considered to be part of a longer whole (i.e., BEEF activates BEE more often than BEE activates BEEF). Nonetheless, whether the orthographically related probe was substring or superstring, sensitivity was significantly worse in the morphological overlap condition. Furthermore, probe type did not influence performance in the morphological overlap condition, suggesting that morphologically related words were activated regardless of whether this involved the addition or subtraction of a morpheme and providing further evidence that the morphological effect was not simply due to letter overlap. The probe type effect will be discussed further in the General Discussion of the present chapter (Section 3.4, p72), after presenting Experiment 1b.

There are several interpretations possible for the morphological overlap effect observed in the present study. Participants may choose to ignore the plural marking. However, this seems unlikely given that participants were highly literate and because the presence of a substantial number of inflected forms throughout the task should, if anything, motivate attending to the suffix. The effect may be caused by activation of both root and inflected forms due to morphological association (either through activation of the root or through activation of the whole morphological family) or due to semantic association because of the high degree of semantic similarity of root and inflected forms. Both of these explanations depend on a strong connection between morphologically related words but they differ as to whether the connection is based on morphological or semantic properties.

Finding that the morphological effect is stronger for word pairs perceived to be in the same part-of-speech may support a grammatical basis for the morphological effect. The noun CAR activated the plural noun CARS more than the noun PET activated the past-tense verb PETTED. This may be because the morphological relationship is closer for CAR-CARS than PET(noun)-PETTED. Consistent with this, nouns and verbs are argued to be differently distributed (Damasio & Tranel, 1993; Deutsch et al., 1998). Thus, it seems more likely that activation will spread from noun-to-noun inflection than noun-to-verb-to-verb inflection. However, this is not necessarily a morphological effect. The semantic similarity of related words in the same part-of-speech will also be closer than related words in different parts-of-speech. In Experiment 1b, further attempts will be made to distinguish the effect of semantic overlap from morphological overlap.

3.3 Experiment 1b: Morphological, orthographic and semantic overlap

Experiment 1b aimed to replicate and extend the findings from Experiment 1a by demonstrating that the morphological effect was not simply due to the semantic similarity of morphologically related words or a combination of semantic as well as orthographic overlap. A new set of stimuli were designed to compare sensitivity to list and probe words with morphological, orthographic, semantic and no overlap. If the effect of morphology was a mere semantic effect, then morphological and semantic overlap should lead to a comparable level of confusion. If the effect of morphology was due to the combined effects of orthographic and semantic overlap, then the difference in performance on the morphological overlap and unrelated conditions should be equal to the combined effects of orthographic and semantic overlap. If morphological relatedness has an effect of its own, then performance on the morphological overlap condition should be worse than both the individual and combined effects of orthographic and semantic overlap.

3.3.1 Method

3.3.1.1 Participants

Twenty native English speakers (14 female) volunteered to participate in exchange for £6. Participants were either current students of the University of Birmingham or were educated to degree level or above. They were aged 19 to 27-years, had normal or corrected to normal vision and did not have any language, literacy or learning impairments.

3.3.1.2 Design

As in Experiment 1a, the factors overlap (morphological, orthographic, unrelated and additionally semantic) and probe type (substring, superstring) were tested within-participants.

Substring words could not be identical in the morphological, semantic, orthographic and unrelated conditions due to a limited set of suitable words. Therefore, morphological and semantic overlap conditions shared the same substring words while orthographic overlap and unrelated conditions shared a second substring word. The two substring words were, however, matched for frequency and length (see below). In the morphological overlap condition, superstring words were regular plural noun inflections of the substring (e.g., HAT-HATS). In the semantic overlap condition the same substring word was paired to a close synonym–a semantically related but morphologically unrelated word (e.g., HAT-CAP). Orthographic superstring words contained a shorter (substring) word embedded at the beginning of a semantically and morphologically unrelated word (the orthographic superstring word, e.g., WIN-WING) and for the matched unrelated condition the same substring word was paired with a word unrelated in meaning or form (e.g., WIN-DAD). Probe type was manipulated so that in each condition substring and superstring words occurred as probes for both probe present and absent trials, resulting in sets of 16 trials–eight probe present and eight probe absent trials (see Table 3.3).

Table 3.3: Overlap conditions and example trials in Experiment 1b

Probe present on the list?	Overlap			
	Morphology	Semantics	Orthography	Unrelated
Present	HATS-*HATS*	CAP-*CAP*	WING-*WING*	DAD-*DAD*
	HAT-*HAT*	HAT-*HAT*	WIN-*WIN*	WIN-*WIN*
Absent	HAT-*HATS*	HAT-*CAP*	WIN-*WING*	WIN-*DAD*
	HATS-*HAT*	CAP-*HAT*	WING-*WIN*	DAD-*WIN*

Note. CAPS: Critical list word. *ITALICISED CAPS*: Probe.

3.3.1.3 Materials

Sixteen sets of experimental words were selected resulting in a 256 trials. A complete list of experimental words is provided in Appendix 1b. Within each set of experimental words there were two substring words–one was used in the morphological and semantic condition while the other was used in the orthographic and unrelated condition. Substring words were matched for frequency (taken from the CELEX Database–Baayen et al., 1993) and length (independent sample t tests, $p > 0.8$). The superstring words in all four conditions were also matched for frequency and length (independent samples *t* tests, $p > 0.2$. See Table 3.4)[2].

Table 3.4: Descriptive statistics for each type of word in Experiment 1b

	Substring		Superstring		Semantic similarity rating *M (SD)*
	LEN *M (SD)*	Freq *M (SD)*	LEN *M (SD)*	Freq *M (SD)*	
Morphological	4 (1)	1033 (901)	5 (1)	455 (462)	6 (0)
Semantic	4 (1)	1033 (901)	5 (1)	740 (816)	6 (0)
Orthographic	4 (1)	1017 (889)	5 (1)	598 (509)	1 (0)
Unrelated	4 (1)	1017 (889)	5 (1)	606 (475)	1 (0)

Note. LEN: Number of letters. Freq: Word frequency. Semantic similarity: 1–7 (7 = similar).

To control for semantic similarity, a different group of 15 native English speakers educated to degree level or above provided semantic relatedness judgements for a total of 100 substring-superstring pairs (including the 64 experimental pairs). The task was completed using an electronic form. To encourage participants to fully process the first word prior to viewing the second, drop-down boxes displayed each pair of words and instructions explicitly stated for them to focus on their initial interpretation of the words without letting the meaning of the second word influence their interpretation of the first. The presentation order of words (within pairs) was counterbalanced between-participants. Participants rated the similarity of meaning of each word pair by checking a box on a Likert scale of 1 (dissimilar) to 7 (similar). The mean of these ratings was used as the measure of semantic overlap and to control the semantic similarity of substring-superstring pairs in the morphological and semantic overlap conditions (with no pairs having a mean rating less than 5) and also in orthographic and unrelated conditions (with no pairs having

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[2] Words were also categorised by perceived part-of-speech as per Experiment 1a. All of the morphological overlap words were perceived to be nouns and agreement between participants was 80% or greater for all but one pair. Therefore, perceived part-of-speech was not a factor in the analysis.

a mean rating greater than 2). Independent sample t tests confirmed that differences in the similarity ratings of semantic and morphological ($p = 0.2$) and orthographic and unrelated ($p = 0.5$) substring-superstring pairs were not significant and therefore these pairs of conditions were matched for semantic relatedness. All other differences were significant ($p < 0.001$).

Consistent with Experiment 1a, trial lists consisted of seven words and the critical word was counterbalanced in positions two-to-six. Fillers were matched to critical words for length, frequency and included a range of root and inflected words. In order to balance the presentation frequency of experimental words, superstring words (morphological, orthographic, semantic and unrelated) also occurred as fillers for two unrelated trials. The words on individual lists for each trial were semantically unrelated and orthographically dissimilar.

3.3.1.4 Procedure

The procedure was the same as described for Experiment 1a.

3.3.2 Results

As in Experiment 1a, *d'* values were calculated from counts of "yes" and "no" responses for each condition (adding 0.5 to each cell) and statistical differences were tested using hierarchical log-linear analyses. The first analysis examines the effect of overlap (morphological, orthographic, semantic and unrelated) on sensitivity. The second analysis examines whether probe type (substring or superstring) influences sensitivity and finally, the third analysis examines whether the effect of morphological overlap can be distinguished from the combined effect of orthographic and semantic overlap.

3.3.2.1 The effect of overlap

Mean *d’* values for each condition (see Figure 3.4) suggested that sensitivity was high when probe and list words were unrelated (mean *d’* 2.51, *SD* 0.59, bias 0.22), poor when they shared morphological overlap (mean *d’* 1.08, *SD* 0.59, bias -0.11) and intermediate when they shared orthographic (mean *d’* 2.06, *SD* 0.65, bias 0.14) or semantic overlap (mean *d’* 2.14, *SD* 0.49, bias 0.02). Hierarchical log-linear analysis with the factors overlap (morphological, orthographic, semantic, unrelated), probe presence (present, absent) and response (yes, no) indicated a significant effect of overlap on sensitivity; Overlap*Probe presence*Response, $G^2(3) = 180.72$, $p < 0.0001$. To investigate whether sensitivity differed between all four conditions, follow-up analyses were conducted for every pair. Sensitivity did not differ between the orthographic and semantic overlap conditions ($p = 0.2$). However, sensitivity in the morphological overlap condition

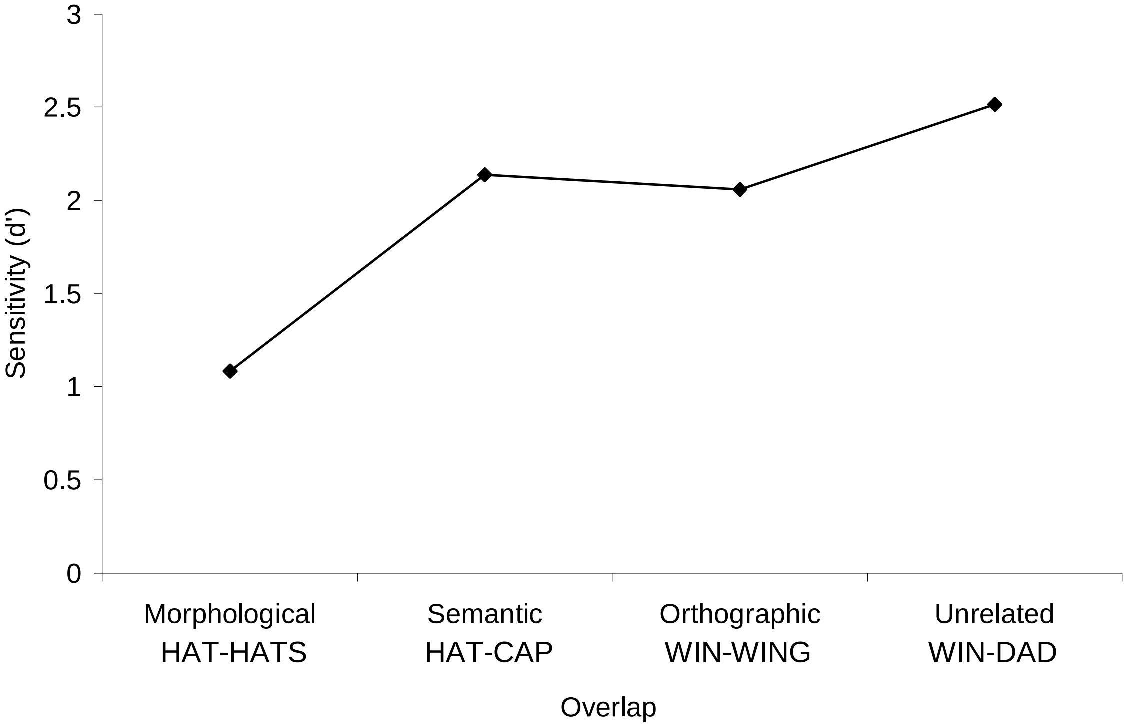

Figure 3.4: The effect of overlap condition (morphological, semantic, orthographic and unrelated) on sensitivity (mean d’) in Experiment 1b

was significantly less than in the orthographic, semantic or unrelated conditions; Overlap*Probe presence*Response, $G^2(1) = 72.46$, $p < 0.0001$; $G^2(1) = 92.64$, $p < 0.0001$ and $G^2(1) = 157.67$, $p < 0.0001$ respectively. Furthermore, sensitivity to the unrelated condition was significantly greater than on either the orthographic or semantic overlap conditions; Overlap*Probe presence*Response, $G^2(1) = 19.32$, $p < 0.0001$ and $G^2(1) = 9.59$, $p < 0.005$ respectively. In other words, participants were more likely to make errors when there was morphological overlap between the probe and critical list item (e.g., HAT-*HATS*) than when there was orthographic or semantic overlap. Words with orthographic overlap (e.g., WIN-*WING*) were equally likely to be confused as words with semantic overlap (e.g., HAT-*CAP*).

3.3.2.2 The effect of probe type

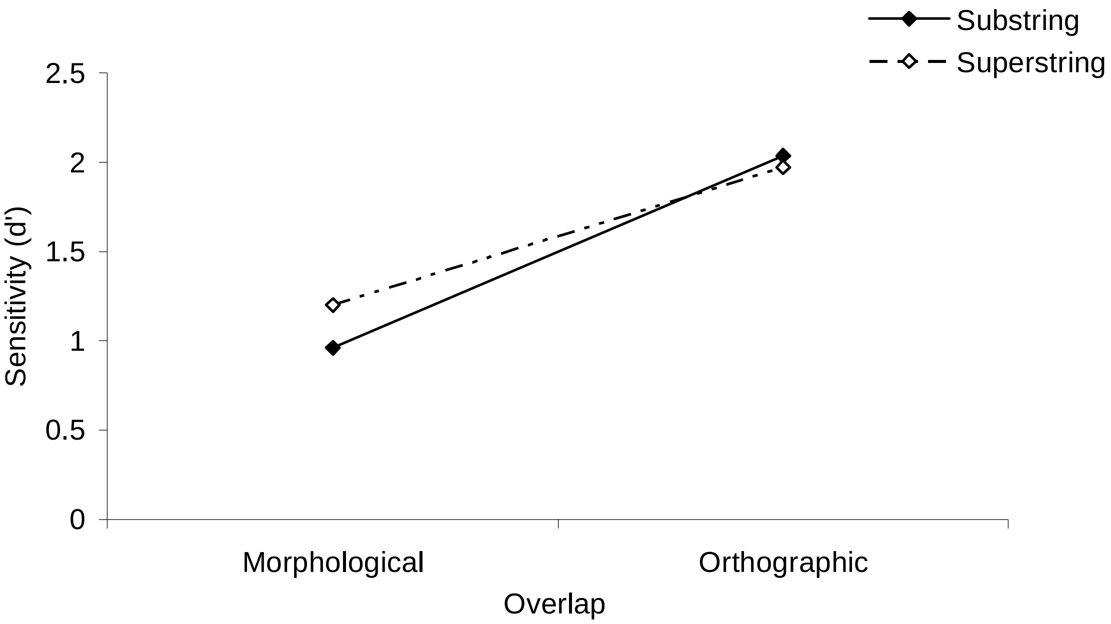

Figure 3.5: Sensitivity (mean d') in morphological and orthographic overlap conditions as a function of probe type (e.g. substring probe HAT/WIN, superstring probe HATS/WING) in Experiment 1b

A second analysis tested whether effects of relatedness in morphological and orthographic overlap conditions were dependent on the probe being a substring or superstring word. Figure 3.5 suggests an effect of the type of overlap on sensitivity but no effect of probe type in either overlap condition (morphological superstring mean *d'* 1.20, *SD* 0.70, bias -0.06; substring mean *d'* 0.96, *SD* 0.63, bias -0.12; orthographic substring mean *d'* 2.04, *SD* 0.71, bias 0.03; superstring mean *d'* 1.97, *SD* 0.72, bias 0.01). Hierarchical log-linear analysis with the factors probe type (substring, superstring), overlap (morphological, orthographic), probe presence on the list (present, absent) and response (yes, no) indicated that, consistent with the previous analysis, there was a significant effect of overlap on sensitivity; Overlap*Probe presence*Response $G^2(1) = 72.46$, $p < 0.0001$. Neither the effect of probe type nor the interaction between probe type and overlap significantly influenced sensitivity ($p > 0.2$)[3].

3.3.2.3 Combined effects of morphology, semantics and orthography

The analyses above demonstrate that the effect of morphology is greater than the *separate* effects of orthography and semantics. However, because morphologically related words share both orthographic and semantic overlap the morphological effect could be the result of the *combined* influence of semantic and orthographic overlap.

A generalised linear model allows us to test whether the additive effects of semantic similarity, orthographic overlap and morphological relationship modify sensitivity to the presence of the probe on the list. The equation "probe presence*response*(semantic similarity + orthographic overlap + morphological relationship)" was used to model counts of "yes" and "no" responses by items. Once again, the interaction between probe presence (present, absent) and response (yes, no) quantifies sensitivity. Semantic similarity was the mean rating for substring-superstring pairs

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[3] There was a small (but significant) interaction between probe type and overlap on bias; Probe type*Overlap*Response $G^2(1) = 4.40$, $p = 0.04$. Note that this is an effect on bias (tendency to produce a given response regardless of the presence of the probe on the list) not sensitivity (tendency of the presence of the probe on the list to modify responses).

obtained from the relatedness judgements (1–7, see p65). Orthographic overlap was measured by identifying the longest common subsequence (Gusfield, 1997) in probe and list words. The proportion of overlap was quantified using the equation $2A/B$ where A = number of letters in the same order that the two strings share and B = total length of both the substring and superstring. The variable morphological relatedness was binary (0 = unrelated, 1 = related). The model proved to be a good fit to the data, as the difference between the observed and expected values was not significant ($p = 1.0$). If the morphological effect was simply a combined effect of orthographic and semantic overlap, morphological relatedness should not add to the predictive power of the model. In other words, a model without morphological relatedness should predict responses nearly as well as the model containing morphological relatedness. However, removing morphological relatedness significantly reduced the model's ability to account for the data; Probe presence*Response*Morphological relatedness, $G^2(1) = 15.55$, $p < 0.001$. Therefore, morphological overlap contributes to the prediction of sensitivity in addition to the combined effects of semantic and orthographic overlap. Both of the other components (semantic similarity, orthographic overlap) also had a significant influence on the model fit; removing Probe presence*Response*Semantic similarity, $G^2(1) = 5.98$, $p < 0.05$, removing Probe presence*Response*Orthographic overlap, $G^2(1) = 19.77$, $p < 0.001$. Therefore, all three components (morphological, orthographic and semantic relatedness) were required to obtain the optimal fit of the observed data.

3.3.3 Discussion

Experiment 1b confirmed the morphological effect from Experiment 1a–sensitivity was very poor when list and probe words shared morphological overlap and probe type (substring, superstring) did not influence performance. The effect of morphological overlap was significantly greater than orthographic or semantic overlap and, most importantly, morphological relatedness contributed to the prediction of participants' performance in addition to the combined effects of semantic and orthographic overlap. Although orthographic and semantic effects were weaker than the morphological effect, they were nonetheless still clearly significant. Thus, morphology, orthography and semantics all influenced performance on the STM probe.

In Experiment 1a, sensitivity was greater in the orthographic overlap condition when the probe was a superstring word (e.g., BEE-*BEEF*) than when it was a substring (e.g., BEEF-*BEE*) but this effect was not observed in Experiment 1b. Word frequency differences offer a possible explanation for this discrepancy. In both experiments, substring words tended to be higher frequency than superstring words (23/27 items in Experiment 1a and 10/16 items in Experiment 1b). However, paired-samples *t* tests revealed that the difference in frequency of orthographic substring and superstring words was only significant in Experiment 1a; mean frequency difference 1426, $t(26) = 3.57$, $p = 0.001$. The difference was not significant in Experiment 1b; mean difference 419, $t(15) = 1.56$, $p = 0.14$.

Larger frequency differences in Experiment 1a could explain the apparent effect of probe type observed in the orthographic overlap condition. When the lower frequency word is on the list, it will be harder to access and store it in STM. At the same time, when the list item is the superstring word it will partially activate the higher frequency substring probe embedded within it. Partial activation of the higher frequency probe will compete with weaker activation of the low frequency list word (particularly since the probe will have a higher level of resting activation, by virtue of it being high frequency) and false-positives are likely to occur when the substring probe is presented. When the higher frequency (substring) word is on the list, partial activation passing to the lower frequency (superstring) probe will produce much weaker competition and, therefore, fewer confusions when the lower frequency probe is presented. Further research would be necessary to clarify the nature of these word frequency effects. However, this is outside of the remit of the present thesis.

3.4 General discussion

Together, the findings from Experiments 1a and 1b demonstrate that, for mature readers, the relationship between root and inflected words influences short-term recall in a way that is distinct from both the individual and combined effects of orthographic and semantic overlap. When words were matched for semantic similarity and orthographic overlap, morphologically related words were still confused more often than words that were not morphologically related. Furthermore, morphological relatedness accounted for variance in sensitivity to the presence of the probe on the list in addition to the additive effects of semantic similarity and orthographic overlap. The morphological effect may be caused by activation of both root and inflected forms during encoding, storage or retrieval (either through activation of the root or through co-activation of the whole set of morphologically related words). For the purpose of the present thesis, the exact location of the morphological effect is not important. The crucial finding is that hearing adults have difficulty distinguishing root and inflected forms in the STM probe task and therefore demonstrate awareness of the relationship between these words.

Probe type (substring, superstring) did not influence the morphological overlap effect in either experiment; the probe *BEE* was just as likely to be mistakenly accepted for the list word BEES as *BEES* was for BEE. This finding for inflectional morphology is consistent with previous evidence for derived words indicating that roots prime suffixed derived words and vice versa (Marslen-Wilson et al., 1994). The story was not quite so simple for orthographic overlap, as an effect of probe type was observed in Experiment 1a but not 1b. Since substring-superstring frequency was strictly controlled in Experiment 1b, we can conclude that (at least in these circumstances) substring words activated superstring words and vice versa, whether morphologically or orthographically related. Putting these findings within the context of a hierarchical interactive activation account (e.g., Colombo, 1986; McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) we come to similar conclusions as those drawn by Drews and Zwitserlood (1995) in the context of lexical decision. When a participant views a superset list word (e.g., CARD/CARS) activation of letter nodes results in activation of all related words (including the substring probe, *CAR*). Increased activation of the substring probe representation (*CAR*) results in confusion errors. The difference in sensitivity on the morphological and orthographic overlap conditions confirms that additional associations are made when the words are morphologically related. However, the same result would be expected if either the whole set of morphologically related words is activated or an additional level of representation (of the stem morpheme) exists intermediate between the letter and word nodes. However, as previously stated, the important finding here is that, for hearing adults, morphologically related words are confused in the STM probe task.

Since the morphological effect is based on morphological relatedness and not simply orthographic and semantic similarity, it indexes awareness of the morphological relationship between root and inflected words. Because the effects of orthographic, semantic and morphological overlap can be both observed and distinguished within the STM probe paradigm, the same task can be used with deaf adolescents to ascertain the relative contribution of each factor within this population (Chapter Four).

CHAPTER FOUR

DEAF CHILDREN'S AWARENESS OF MORPHOLOGICAL RELATIONSHIPS

The present chapter examines whether deaf children demonstrate the first level of morphological awareness (see Chapter Two)–an awareness of the relationship between morphologically related words. Chapter Three showed that hearing adults demonstrated an awareness of the relationship between root and inflected words by confusing morphologically related list and probe words in the STM probe task more frequently than words sharing the same degree of orthographic (Experiment 1a) and/or semantic (Experiment 1b) overlap. In the present chapter, the STM probe task was adapted and applied to deaf and hearing children to establish whether they are aware of morphological relationships. Experiment 2a aims to distinguish morphological effects from orthographic overlap. Experiment 2b aims to distinguish morphological effects from those of overlapping orthography and semantics. Deaf and reading-age (RA) matched hearing children's performance will be compared, to establish whether or not deaf children's morphological awareness is appropriate for their reading-age.

4.1 Short-term memory for morphology, orthography and semantics in the deaf population

Deaf children's literacy impairments are commonly thought to result from a focus on visual-orthographic strategies (e.g., Aaron et al., 1998; Musselman, 2000; Sterne & Goswami, 2000) and so it is all the more important to distinguish the effect of morphological overlap between related words from the effect of letter overlap. In contrast to the plethora of evidence distinguishing morphological and orthographic effects in hearing adults (discussed in Chapter Three), only one study has contrasted these effects within the deaf population. Hanson and Wilkenfeld (1985) applied long-lag priming (with an average of 10 intervening items) to examine morphological and orthographic priming effects on the visual lexical decisions of deaf students. Morphological primes were irregular inflections and derived words (e.g., THOUGHT-*THINK*) and orthographic primes were morphologically unrelated words, sharing at least the first three letters with the target (e.g., THIN-*THINK*). Both deaf and hearing American college students demonstrated morphological facilitation equivalent to identity priming. Orthographic overlap between prime and target did not influence performance. This finding suggests that deaf students make use of morphology in visual word recognition. However, the deaf participants were students of Gallaudet College and are therefore amongst the most literate in the American deaf population. Although these results may indicate what it is possible to achieve, they are not necessarily generalisable to the deaf population as a whole or representative of the situation for deaf children with lower literacy levels. Furthermore, the stimuli varied in the degree and location of orthographic overlap for both morphologically and orthographically related words which could have influenced the priming effects in these two conditions. Furthermore, morphological primes tended to be of a similar length to the target whereas many orthographic primes were shorter (e.g., CATCH-*CAUGHT-CAT*), which could have caused weaker priming effects in the orthographic overlap condition. In the current research, the effect of morphological overlap is distinguished from orthographic overlap using stimuli which are more closely matched for frequency and length.

In the present chapter, the STM probe will be applied to the deaf population to distinguish the effects of morphological overlap from both orthographic (Experiment 2a) and semantic (Experiment 2b) overlap. Prior to presenting these two experiments, I will briefly review the existing literature regarding STM in the deaf. There is a well established positive correlation between STM capabilities and reading for deaf and hearing adults as well as children (Blair, 1957; Garrison, Long, & Dowaliby, 1997; Gathercole & Baddeley, 1993). The majority of models of STM and working memory place great importance on speech/verbal coding (e.g., the phonological loop–Baddeley, 1990) and therefore, as deaf children typically have limited experience with speech, memory deficits are anticipated by these accounts. Deaf and hearing participants demonstrate equivalent STM spans on non-linguistic tasks (Cumming & Rodda, 1985; Logan, Maybery, & Fletcher, 1996) but on linguistic tasks, deaf individuals typically demonstrate shorter STM spans than hearing people (Bellugi et al., 1975; Blair, 1957; Conrad, 1972, 1979; Logan et al., 1996; Rodda & Grove, 1987). Nonetheless, it has been demonstrated that deaf children have STM capacity equivalent to RA (not chronological-age) matched hearing children in a picture naming task (Harris & Moreno, 2004).

STM for text has been used to support claims that, while hearing children use a phonological code, deaf children use visual-orthographic strategies. For example, hearing children's recall errors typically indicate confusions based on acoustic or articulatory similarities of words and letters (Conrad, 1971), whereas deaf children's errors suggest confusions based on visual properties (Conrad, 1972; Conrad & Rush, 1965; Wallace & Corballis, 1973). However, under some circumstances, deaf people are able to use speech-based coding strategies, demonstrating phonological effects in STM (Conrad, 1979; Hanson, 1982a; Waters & Doehring, 1990) and effects of articulatory suppression (MacSweeney, Campbell, & Donlan, 1996). Conrad (1970) argued that deaf students fall into two categories; one group produce acoustic confusions similar to those observed in the hearing population, whilst a second group produce visual confusions. Therefore, at least some deaf children use phonological coding in STM. Furthermore, young hearing children, like deaf children, demonstrate an increased tendency to make visual rather than phonological errors (Hitch, Halliday, Schaafstal, & Schraagen, 1988). Indeed, studies examining hearing children's STM strategies at different ages during childhood suggest a developmental pattern, where an initial focus on visual strategies gradually turns into a focus on phonological strategies (e.g., 5-year-olds versus 11-year-olds–MacSweeney et al., 1996). Therefore, rather than being a feature of deafness per se, deaf children's focus on visual-orthographic strategies in memory for text may simply be symptomatic of their reading delay. Nonetheless, note that deaf participants appear to have a range of encoding strategies available to them which they use flexibly, including sign coding as well as phonological, visual and semantic strategies (Frumkin & Anisfeld, 1977; Harris & Moreno, 2004; Locke & Locke, 1971; MacSweeney et al., 1996; Moulton & Beasley, 1975).

Tasks examining STM for text have also been used to argue that deaf children rely more on semantic processes in memory than on formal features (i.e., orthographic or phonological). For hearing children, developmental research examining STM for lists of words suggests that younger children focus on phonological features and then progress to a focus on semantic features. For example, Felzen and Anisfeld (1970) and Bach and Underwood (1970) demonstrated that hearing children aged around 8-years-old were more likely to make false-positive errors on phonologically similar words than semantically similar words, whereas older children (around 11-years-old) made more false-positive errors on semantically related words than on phonologically similar words. Both groups of children consistently made more semantic or phonetic false-positives than choosing an unrelated filler word. In contrast, Frumkin and Anisfeld (1977) demonstrated within the deaf population, both younger (8;9) and older (14;7) children were more likely to produce false-positives on semantically (synonym/antonym) related words than orthographically (rhyming–sharing both orthographic and phonological overlap) related words, although errors were always more frequent for orthographically similar than unrelated words. Using the same stimulus set, Frumkin and Anisfeld (1977) also demonstrated that young hearing children (8;2 years) produced more false-positives for orthographically related words than semantically related words and that young deaf children produced more semantic confusions than the hearing children. Taking these findings together, deaf children appeared to use semantic relationships to aid STM from a younger age than observed in the hearing population.

In the present chapter "orthographic" effects could be the result of visual-orthographic and/or phonological processes. This distinction was not the focus of the present investigation and therefore no attempt was made to distinguish these effects. The present chapter aims to distinguish effects of morphological overlap from those of orthographic (Experiment 2a) or semantic (Experiment 2b) overlap, in order to establish whether deaf children have an awareness of the relationship between morphologically related words. While STM has been utilised to examine deaf and hearing children's focus on orthographic and semantic factors during reading, it has not been used to investigate sensitivity to morphological relatedness. Experiment 2a aims to distinguish the effects of morphological overlap from orthographic overlap by testing whether morphologically related probes are confused with list words more often than orthographically related probes. Hearing children develop morphological awareness from their experience with speech prior to literacy acquisition and therefore it was predicted that they would have associated root and inflected words and, in the STM probe task, they would confuse morphologically related words more frequently than orthographically related words. Experiment 2b aims to distinguish the effects of morphological overlap from orthographic and semantic overlap. Hearing children had a mean RA of around 8-years-old and, therefore, should rely on the formal properties of words more than the semantic properties (Bach & Underwood, 1970; Felzen & Anisfeld, 1970; Frumkin & Anisfeld, 1977). Thus, it was predicted that hearing children would confuse morphologically related words most frequently, semantically related words least frequently and perform intermediately in the orthographic overlap condition.

If deaf children have not associated morphologically related words and are using visual-orthographic strategies to process text, performance on the morphological and orthographic conditions of Experiments 2a and 2b should be equivalent (because both conditions involve orthographic overlap). If, on the other hand, deaf children have an awareness of morphological relationships then they (like the hearing children and adults) should make more false-positives on probes that are morphologically related to a list word than those that are orthographically (Experiment 2a) or semantically (Experiment 2b) related. If, as Frumkin and Anisfeld (1977) argued, deaf children have a stronger preference for short-term coding using semantic information rather than formal properties, then deaf children should make more false-positive errors when list and probe words share semantic overlap than when they share orthographic overlap.

In Chapter Three I discussed the possibility that the morphological effect in Experiment 1a could actually be the result of overlapping semantics, since morphologically related words share both orthographic and semantic overlap. Indeed, this was the motivation for Experiment 1b, in which hearing adults demonstrated that the effect of morphological overlap was distinct from both the individual and combined effects of orthographic and semantic overlap. In the present chapter there is also a need to distinguish these effects. If the morphological effect in Experiment 2a is actually a semantic effect, in Experiment 2b there should be no difference in performance on the morphological and semantic overlap conditions.

4.2 Experiment 2a: Distinguishing morphological and orthographic effects in deaf children's short-term memory

Experiment 2a aims to establish whether deaf children and RA matched hearing children associate morphologically related words in a manner that is distinct from the effects of overlapping orthography. The STM probe from Experiment 1a was adapted for child participants. The presentation duration of each word was increased to allow more time for reading. List length was decreased because STM capacity may be reduced in the deaf population (Bellugi et al., 1975; Blair, 1957; Conrad, 1972, 1979; Logan et al., 1996; Rodda & Grove, 1987). Finally, the experiment was shortened because of the limited attentional capacity of child participants. Therefore, the design was simplified by removing the factor of probe complexity (the probe was always superstring) and the number of items was reduced.

4.2.1 Method

4.2.1.2 Participants

Twenty-one deaf and 21 RA matched hearing children participated.

Deaf children

Twenty-one deaf children (16 male) were recruited from schools within the Midlands, UK. All of the children became deaf before the age of 3 and they had a mean better ear average (BEA) of 105dB (range 68–120dB, with only two participants having a BEA less than 90dB, none of the children had cochlear implants), a mean chronological age (CA) of 14;0 years (range 11;8–16;4) and a mean RA[1] of 8;2 years (range 6;7–>11).

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[1] Reading-age was measured using the NFER-Nelson Group Reading Test II Form B (Group Reading Test, 1997), which has a lower bound of 6-years and an upper bound of 11-years. Children with RAs beyond these limits were matched on the basis of their raw scores (two matched pairs >11). One hearing child had an RA <6 (CA 5;11 years) but performance on the experimental task was comparable to his deaf counterpart.

None of these children had any additional special educational needs. Eight participants were educated at a specialist Secondary School for deaf children located on the campus of a hearing school. These children were primarily educated using BSL. An additional 12 students were educated at a specialist Secondary School teaching both English and BSL. Finally, one participant attended a mainstream Primary School with a small Hearing Impairment Unit, spending half the day in the unit within a Total Communication setting and half the day taught alongside hearing peers where both deaf and hearing children were encouraged to use BSL.

Parents were asked to provide information regarding their own hearing and communication with their child. Four sets of parents did not complete this section of the consent form. Of the remaining children, four had two deaf parents, one had a deaf mother and a hearing father and 12 children were born to hearing parents. The parents of 13 children reported primarily communicating through BSL, three used a combination of BSL and English and only one parent reported primarily oral/aural communication with their child.

Reading-age matched hearing children

Twenty-one hearing children (11 male) were recruited from a Junior School and an Infant School in Berkshire and a Primary School in the West Midlands, England. These children had no language, literacy or hearing impairments, they had normal or corrected to normal vision and were native English speakers. Hearing children were reading appropriately for their age, had a mean CA of 8;7 years (range 5;11–11;11) and a mean RA of 8;6 (range <6–>11). Each hearing child was individually reading-age matched to a deaf child.

4.2.1.3 Design

Overlap between list-probe pairs (morphological, orthographic and unrelated) was tested within-participants. Hearing Group (deaf, hearing) was tested between-participants. The dependent variable was accuracy of judging whether the probe had been on the list (henceforth *sensitivity*). The main change to the design when compared to Experiment 1a was that probe complexity was removed from the experimental design (to reduce the number of trials). All related probes were superstring words (having found in Experiment 1a that the morphological effect was stronger for superstring probes rather than substring probes). This design resulted in six trials for each stimulus set (see Table 4.1), three where the probe was present and three where it was absent from the list.

Table 4.1: Overlap conditions (morphological, orthographic and unrelated) and example trials in Experiment 2a

Probe present on the list?	Overlap		
	Morphology	Orthography	Unrelated
Present	PENS-*PENS*	PENCE-*PENCE*	PEN-*PEN*
Absent	PEN-*PENS*	PEN-*PENCE*	BARS-*PEN*

Note. CAPS: Critical list word. *ITALICISED CAPS:* Probe word.

4.2.1.4 Materials

Ten sets of stimuli (nine plural nouns and one past-tense verb) were selected from Experiment 1a (see Appendix 2a for a full list of stimuli). There were six trials for each set, resulting in 60 total trials. In Experiment 1a, morphological effects were strongest when the root and inflection were perceived as being in the same part-of-speech. Therefore, the stimuli for Experiment 2a were selected from those with at least 75% agreement on the perceived part-of-speech of corresponding root-inflection pairs. Morphological and orthographic superstring words were matched for frequency (based on 17.9 million token text corpus taken from the CELEX Database by Baayen et al., 1993 and on a 268,028 token children's text corpus from the Children's Early Reading Vocabulary

(CERV) by Stuart, Dixon, Masterson, & Gray, 2003), number of letters and number of phonemes (independent samples *t* tests, $p > 0.07$. See Table 4.2). Furthermore, even though the means in Table 4.2 suggest that substring words were generally of higher frequency than superstring words, the difference was not significant for orthographic or morphological conditions[2] ($p > 0.09$).

Table 4.2: Descriptive statistics for each word type in Experiment 2a

Word types	CELEX Frequency *M (SD)*	CERV Frequency *M (SD)*	LEN *M (SD)*	PhN *M (SD)*
Substring	1585 (1809)	66 (121)[a]	3 (1)	3 (1)
Orthographic superstring	454 (578)	2 (1)	5 (1)	4 (1)
Morphological superstring	483 (780)	1 (0)	5 (1)	4 (1)

Note. CELEX Frequency: Based on 17.9 million token text corpus taken from the CELEX Database (Baayen et al., 1993). CERV Frequency: Based on 268,028 token children's text corpus taken from the Children's Early Reading Vocabulary database (Stuart et al., 2003). LEN: Number of letters. PhN: Number of phonemes.

[a] CERV Frequency missing for one substring item.

Trial lists from Experiment 1a were reduced to five words. The position of the critical list word was counterbalanced through positions one-to-five. To control for presentation frequency, orthographic and morphological superset probes occurred as fillers in two unrelated trials. Thus, across trials, each experimental superset word occurred on three lists (once as critical word and twice as filler). Remaining fillers were selected from Experiment 1a. Fillers and experimental words were also matched for word length and frequency (independent samples *t* tests, $p > 0.07$).

4.3.1.5 Procedure

Instructions were provided in writing and reiterated verbally (with signed

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[2] The Children's Early Reading Vocabulary (Stuart et al., 2003) is based on 268,028 tokens from 685 children's books (reading schemes and story books used with 5 to 7-year-olds in UK schools). One substring item was missing from the corpus but the remaining substring words did not differ from either type of superstring word ($p > 0.1$).

interpretation as appropriate). Participants were told that they would see a list of words which they had to memorise and that at the end of the list they would see a word written in red. Their task was to say whether they had seen this word on the list or not. Participants completed four practice trials (which were comparable to the experimental trials) prior to commencing the experiment.

The experimental procedure was similar to Experiment 1a, with the following exceptions. List words were presented for longer (1250ms each) to accommodate children's slower reading speed. A fixation cross was introduced at the beginning of each list and a key press was required to start each trial. This enabled the experimenter to pause the procedure if necessary and prevented loss of data if the child became distracted. Positive responses were provided by pressing 'M' (with a sticker depicting a tick on the key). Negative responses were provided by pressing 'C' (with a sticker depicting a cross on the key). Every 10 trials the procedure paused and participants viewed a scoreboard (with scores based on speed and accuracy) and an animation of a character jumping up and down as an incentive to attend to the task. After completing the experiment, children were thanked and given a sticker.

4.2.2 Results

Sensitivity was measured using *d'*, calculated from counts of "yes" and "no" responses (adding 0.5 to each total cell count, see Chapter Three). Figure 4.1 illustrates deaf and hearing children's *d'* values in the unrelated condition, which were used to remove participants with low sensitivity. All of the hearing children demonstrated good sensitivity but three deaf participants had a *d'* of 0 (biases of -1.69, -1.69 and -0.75). These three deaf participants and their corresponding RA matched hearing counterparts were removed from the analysis, since they were unable to perform the memory task even when the list and probe words were unrelated. Following exclusion of these participants[3], the mean unrelated *d'* for the remaining 18 deaf children was 1.64 (*SD* 0.70, mean bias 0.16) and 1.72 (*SD* 0.64, mean bias 0.27) for the hearing children. Overall (across all three conditions) the deaf children had a mean accuracy of 72% correct (*SD* 11) and the hearing children had a mean accuracy of 71% (*SD* 9).

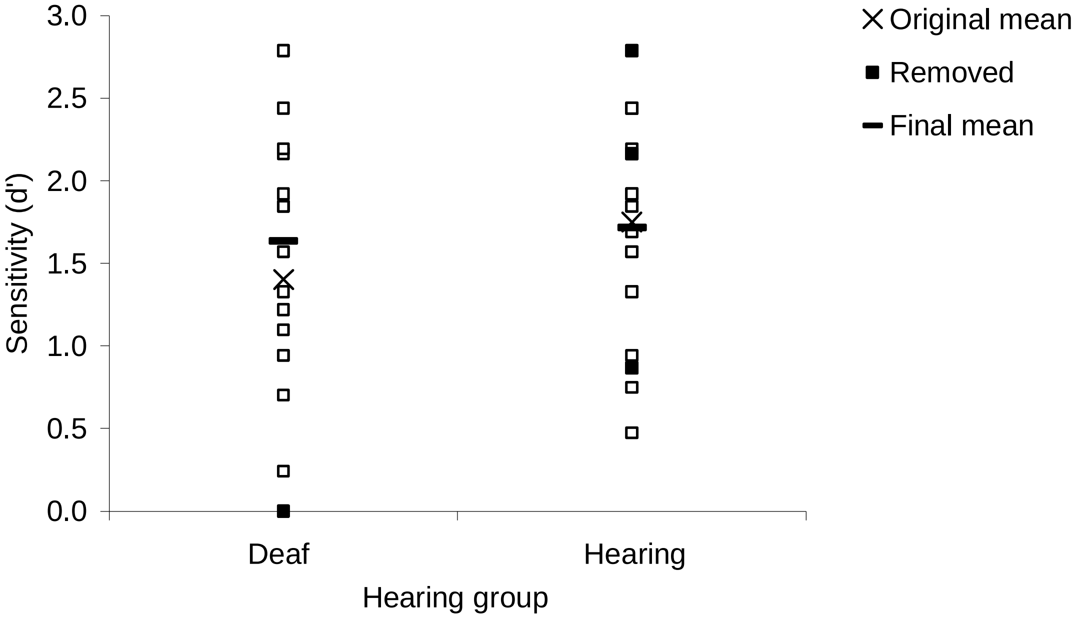

Figure 4.1: Deaf and hearing children's sensitivity (d') in the unrelated condition in Experiment 2a

Figure 4.2 shows that mean *d'* values for each condition suggested a similar pattern of performance for deaf and hearing children. Sensitivity was high (i.e., confusions/false-positives were rare) when the probe and list words were unrelated and sensitivity was low (i.e., confusions/false-positives were common) when there was morphological overlap (deaf mean *d'* 0.53, *SD* 0.86, bias -0.36; hearing mean *d'* 0.50, *SD* 0.69, bias -0.33). In the orthographic overlap condition, sensitivity was similar to the unrelated condition, particularly for deaf children (deaf mean *d'* 1.58, *SD* 0.79, bias -0.13; hearing mean *d'*

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[3] The remaining deaf participants had a mean CA of 14;4 years and mean RA of 8;3 years. The hearing children had a mean CA of 8;5 years and mean RA of 8;4 years.

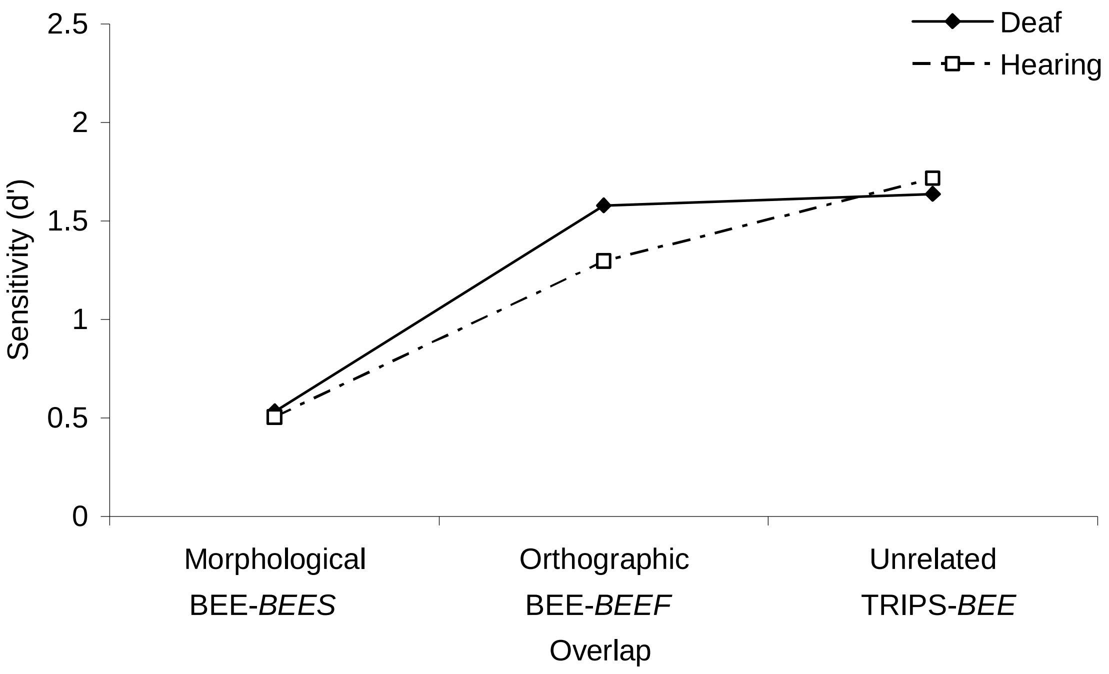

Figure 4.2: Deaf and hearing children's sensitivity (mean d') on unrelated, orthographic and morphological overlap conditions in Experiment 2a

1.29, *SD* 0.91, bias 0.00). To establish whether these differences were statistically significant, a hierarchical log-linear analysis was conducted. The factors were hearing group (deaf, hearing), overlap (unrelated, orthographic and morphological), probe presence on the list (present, absent) and response (yes, no). These analyses revealed a significant effect of overlap on sensitivity; Overlap*Probe presence*Response, $G^2(2) = 59.99$, $p < 0.0001$. However, the effect of overlap was not mediated by hearing group[4] ($p = 0.2$) and therefore deaf and hearing children showed the same pattern of performance across overlap conditions. Furthermore, hearing group did not have a significant effect on sensitivity ($p > 0.4$), indicating that deaf and hearing children were equally sensitive to the presence of the probe on the list.

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[4] The factor hearing group had a significant effect on bias; Hearing group*Response, $G^2(1) = 10.40$, $p = 0.0013$. The overall means indicated that deaf children had a greater bias to give a “yes” response than hearing children (deaf mean *d’* 1.25, *SD* 0.93, bias -0.11; hearing mean *d’* 1.17, *SD* 0.90, bias -0.02). However, since overlap did not interact with the effect of hearing group on bias and hearing group did not influence sensitivity ($p > 0.4$), the effect of hearing group on bias is not of concern.

To investigate whether sensitivity changed with overlap condition three further log-linear analyses were conducted, comparing (a) orthographic and morphological overlap, (b) morphological and unrelated, and (c) orthographic and unrelated. Overlap had a significant effect on sensitivity for the first two of these analyses but not for the last; Overlap*Probe presence*Response, (a) $G^2(1) = 37.18$, $p < 0.0001$, (b) $G^2(1) = 52.11$, $p < 0.0001$, (c) $G^2(1) = 1.28$, $p = 0.26$. The interaction with hearing group was not significant in any comparison ($p > 0.08$). To confirm that the effect of morphology could be distinguished from orthography specifically for the deaf children, these analyses were repeated on the deaf data alone (despite the non-significant interaction between hearing group and overlap, this analysis is justified on a priori grounds). These analyses confirmed the same pattern as described above. Deaf children's sensitivity on the morphological overlap condition was significantly lower than in either the orthographic overlap or unrelated conditions, which did not differ from one another; Overlap*Probe presence*Response, (a) $G^2(1) = 25.76$, $p < 0.0001$, (b) $G^2(1) = 25.98$, $p < 0.0001$, (c) $G^2(1) = 0.00$, $p = 0.97$. Thus, for both deaf and hearing children, sensitivity was significantly impaired when there was morphological overlap between probe and list words compared to when the words were unrelated or orthographically related. However, sensitivity for list and probe words with orthographic overlap did not differ from when they were unrelated.

4.2.3 Discussion

As observed with hearing adults in Experiment 1a and younger RA matched hearing children in the present study, deaf children's sensitivity to the presence or absence of the probe on the list was significantly reduced in the morphological overlap condition compared to the orthographic or unrelated conditions, indicating that they associated morphologically related words. Neither deaf nor hearing children's sensitivity in the orthographic overlap condition differed significantly from the unrelated condition.

Furthermore, if anything, orthographic overlap had a greater effect on the hearing children than the deaf, which is not consistent with the view that deaf children are constrained to using visual-orthographic properties or that they rely on them more than RA matched hearing children. Previous evidence highlighting the use of visual-orthographic strategies in the STM of deaf children has largely come from studies involving memory for letters rather than words (e.g., Conrad, 1972; Conrad & Rush, 1965; Wallace & Corballis, 1973). The range of coding strategies available for letters is likely to be more limited than for words (for example, morphological information cannot be accessed for letters) and this may account for the different findings. Nonetheless, STM for words is more relevant to the reading process than STM for individual letters. In contrast to the findings from Experiment 1a with hearing adults, deaf and hearing children's sensitivity in the orthographic overlap condition did not differ significantly from the unrelated condition. The children did not confuse orthographically similar words as frequently as the adults.

Finding similar patterns of performance on the STM probe task does not necessarily mean that deaf and hearing children are representing words in the same way. There are several alternative explanations for decreased sensitivity to morphologically related list and probe words compared to those with orthographic overlap. Two explanations have a morphological basis. Children may confuse singular and plural words. Alternatively, they may focus strongly on the root and pay little attention to the suffix.

Morphologically related words are, by definition, semantically related and there was not a semantic overlap condition in Experiment 2a. Furthermore, the high degree of orthographic overlap between most of the words in this experiment may have led to participants strategically using semantic coding (since this would have been a more effective means of coding information than focusing on orthographic overlap). Therefore, in Experiment 2a, the morphological effect might actually have been due to semantic overlap between related words. Experiment 2b tests the semantic account of these effects.

4.3 Experiment 2b: Distinguishing morphological from orthographic and semantic effects in deaf children's short-term memory

If the morphological effect observed in Experiment 2a is actually due to semantic overlap between list and probe words, words with a high degree of semantic relatedness should be confused just as frequently as those with morphological overlap, particularly since orthographic overlap did not influence performance in Experiment 2a. Differences in the magnitude of morphological, semantic and orthographic effects will reveal differences in the dominant word processing strategies of the deaf and hearing children. Previous research has suggested that hearing children of the age tested in the present study (around 8-years-old) focus on the formal properties of words to a greater degree than the semantic properties (Bach & Underwood, 1970; Felzen & Anisfeld, 1970; Frumkin & Anisfeld, 1977). If so, false-positive errors should be more frequent in the orthographic overlap condition than in the semantic overlap condition. Nonetheless, given the results of Experiment 2a, hearing children were expected to be least sensitive in the morphological overlap condition, since these words share both orthographic and morphological properties.

If deaf children have a preference for using semantic information in STM over orthographic properties (Frumkin & Anisfeld, 1977), they should make more false-positive errors in the morphological and semantic overlap conditions than in the orthographic overlap condition. This pattern would allow the possibility that the results from Experiment 2a were due to semantic rather than morphological overlap. If deaf children have developed an awareness of morphological relationships that goes beyond the semantic and orthographic overlap between related words, false-positives should be more frequent in the morphological overlap condition than in both the orthographic and semantic overlap conditions.

It is important to note that there may be differences in the semantic knowledge of deaf and hearing children. A large body of evidence has indicated that deaf children typically have a limited vocabulary (Paul, 1996; Silverman-Dresner & Guilfoyle, 1972; Walter, 1978; Waters & Doehring, 1990). Within hearing populations, young children typically assign a novel word to a novel object rather than to an object for which they already have a name (the mutual exclusivity word-learning principle, e.g., Halberda, 2003; Markman & Wachtel, 1988; Merriman & Bowman, 1989). In other words, during early vocabulary acquisition, children find it difficult to understand that the same object can have multiple labels. If deaf children were at a very early stage of vocabulary acquisition then they might not confuse semantically related pairs of words to the same extent as hearing children. Therefore, to assess the semantic relatedness of the stimuli a semantic vocabulary test was given after completion of the STM probe task.

4.3.1 Method

Experiment 1b was adapted for child participants, making the same procedural changes as Experiment 2a.

4.3.1.1 Participants

Deaf children

Eighteen deaf children (12 male) were recruited from schools in central England. Two of the deaf participants attended a large mainstream Secondary School with a Unit for the Hearing Impaired. These students spent at least one day a week in the Unit with a Teacher of the Deaf using BSL or Sign Supported English (an MCE approach, see Chapter Two). The remainder of the week was spent in mainstream lessons with the support of a signing Teaching Assistant. These children had good competence in BSL and English.

The remaining 16 deaf participants attended a Secondary School located on a campus comprising of Primary, Secondary and Post-16 specialist day and residential provision for deaf children. These children were educated using BSL and English.

Four deaf children had cochlear implants (mean BEA 38dB, range 28–45dB), three of whom became deaf before the age of three. The remaining 14 deaf children without cochlear implants became deaf before aged three and had a mean BEA of 110dB (range 93–120dB). The deaf children had a mean CA of 13;9 years (range 11;11–16;2) and a mean RA of 8;1 years[5] (range 6;4–>11). None of the children had any additional special educational needs.

Parents of participating children were asked to complete a short questionnaire to provide information on their own hearing and how they communicated with their child at home. Four children had at least one deaf parent, 11 had two hearing parents and one parent did not complete this part of the consent form. The parents of 10 children reported primarily communicating with their child using BSL, six used a combination of BSL and English and two parents did not complete this part of the form. No parents reported solely communicating using oral/aural language.

Reading-age matched hearing children

Eighteen hearing children (5 male) were recruited to individually match the deaf children on the basis of reading-age. Eleven children were recruited from a Junior School and one child from an Infant School in Berkshire, England. Six children were recruited

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[5] One deaf child had an RA greater than 11-years. This child was matched to a hearing child on the basis of their raw score on the reading test but it should be noted that this may have been a conservative match as the deaf child also hit ceiling (Post High School reading level) on the Reading Comprehension subtest of the Gates-MacGinitie reading test Form 6S (MacGinitie, MacGinitie, Maria, & Dreyer, 2000). His English teacher kindly shared his score from the Edinburgh Reading Test, on which he had scored a RA of 17 years (his chronological age at that time was 16;1 years). It is important to note this rare example of a profoundly and prelingually deaf child with reading abilities in advance of his years. This child had hearing parents and used BSL as a primary mode of communication. His speech reading abilities were good but his speech production was fairly poor.

from a Primary School in Warwickshire, England. The hearing children had no known language, literacy or hearing impairments, had normal or corrected to normal vision and were native English speakers. The hearing children were reading appropriately for their age. They had a mean CA of 8;2 years (range 5;11–11;2) and a mean RA of 8;1 years (range 6;4–>11).

4.3.1.2 Design

As in Experiment 2a, the dependent variable was accuracy of judging whether the probe had been on the list (henceforth *sensitivity*). The main change to the design when compared to Experiment 1b was that Probe Complexity was removed from the experimental design and all related probes were superstring words (as Experiment 2a). This design resulted in eight trials for each stimulus set (see Table 4.3)–four where the probe was present on the list and four where it was absent. Experimental words were not used as fillers in this experiment since the presentation frequency was already similar across words.

Table 4.3: Overlap conditions (morphological, semantic, orthographic and unrelated) and example trials in Experiment 2b

Probe present on the list?	Overlap			
	Morphology	Semantics	Orthography	Unrelated
Present	BOATS-*BOATS*	SHIP-*SHIP*	START-*START*	DOORS-*DOORS*
Absent	BOAT-*BOATS*	BOAT-*SHIP*	STAR-*START*	STAR-*DOORS*

Note. CAPS: Critical list word. *ITALICISED CAPS:* Probe word.

4.3.1.3 Materials

Eight sets of stimuli (all plural nouns) were selected from Experiment 1b (see Appendix 2b for a full list of stimuli). There were eight trials for each set, resulting in 64 total trials. In Experiments 1a and 1b, morphological effects were strongest for root-inflected word pairs perceived as being in the same part-of-speech and therefore this factor

Table 4.4: Descriptive statistics for each word type in Experiment 2b

Word types	CELEX Frequency *M (SD)*	CERV Frequency *M (SD)*	LEN *M (SD)*	Semantic relatedness *M (SD)*
Substring				
Morphological/semantic	988 (869)	140 (177)	4 (1)	
Orthographic/unrelated	964 (954)	12 (11)	4 (1)	
Superstring				
Morphological	378 (367)	24 (28)	5 (1)	6 (0)
Semantic	516 (593)	100 (178)	5 (1)	6 (1)
Orthographic	559 (468)	15 (22)	5 (1)	1 (0)
Unrelated	464 (311)	239 (374)[a]	5 (1)	1 (0)

Note. CELEX Frequency: Based on 17.9 million token text corpus taken from the CELEX Database (Baayen et al., 1993). CERV Frequency: Based on 268,028 token children's text corpus taken from the Children's Early Reading Vocabulary database (Stuart et al., 2003). LEN: Number of letters.

[a] CERV Frequency missing for one unrelated superstring item.

was controlled in Experiment 2a. In the present experiment, the morphologically and semantically related words were selected from those perceived as being the same part-of-speech (with 70% or more participants agreeing that both related items were nouns) but it was not possible to control for this factor when selecting words for the orthographic overlap and unrelated conditions[6]. Within each set of stimuli there were two substring words–one was used in morphological and semantic conditions whilst the other was used in orthographic and unrelated conditions. Substring words were matched for frequency (CELEX Database–Baayen et al., 1993, and CERV–Stuart et al., 2003) and length (see Table 4.4, independent samples *t* tests, $p > 0.2$). Similarly, superstring words were matched for frequency[7] and length (independent samples *t* tests, $p > 0.2$). Finally, word pairs in the morphological and semantic overlap conditions were matched for semantic similarity based on the adults' ratings described in Experiment 1b (morphological mean 6.24, *SD* 0.13; semantic mean 5.93, *SD* 0.53; independent samples *t* tests, $p = 0.2$). Word

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[6] In both the orthographic overlap and unrelated conditions, 5/8 pairs of stimuli were both classified as nouns and 3/8 pairs of stimuli were classified as different parts-of-speech.

[7] Two unrelated superstring items did not occur in the Children's Early Reading Vocabulary (Stuart et al., 2003) but frequency differences on remaining items did not differ between any two categories of superstrings ($p > 0.2$).

pairs were also matched in the orthographic overlap and unrelated conditions (orthographic mean 1.06, *SD* 0.14; unrelated mean 1.03, *SD* 0.05; independent samples *t* tests, $p = 0.5$). The semantic and morphologically related word-pairs had significantly higher ratings than the orthographically related and unrelated word-pairs ($p < 0.001$).

The remaining procedural changes made the task comparable to Experiment 2a. Trial lists were reduced to five words and the position of the critical word was counterbalanced in positions one-to-five. Fillers were selected from those used for these items in Experiment 1b.

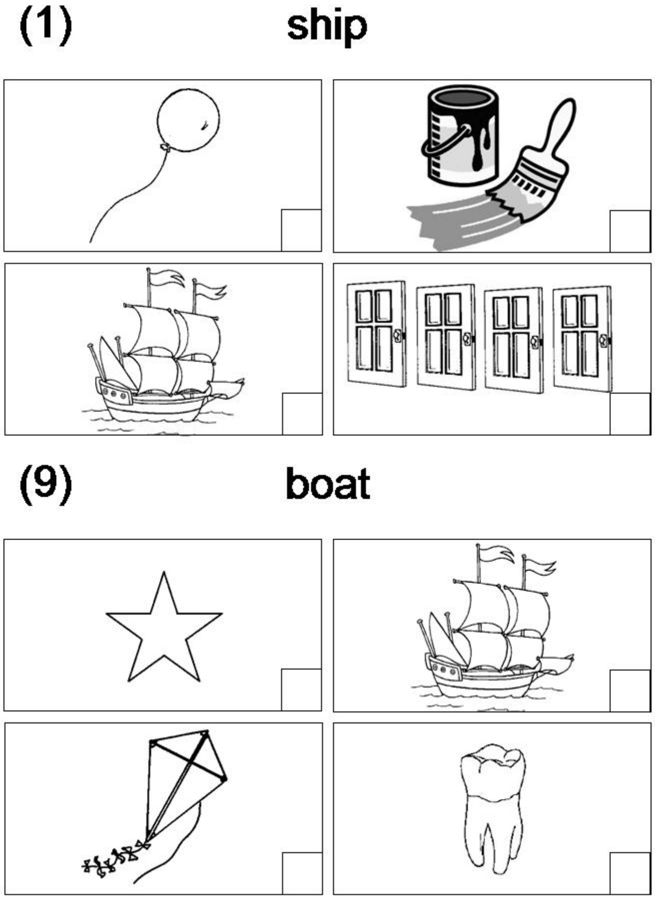

Figure 4.3: Examples trials for the semantically related words SHIP and BOAT in the vocabulary test for Experiment 2b

To ensure that participants were able to understand that different referents can be used for the same object (i.e., that the semantically related items were indeed semantically related), the children completed a paper-and-pencil vocabulary test on the semantically related words. For each semantically related pair (e.g., ship and boat), four pictures were selected, with one being a possible referent for both of the semantically related words (see Figure 4.3). For each item, the word was written above four pictures and the children simply had to tick the picture that was "most like the word" (see Figure 4.3). Each child provided a response for all of the stimuli in the semantic overlap condition. Two booklets were produced by swapping the order of semantically related words. Within each booklet, semantically related words were not presented on the same page (but both words did occur within each booklet). Each participant completed only one version of the semantic vocabulary test.

4.3.1.4 Procedure

The procedure for the STM probe task was identical to Experiment 2a. The semantic vocabulary test was completed after the STM probe.

4.3.2 Results

The mean *d'* values in the unrelated condition (Figure 4.4) indicated that four of the deaf children were not sensitive to the presence of the probe on the list (*d'* =< 0, biases 0.97, -0.78, 0.00, 0.97). Therefore, these children and their RA matched hearing counterparts (*d'* 0, 0, 0.69, 2.56; bias -1.59, -0.97, -0.62, 0.31) were removed from the remainder of the analyses. None of the remaining participants had a *d'* =< 0 in the unrelated condition. The mean unrelated *d'* for the remaining 14 deaf and 14 hearing children[8] was 2.51 (*SD* 0.65; mean bias -0.02) and 2.10 (*SD* 0.67; mean bias 0.26) respectively. Overall (across all four conditions) the deaf children had a mean accuracy of 78% correct (*SD* 10) and the hearing children had a mean accuracy of 79% (*SD* 10).

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[8] The remaining 14 deaf participants had a mean RA of 8;5 years and a mean CA of 14;0 years. The hearing children had a mean RA of 8;5 years and a mean CA of 8;8 years.

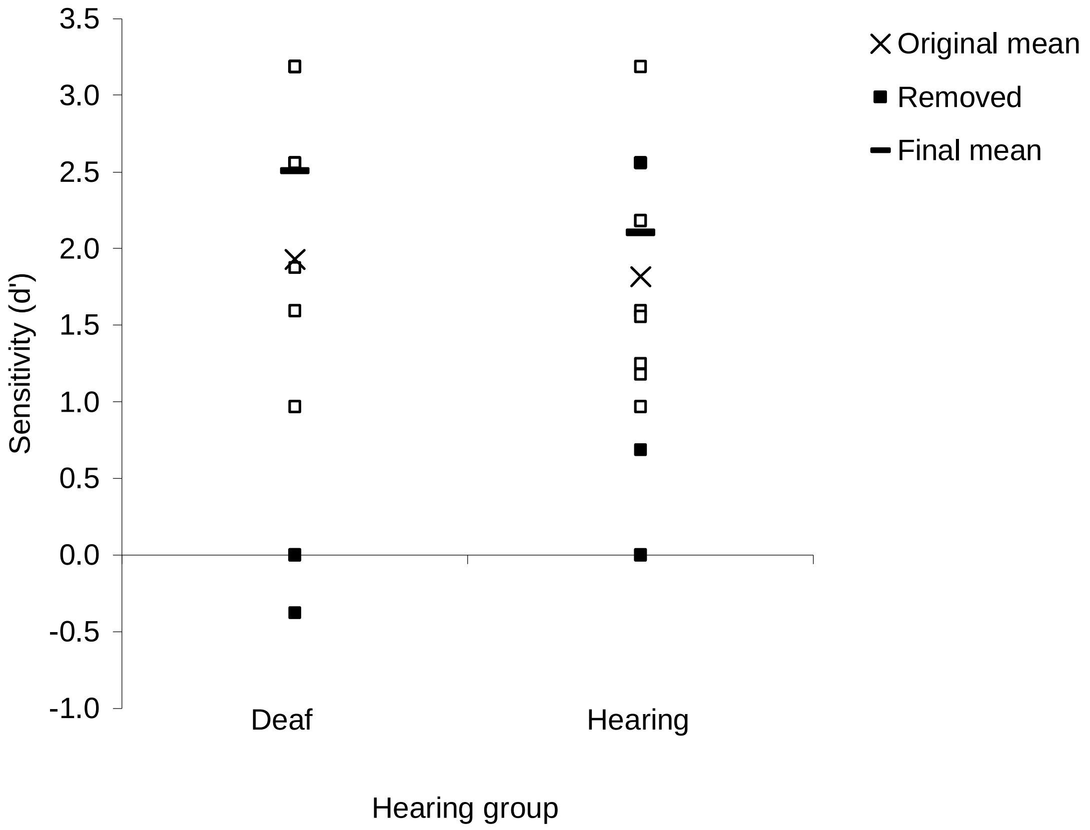

Figure 4.4: Deaf and hearing children's sensitivity (d') in the unrelated condition of Experiment 2b

4.3.2.1 Semantic vocabulary test

Table 4.5: Counts of deaf and hearing children's responses to the semantic vocabulary test of Experiment 2b

Word pair	Deaf			Hearing		
	Both correct	One or more errors	One or more omissions	Both correct	One or more errors	One or more omissions
boat–ship	14	0	0	12	0	2
cap–hat	14	0	0	14	0	0
chair–seat	14	0	0	11	1	2
ocean–sea	14	0	0	12	2	0
blossom–flower	10	4	0	12	0	2
frog–toad	9	5	0	12	0	2
blouse–shirt	8	6	0	5	9	0
oven–stove	8	6	0	11	3	0
Total	91	21	0	89	15	8

Both deaf and hearing children were generally accurate on the semantic vocabulary test (Table 4.5). In particular, both deaf and hearing children were highly accurate on the semantically related pairs *boat-ship*, *cap-hat, chair-seat* and *ocean-sea* and far less accurate on the semantically related pairs *blouse-shirt* and *oven-stove*. Finally, deaf children seemed to be less accurate than hearing children on the words *blossom-flower* and *frog-toad.* Nonetheless, on the whole, deaf and hearing children were highly accurate on this task, indicating that most of the children were aware of the semantic relationship between the words in the semantic overlap condition.

4.3.2.2 Overlap effects

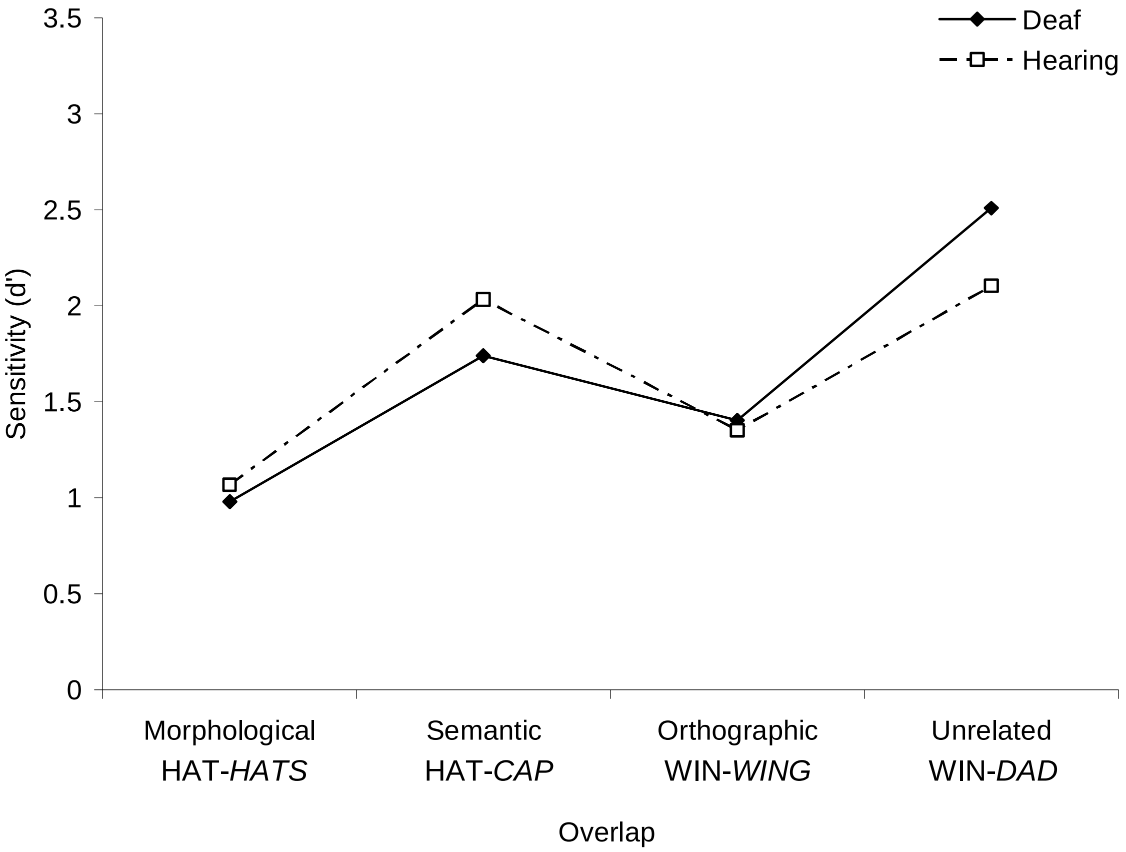

Figure 4.5: Deaf and hearing children's sensitivity (mean d') on unrelated, orthographic, semantic and morphological overlap conditions in Experiment 2b

Mean *d'* values for each condition suggested that deaf and hearing children performed similarly across the levels of overlap (Figure 4.5). Sensitivity was high when probe and list words were unrelated and low when there was morphological overlap (deaf mean *d'* 0.98, *SD* 0.67, bias -0.50; hearing mean *d'* 1.07, *SD* 0.94, bias -0.27). Sensitivity was moderate when the list and probe words shared semantic overlap (deaf mean *d'* 1.74, *SD* 0.84, bias -0.00; hearing mean *d'* 2.03, *SD* 0.73, bias 0.22) or orthographic overlap (deaf mean *d'* 1.40, *SD* 1.02, bias -0.29; hearing mean *d'* 1.35, *SD* 0.75, bias -0.13). To establish whether these differences were statistically significant, hierarchical log-linear analysis was conducted with the factors hearing group (deaf, hearing), overlap (morphological, orthographic, semantic, unrelated), probe presence (present, absent) and response (yes, no). These analyses revealed a significant effect of overlap on sensitivity; Overlap*Probe presence*Response, $G^2(3) = 54.45$, $p < 0.0001$. Hearing group[9] did not moderate the effect of overlap on sensitivity ($p = 0.3$).

Follow-up analyses were conducted to compare sensitivity between each pair of overlap conditions. These analyses revealed that sensitivity did not differ significantly between the morphological and orthographic overlap conditions ($p = 0.2$). However, sensitivity was significantly less in the orthographic overlap condition than in the semantic overlap or unrelated conditions; Overlap*Probe presence*Response, $G^2(1) = 9.09$, $p = 0.0026$ and $G^2(1) =30.44$, $p < 0.0001$. Sensitivity in the semantic overlap condition was significantly less than in the unrelated condition; Overlap*Probe presence*Response, $G^2(1) = 6.56$, $p = 0.0105$. Furthermore, sensitivity in the morphological overlap condition was significantly less than in either the semantic overlap or unrelated conditions; $G^2(1) = 18.36$, $p < 0.0001$ and $G^2(1) = 44.68$, $p < 0.0001$ respectively.

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[9] Hearing group had a significant effect on bias; Hearing Group*Response, $G^2(1) = 12.24$, $p = 0.0005$. Deaf children were more likely to give “yes” responses than hearing children (mean bias -0.27 and -0.01). However, overlap did not influence the effect of hearing group on bias and hearing group did not influence sensitivity ($p > 0.7$), so the effect on bias is not a concern. In addition, entering the factor Cochlear Implant (CI, non-CI) into the log-linear analysis did not effect the outcome. Neither the main effect of CI nor any of the interactions were significant ($p > 0.99$). Thus, deaf children with cochlear implants performed very similarly to those without cochlear implants.

4.3.3 Discussion

As observed in Experiment 2a, deaf and RA matched hearing children's performance across the levels of overlap were very similar. The main aim of Experiment 2b was to distinguish the morphological effect from that of semantic overlap. For both groups of children, sensitivity to the presence or absence of the probe word on the list was significantly less when list and probe words shared morphological overlap than when they shared semantic overlap. Therefore, the morphological effect was successfully distinguished from a purely semantic effect. Both deaf and hearing children performed well on the semantic vocabulary test, indicating that they were aware of the relationship between the words in the semantic overlap condition. Furthermore, the children were significantly less sensitive in the semantic overlap condition than when the words were unrelated, indicating that semantic overlap did have a detrimental effect on performance but that the effect of morphological overlap was greater.

If deaf children used visual-orthographic strategies to process text without associating morphologically related words, performance should have been equal whether the list and probe words shared morphological or orthographic overlap. Performance was numerically lower in the morphological overlap condition than in the orthographic overlap condition but, in contrast to the finding from Experiment 2a, the difference between these conditions was not significant. Furthermore, unlike the findings from Experiment 1b with hearing adults, it was not possible to distinguish the effect of morphological overlap from the combined effects of overlapping orthographic and semantic features. These findings will be discussed further in the General Discussion.

4.4 General Discussion

If children associate morphologically related words, then more false-positives should have occurred in the STM probe experiments when the list and probe words shared morphological overlap. Experiment 2a demonstrated that both deaf and RA matched hearing children made more false-positives when the words were morphologically related than when they were orthographically related. Sensitivity in the orthographic overlap condition was equal to when list and probe words were unrelated. Therefore, both deaf and hearing children demonstrated morphological awareness that was distinct from the effect of overlapping orthography.

Experiment 2b provided further evidence that deaf and RA matched hearing children had an awareness of morphological relationships which was distinct from associations based on semantics, since both groups of children made more false-positives when list and probe words were morphologically related than when they were semantically related.

Unfortunately, the findings from Experiment 2b were not as transparent as those from Experiment 2a with regards to the difference between orthographic and morphological overlap. In Experiment 2a, sensitivity in the orthographic overlap condition was similar to the unrelated condition and significantly higher than morphological overlap. In contrast, in Experiment 2b, sensitivity in the orthographic overlap condition was similar to morphological overlap and significantly lower than in the unrelated condition. This difference is unlikely to be due to RA differences between the two Experiments, since these were very consistent (once children with low *d'* had been excluded, the mean RAs of the deaf and hearing children were 8;3 and 8;4 years in Experiment 2a and both 8;5 years in Experiment 2b). To further understand the difference between these two findings we should also consider the results from Chapter Three with hearing adults (Experiments 1a and 1b, see Table 4.6). Caution must be taken when making comparisons between experiments since the stimuli for the experiments with child participants were drawn from a subset of the stimuli for adults and in both cases new stimuli were selected for the experiments that contained the semantic condition.

When the semantic overlap condition was not included in the STM probe, the pattern of performance for hearing adults was morphological < orthographic < unrelated (Experiment 1a) whilst the pattern for both deaf and hearing children was morphological < orthographic = unrelated (Experiment 2a). Therefore, both groups of children appeared to be less influenced by the formal properties of the words than the hearing adults.

Table 4.6: Comparison of hearing adults, deaf and hearing children's sensitivity (d') in the STM probe task with and without the semantic condition

Experiment	Hearing group	Overlap			
		Morphological *M (SD)*	Semantic *M (SD)*	Orthographic *M (SD)*	Unrelated *M (SD)*
1a	HA	1.09 (0.43)	N/A	1.80 (0.53)	2.63 (0.72)
2a	DC	0.53 (0.86)	N/A	1.58 (0.79)	1.64 (0.70)
	HC	0.50 (0.69)	N/A	1.29 (0.91)	1.72 (0.64)
1b	HA	1.08 (0.59)	2.14 (0.49)	2.06 (0.65)	2.51 (0.59)
2b	DC	0.98 (0.67)	1.74 (0.84)	1.40 (1.02)	2.51 (0.65)
	HC	1.07 (0.94)	2.03 (0.73)	1.35 (0.75)	2.10 (0.67)

Note. HA: Hearing adults. DC: Deaf children. HC: Hearing children. In Experiments 1a and 1b hearing adults were presented with the full set of stimuli for Experiments 2a and 2b respectively. There were an additional 17 sets of stimuli in Experiment 1a compared to 2a and an additional 8 sets of stimuli in Experiment 1b compared to 2b. Furthermore, the adult studies had the additional factor probe complexity in the design, whereas in the child studies the probe was always superstring.

When the semantic condition was included in the STM probe, the pattern of performance for hearing adults took the form morphological < orthographic = semantic < unrelated (Experiment 1b) whilst the pattern for both deaf and hearing children was morphological = orthographic < semantic < unrelated (Experiment 2b). Therefore, for the hearing adults, the pattern across morphological, orthographic and unrelated conditions does not appear to have been altered by the introduction of the semantic overlap condition. However, for the two groups of children, the addition of the semantic condition did affect performance on the morphological and unrelated conditions (notice from Table 4.6 that the *d’* values are higher in these conditions in Experiment 2b than in Experiment 2a) but sensitivity in the orthographic overlap condition remains the same. The difference between morphological and unrelated conditions is larger in Experiment 2b than Experiment 2a. Therefore, the morphological effect is stronger in Experiment 2b, although so is the orthographic effect. Design differences between the two experiments may account for this variation. In Experiment 2a, the same substring words were used in morphological and orthographic overlap conditions. In Experiment 2b, two different substring words were used in these two conditions, albeit matched for frequency and length (the same was true of Experiments 1a compared to 1b). Therefore, item differences may have influenced these two experiments in different ways. In Experiment 2a, items were viewed much more frequently within the experiment. For example, the orthographic sequence *pen* occurred on seven lists (3xPEN, 2xPENS, 2xPENCE) and six times as a probe (2x*PEN*, 2x*PENS*, 2x*PENCE*). In contrast, in Experiment 2b, the orthographic sequence *boat* occurred on only three lists (2xBOAT, 1xBOATS) and two probes (2x*BOATS*). Thus, attending to orthographic properties would have led to more confusion in Experiment 2a than 2b. Furthermore, in Experiment 2a, a semantic coding strategy would have been quite effective, since semantics would only have led to confusions in 1/3 of the probe absent trials. In contrast, in Experiment 2b, a semantic coding strategy would have been ineffective in 2/3 of probe absent trials. Another possible explanation then, is that deaf and hearing children have flexible encoding strategies which can shift between relying more on orthographic or semantic codes. Whether participants switched to relying more heavily on semantic or orthographic coding, they remained poor in the morphological overlap condition. Therefore, to conclude, the effect of morphology was distinguished from the individual effects of orthographic or semantic overlap but not from the combined effect of these features (which was possible for hearing adults in Chapter Three).

The present findings suggest that deaf children, like their RA matched hearing peers, may be aware of the relationship between morphologically related words and may have associated these words in a manner that is distinct from the effects of solely overlapping orthographic or semantic features (although the possibility that, for deaf and hearing children, morphology simply represents a combination of these features without having independent representations in their mental lexicons cannot be ruled out). Evidence for associations between morphologically related words will receive further attention in Chapter Five.

If, for now, one accepts that the morphological overlap effect in the present STM probe tasks truly was caused by participants associating morphologically related words due to morphological overlap, there remain at least two alternative explanations for the effect. Children may genuinely understand the relationship between root and inflected forms, either because these are connected within the lexicon or at some point during processing. However, a less favourable explanation would be that the children were focusing on the root and paying less attention to the suffix. This strategy would indicate some degree of morphological awareness, as it would signify an ability to segment morphemes (as they segment [BEE][S] but not [BEE][F]), but this type of knowledge would not be productive because the child has not identified the function of the inflection marker +<s>. To address this issue and in the hope of demonstrating evidence of the next level of morphological awareness (productive morphology, as described in Chapter Two), Chapter Five examines deaf children's morphological generalisations and productive use of morphology in spelling, or more precisely, productive use of plural suffixes. If the morphological effects that were observed in the present chapter were actually due to the combined effects of morphological and semantic overlap or due to children failing to attend sufficiently to the suffix, then knowledge of plural spelling should be poor and plural spelling accuracy should be independent of singular spelling accuracy.

CHAPTER FIVE

MORPHOLOGY IN PRODUCTION

The findings from the STM probe tasks (Chapters Three and Four) suggest that deaf children, like hearing children and adults, may associate morphologically related words in a manner that is distinct from solely overlapping orthographic or solely semantic features. The present chapter examines deaf children's knowledge of plural noun formation and asks whether deaf children are able to use morphology productively, which represents the next level of morphological awareness necessary in order for morphology to aid literacy. Experiment 3a examines spelling of real English plural nouns when the singular form is provided, Experiment 3b examines plural formation for nonwords and finally, Experiment 3c examines spelling of plural nouns when the singular is not provided. In addition, comparisons between Experiments 3a and 3c will be used to test whether deaf children associate singular and plural forms.

To my knowledge, no published study has explicitly examined deaf children's knowledge of plural spelling in English. In her Ph.D. thesis, Diana Burman (2004) examined 29 profoundly deaf children's (10-years-old, BSL users) spelling of plural nouns, third person singular verbs and monomorphemic words ending in <s>, <ks> and <x>. The results indicated that deaf children were more accurate at spelling word-final <s> in monomorphemic words (approximately 75% correct) than in plurals (just over 50% correct) but the children were particularly poor at spelling <s> as a third person singular marker (around 5% correct). These findings suggest that deaf children have difficulty spelling the suffix <s> but that this is not simply because the children cannot hear the phoneme, since spelling was accurate on monomorphemic final <s>. There was not a group of hearing children for comparison and therefore it remains unclear whether the deaf children's performance on plural nouns (or third person singular verbs) was actually impaired or whether this represents a normal pattern of development that is also present amongst hearing children of the same reading-age. Furthermore, it is not clear what the children did when they failed to produce the final <s> (whether these were omissions of the morphological marker or substitutions, etc.). The present chapter provides a closer examination of deaf children's plural noun spellings in comparison to reading-age matched hearing children to ascertain the level of morphographic development that has been achieved and whether this is reading-age appropriate.

Prior to attaining any morphological awareness, children should store singular and plural forms of words separately and use visual-orthographic memory strategies used to retain known plurals (see Chapter Two, Section 2.6.2). Such a strategy predicts that spelling accuracy on known plural nouns would be equal across levels of regularity (i.e., for irregular, regular or semi-regular plurals, see Experiment 3a). Since the rules for plural formation have not yet been generalised, plausible plurals would not be produced for unknown nouns (Experiment 3b). Instead of systematic application of morphographic rules, attempts to spell nonword plurals would include producing the singular only, changing the singular itself or failure to respond altogether (Experiment 3b). Finally, accuracy of plural noun spelling would be independent of singular accuracy (Experiment 3c), since the representations for the two words would not be related.

At the first level of morphological awareness outlined in Chapter Two (Section 2.6.2), children have associated singular and plural forms. If deaf children have reached this level, as suggested in the findings of Chapter Four, then their plural accuracy would be dependent on their singular accuracy (Experiment 3c). At this stage children may have begun to notice that systematic changes in meaning co-occur with orthographic changes, leading to better performance on regular plurals (where the changes are systematic) than irregular plurals (Experiment 3a). Nonetheless, children would not have generalised morphological rules and, therefore, would not be able to produce plausible nonword plurals (Experiment 3b). Furthermore, plural noun spelling would be no more accurate when the child is provided with the correct singular spelling (Experiment 3a) than when they have to generate the singular spelling themselves (Experiment 3c), since plural accuracy is still dependent on the word being within the child's sight vocabulary.

Once children begin to generalise morphological rules, high frequency rules would result in greater accuracy than low frequency rules, as they are more likely to have been abstracted (i.e., performance on regular plurals would be superior to performance on semi-regular plurals). Errors on exceptions (irregular plurals in Experiment 3a) would show over-regularisation (i.e., singular+<s>), plural nonword productions would be based on frequently occurring morphographic rules (Experiment 3b) and plural noun spelling accuracy should be greater when the child is provided with the correct singular spelling (Experiment 3a) than when they must generate this for themselves (Experiment 3c). To develop a fully mature understanding of plural morphology at the single-word level, the child must finally learn the exceptions to the morphographic rules, leading to highly accurate performance on irregular plurals in addition to the features already described (Experiment 3a).

5.1 Experiment 3a: Spelling plural nouns

In the present task, deaf and reading-age matched hearing children produced spellings for plural nouns varying in regularity (regular, semi-regular and irregular). Hearing children's knowledge of plural formation in speech should enable them to apply this knowledge to literacy and therefore accuracy should be high across all levels of regularity. At the same time, part of the process of achieving literacy in English involves learning a new set of morphological rules to apply to text rather than speech. It is possible, therefore, that we will observe a U-shaped developmental path in hearing children's acquisition of morphographic rules, as previously described in the context of acquisition of morphology in speech (see Chapter Two). The prediction of this U-shaped developmental path is that accuracy will improve linearly with reading-age (since young children are only accurate at the specific words that are in their sight vocabulary). The U-shaped curve emerges in rates of over-regularisation. At the beginning and end of development, children should produce few over-regularisations. In the intermediate phases they should produce a large number, because over-regularisations peak when children have learned the rules but not the exceptions. The children tested in the present study have a reading-age of 6 to 11-years and, therefore, should represent a snapshot of this developmental progression.

When looking at the whole sample, errors should mainly take the form of over-regularisations (i.e., singular+<s>). Over-regularisations demonstrate that children have abstracted and generalised plural formation rules rather than simply having noticed that plurals often end in <s>. The nature of other errors (i.e., misspellings that cannot be accounted for by over-regularisation) may also provide information regarding the relative importance of morpho-phonological and morphographic rules. Hearing children have pre-existing knowledge of plural formation from speech, which may complement (e.g., /s/ → <s>) or contradict the morphographic rules (e.g., /əz/ → <s>). If hearing children use their knowledge of plural formation from speech they are likely to make errors that are phonologically plausible. In contrast, deaf children are unlikely to have a well established understanding of plurals from speech prior to learning to read and write (particularly since the current participants primarily communicated using BSL). Therefore, it is predicted that deaf children's errors will be phonologically plausible less often than hearing children's.

Without contradictory evidence from phonology, deaf children may actually focus on morphographic rules to a greater extent than hearing children, leading to more morphographic errors (e.g., adding other, non-plural suffixes) in their misspellings than hearing children.

5.1.1 Method

5.1.1.1 Participants

A total of 39 deaf children (eight of whom had cochlear implants) and 39 reading-age matched hearing children participated in the present experiment.

Deaf children

Thirty-nine deaf children (28 male) were recruited from and tested in four schools in central-southern England. Of these, thirteen participants attended a Secondary School for the Deaf located on the campus of a mainstream school and were primarily educated using BSL. Twenty-one participants attended a Secondary School located on a campus comprising of Primary, Secondary and Post-16 specialist day and residential provision for deaf children. These children were educated using BSL and English. Three deaf participants attended a specialist Hearing Impairment Unit within a mainstream Primary School. These children spent a large part of the day in mainstream classes within a school that encouraged the use of BSL by both deaf and hearing children. They were educated within a Total Communication setting (see Chapter Two) and their signing abilities were good. Finally, two participants attended a large campus-based mainstream Secondary School. These children spent at least one day per week within a specialist Hearing Impairment Unit where they were taught by a Teacher of the Deaf using BSL or Sign Supported English (an MCE approach, see Chapter Two). For the remainder of the week they attended mainstream classes but were supported by a Teaching Assistant fluent in BSL. None of the deaf children had any additional special educational needs.

Eight of the deaf children had cochlear implants (henceforth *deaf CI*). Audiology was only available for five of these participants (mean BEA 37dB, range 28–45dB). The deaf CI group had a mean chronological age (CA) of 13;1 years (range 10;6–15;1) and reading-age[1] (RA) of 8;1 years (range 6;4–>11). Seven of the deaf CI children became deaf before the age of 3. Included on the parental consent form was a short questionnaire for the parents to provide details of their own hearing and how they communicate with their child at home. Two of the parents did not complete these sections of the form. All of the remaining children were born to hearing parents and communicated using a combination of BSL and English.

All 31 of the deaf children who did not have cochlear implants (henceforth *deaf non-CI*) became deaf before 3-years-old and had a mean BEA of 103dB (range 68–120dB, only three participants had a BEA less than 80dB). These participants had a mean CA of 13;11 years (range 11;5–15;7) and RA of 7;10 years (range <6–>11) and therefore are comparable to the deaf CI children in terms of both measures. Details of parental hearing and communication at home were provided in 26/31 cases. Of these, six children had two deaf parents, two had a deaf mother and hearing father and the remaining 18 children were born to two hearing parents. Sixteen parents reported communicating primarily with BSL, seven used a combination of BSL and English and only three reported primarily using speech.

Hearing children

Thirty-nine hearing children (18 male) were recruited from a Primary School in the Midlands and a Junior School and an Infant School in the South of England. These

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[1] Reading-ages were measured using the NFER-Nelson GRTII Form B (Group Reading Test, 1997), which has a lower bound of 6-years and an upper bound of 11-years. One deaf CI child and two non-CI children had RAs greater than 11-years (133 months for the RA analysis), two deaf non-CI children had RAs less than 6-years (71 months for the RA analysis). These participants were matched to hearing children on the basis of raw reading scores.

children had no known language or literacy impairments, had normal hearing and were monolingual English speakers. The hearing children were reading at age appropriate levels and were matched individually to the deaf children on the basis of their reading-age. The eight hearing children matched to the deaf CI children had a mean CA of 8;4 years (range 5;3–11;2) and mean RA of 8;1 years (range 6;4–>11). The mean CA of the thirty-one hearing children matched to the deaf children without cochlear implants was 8;2 years (range 6;5–11;2) and mean RA 8;1 years (range 6;4–>11).

5.1.1.2 Stimuli and design

Thirty-three common English nouns were selected for the spelling test; 11 regular, 11 semi-regular and 11 irregular plurals. For regular plurals, the plural transformation involved adding the suffix +<s> to the root (e.g., BOOK-*BOOKS*). Semi-regular plurals included three different transformations; five nouns required addition of the suffix +<es> to the root (*root+<es>*, e.g., CHURCH-*CHURCHES*), three roots ended in <y> and the transformation involved changing this ending to <ies> (*final <y>*, e.g., BABY-*BABIES*), and three roots contained *final <f~fe>*, thus the transformation was final <f~fe>→<ves> (e.g., KNIFE-*KNIVES*). Irregular plurals also included three different transformations; five nouns involved an *internal change* to the root (e.g., MAN-*MEN*), five were *invariant*–no transformation was required (e.g., SCISSORS-*SCISSORS*), and one involved an *unusual suffix* (e.g., CHILD-*CHILDREN*). Regularity (regular, semi-regular and irregular) was tested within-participants. A full list of stimuli can be found in Appendix 3a.

All words were pictureable concrete nouns, judged to be in the vocabulary of both deaf and hearing children of the age tested in the present study. Both plural and singular words were matched between conditions (regular, semi-regular and irregular) for word frequency (based on the CELEX Database–Baayen et al., 1993 and the CERV–Stuart et al., 2003[2]) and length (number of letters, see Table 5.1). Independent sample *t* tests confirmed that differences between conditions were not significant ($p > 0.1$).

Table 5.1: Features of word stimuli by condition in Experiment 3a

		Inflection type		
		Irregular	Semi-regular	Regular
Word type	Feature	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Singular	CELEX Frequency	2754 (5477)	1295 (1062)	2148 (2748)
	CERV Frequency	90 (127)	67 (69)	67 (75)
	Number of letters	5 (2)	5 (1)	5 (1)
Plural	CELEX Frequency	2890 (4532)	596 (505)	1136 (1537)
	CERV Frequency	99 (156)	20 (21) [a]	25 (20) [a]
	Number of letters	5 (2)	6 (1)	6 (1)

Note. CELEX Frequency: Based on 17.9 million token text corpus taken from the CELEX Database (Baayen et al., 1993). CERV Frequency: Based on 268,028 token children's text corpus taken from the Children's Early Reading Vocabulary database (Stuart et al., 2003).
[a] CERV frequency missing for one regular and one semi-regular plural.

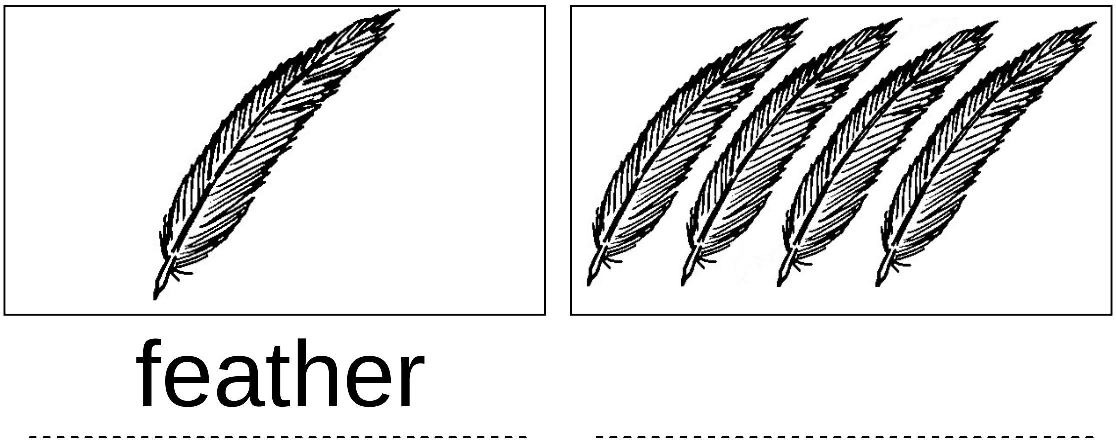

Figure 5.1: Example of a plural word spelling trial for Experiment 3a

Black-and-white images were chosen to depict each word. Singular images were obtained from the International Picture Naming Project (see Szekely et al., 2004) or copyright free from the internet. Singular images were duplicated a random number of

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[2] One regular and one semi-regular plural were missing from the CERV corpus (Stuart et al., 2003). For the remaining words, independent samples *t* tests confirmed that the different levels of regularity did not differ in word frequency in their singular ($p > 0.6$) or plural ($p > 0.1$) forms.

times to create plural images. Singular and plural pictures were placed adjacent to one another on a page (singular on the left), with four pairs per A4 page. Underneath each picture was a dotted line. The singular spelling was provided on the line in black 22pt Arial font (see Figure 5.1). Word order was randomised.

5.1.1.3 Procedure

Participants were tested in small groups (4-10 children). Instructions were provided on the first page of the booklet. These instructions included the following statements about the nature of plurals;*"I want to see how good you are at spelling plurals. Plurals are words that show there is more than one of something…"*. The instructions also explained how to complete the booklet and contained a completed, regular example (HAT-*HATS*). The instructions were reiterated verbally, with signed interpretation as appropriate. Any procedural questions were answered and children were told that they must work alone and could not ask for help reading any of the words. Once the experimenter was sure that the children understood the task, they completed the booklets at their own pace.

5.1.2 Results

The overall spelling accuracy of deaf and hearing children was very similar, with deaf children producing a mean of 46% (*SD* 19) of their spellings correctly compared to 45% (*SD* 19) of the hearing children's spellings. Figure 5.2 demonstrates that the relationship between reading-age and spelling performance was very similar for both deaf and hearing children. Pearson's (two-tailed) correlation analyses indicated a significant positive relationship between reading-age and accuracy for both participant groups[3], demonstrating that good readers produced more accurate spellings than poor readers; deaf $r(39) = 0.75$, $p < 0.001$ and hearing $r(39) = 0.79$, $p < 0.001$. The correlations with reading-

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[3] There was no difference between deaf CI and non-CI participants in any of these analyses and therefore the data from both groups of participants were pooled.

age reflect reading ability, not just age. The correlation between chronological age and accuracy did not reach significance for deaf children (p = 0.08). Therefore, reading-age is a good predictor of children's accuracy on spelling plurals, while chronological age is not.

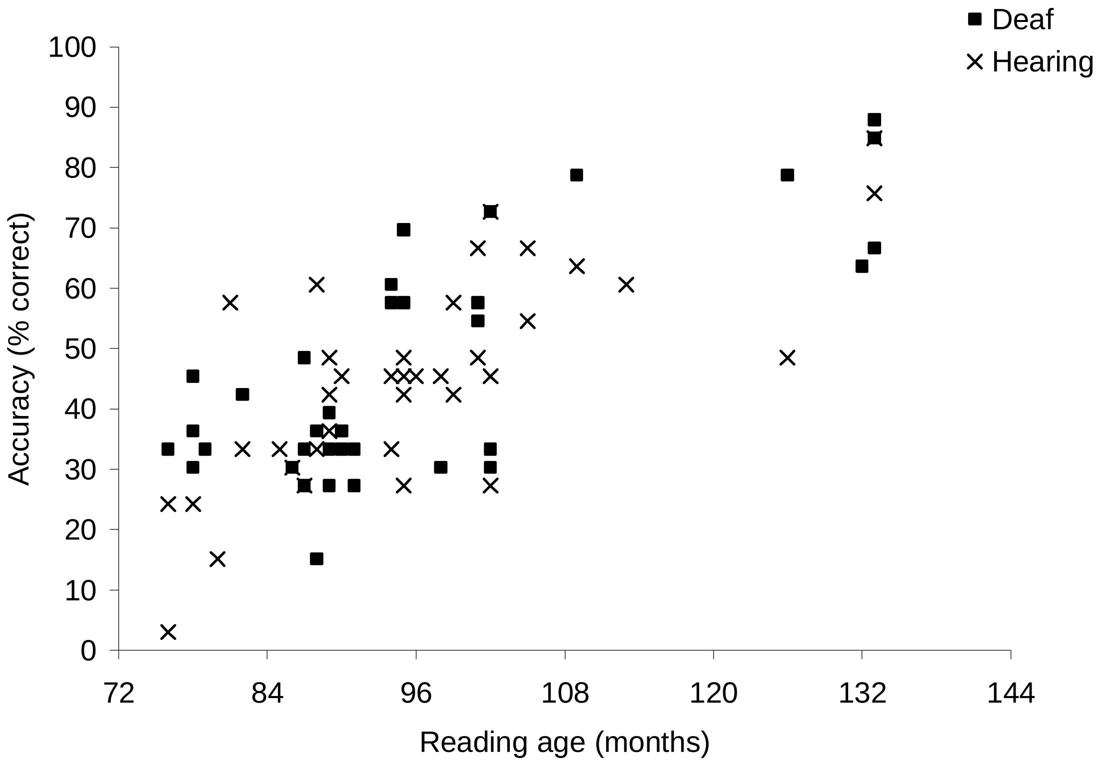

Figure 5.2: The relationship between plural spelling accuracy and reading-age for deaf and hearing children in Experiment 3a

Three types of analyses were conducted to assess productivity of morphological awareness. The first set of analyses explicitly asked whether the cross-section of children demonstrated a developmental progression in generalisation of the plural rule, by examining whether there was a U-shaped curve for over-regularisation errors as a function of reading-age. The second set of analyses examined the effect of morphographic regularity (regular, semi-regular and irregular) on spelling accuracy to test whether the children had generalised the less frequent rules and had begun to learn the exceptions. Finally, the third set of analyses examined the nature of spelling errors on semi-regular and irregular plurals to establish whether morphological or phonological factors determined errors in deaf and hearing groups.

5.1.2.1 Over-regularisation errors

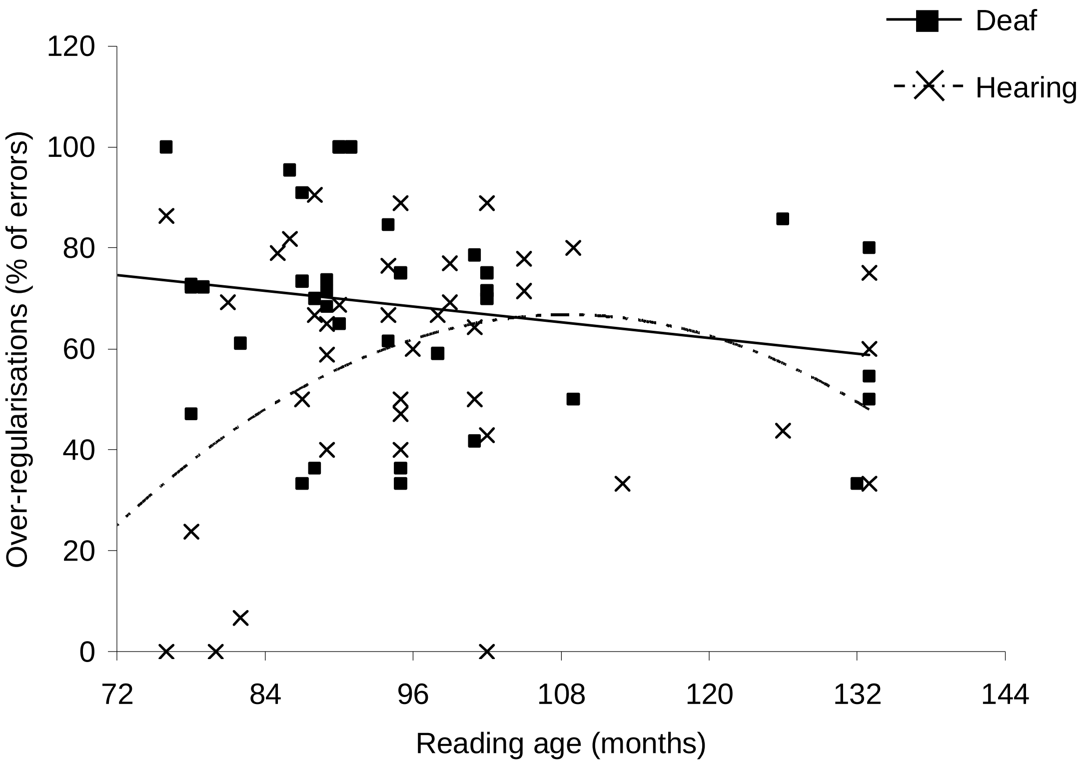

Figure 5.3: The relationship between reading-age and rates of over-regularisation (as a proportion of errors) for deaf and reading-age matched hearing children in Experiment 3a

A larger proportion of the deaf children's spellings were categorised as over-regularisations (singular+<s> responses when an alternative transformation was necessary) than hearing children's, whether considered as a proportion of all responses (51% vs. 38%; $\chi^2(1, N = 1716) = 28.58, p < 0.001$) or as a proportion of errors (71% vs. 55%; $\chi^2(1, N = 1207) = 31.58, p < 0.001$). However, the crucial comparison for testing the developmental pattern is to examine the relationship between rates of over-regularisation (as a proportion of errors) and reading-age (Figure 5.3). For hearing children the predicted U-shaped pattern of development was observed–a linear regression fails to provide a significant fit to the data ($p = 0.3$), while a quadratic regression provides a better fit; $r^2 = 0.16$, $F(2,36) =$

3.52, $p = 0.04$. Thus, hearing children with low or high reading-ages produced few over-regularisations while those reading at around 8 to 10-years-old made a large number of over-regularisation errors. In contrast, neither linear ($p = 0.2$) nor quadratic ($p = 0.4$) regressions provided a significant fit to the deaf children's data. Deaf children's rates of over-regularisation remain essentially constant between the reading-ages of 6 and 11-years.

Thus, despite the spelling abilities of deaf and hearing children being very similar, patterns of over-regularisation were very different. Hearing children with the lowest reading-age demonstrated low accuracy and few over-regularisations. Spelling accuracy improved with reading-age and around the age of 8 to 10-years a large proportion of the hearing children's spelling errors are over-regularisations. In contrast, even the deaf children with the lowest reading-ages produced a large proportion of over-regularisation errors and the rate of over-regularisation reduced only a little with reading-age.

5.1.2.2 The effect of regularity

Figure 5.4 shows deaf and hearing children's accuracy on regular, semi-regular and irregular plurals. To establish whether morphographic regularity influenced accuracy, a split-plot ANOVA was conducted with the within-participants factor regularity (regular, semi-regular, irregular), the between-participants factor hearing group[4] (deaf, hearing) and the dependent variable accuracy (percent correct). The main effect of regularity was significant[5]; $F(2,152) = 177.41$, $p < 0.001$, partial $\eta^2 = 0.70$. The main effect of hearing group was not significant ($p = 0.9$) but the interaction between hearing group and morphographic regularity was; $F(2,152) = 11.94$, $p < 0.001$, partial $\eta^2 = 0.14$. Univariate

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[4] The performance of deaf CI and non-CI children was compared in a separate ANOVA which revealed that neither the main effect of CI nor the interaction between CI and regularity were significant ($p > 0.7$). Therefore, the deaf children were considered as a single group in the remainder of these analyses.

[5] Mauchley's Test of Sphericity indicated that the assumption of sphericity had been violated and therefore the more conservative Greenhouse-Geisser F-statistics were used throughout this chapter.

ANOVAs on each overlap condition separately (with a Bonferroni-adjusted criterion level of 0.05/3 = 0.0167) revealed that deaf children did not differ from hearing children on regular and semi-regular plurals ($p = 0.03$ and $p = 0.2$) but performed significantly worst than hearing children on irregular plurals; irregular $F(1,76) = 14.82$, $p < 0.001$, partial $\eta^2 = 0.16$. Both groups of children were better at spelling regular plurals (hearing mean 76%, *SD* 28, deaf mean 87%, *SD* 13) than semi-regular or irregular plurals ($p > 0.001$) but they differed in their relative accuracy on these two conditions (see Figure 5.4). Hearing children were better at spelling irregular than semi-regular plurals (mean 36%, *SD* 23 vs. mean 23%, *SD* 27); $F(1,38) = 15.10$, $p < 0.001$, partial $\eta^2 = 0.28$. In contrast, deaf children were better at spelling semi-regular than irregular plurals (mean 32%, *SD* 37 vs. mean 18%, *SD* 19); $F(1,38) = 10.55$, $p = 0.002$, partial $\eta^2 = 0.22$. Taking these results together, deaf children made more errors when spelling irregular plurals than hearing children but otherwise performed reading-age appropriately.

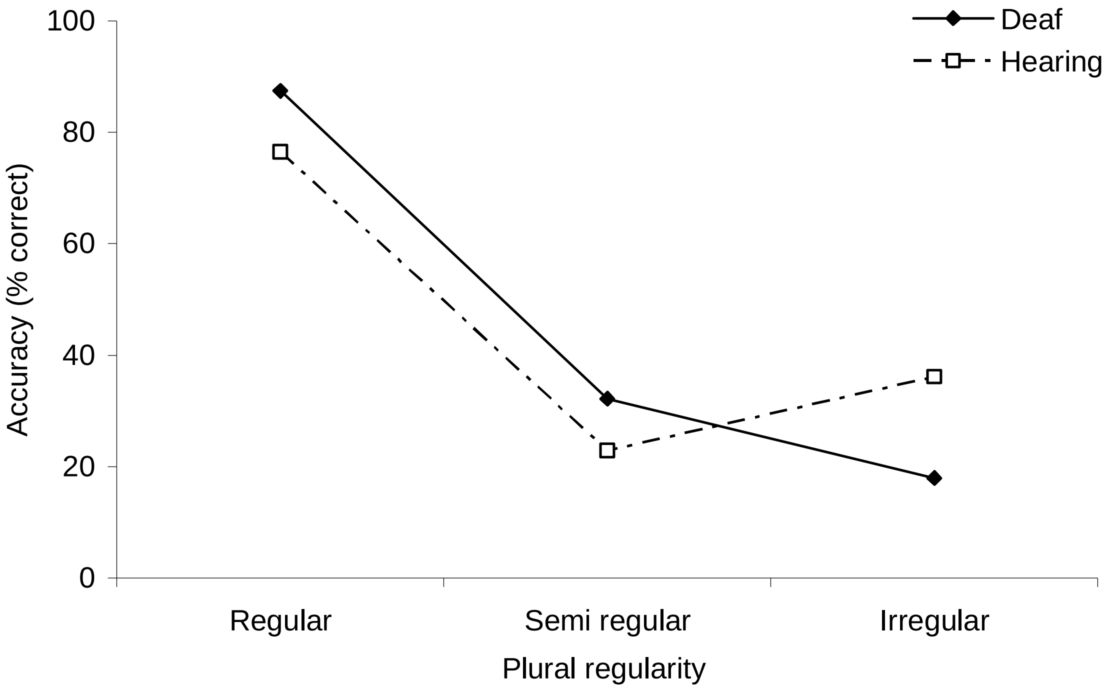

Figure 5.4: The effect of regularity on the spelling accuracy of deaf and hearing children in Experiment 3a

5.1.2.3 The nature of errors

Before children have associated singular and plural nouns, they should be constrained to using visual-orthographic memory strategies to learn plurals. Such a strategy predicts that when a plural is not known, the child would be unable to generate a plausible spelling and so there would be an increased number of misspellings. Furthermore, these errors would rarely be phonologically plausible or morphologically constructed (i.e., they will largely be singular only productions, changes to the singular root or omissions). If they have abstracted and generalised morphographic rules, then misspellings should be consistent with application of the wrong morphographic rule (i.e., over-generalisation errors such as singular+<s> or singular+<es> when an alternative transformation was necessary). However, if children make use of their knowledge of plural formation from speech, they would produce a large number of misspellings that are phonetically plausible (e.g., GLASS-**glassis*). To test which of these strategies deaf and hearing children use to assist plural spelling, analyses were conducted on the spelling errors produced on irregular and semi-regular plurals, since these were the spellings that both groups of children had difficulty with.

The irregular plurals for which no suffixation should occur were included in these analyses (excluded: CHILD-*CHILDREN*). The correct responses for five of these irregular plurals involved leaving the singular form unchanged (*invariant plurals*; *TROUSERS, SCISSORS, DEER, FISH, SHEEP*) and five involved an *internal change* (FOOT-*FEET,* GOOSE-*GEESE,* MAN-*MEN,* TOOTH-*TEETH,* MOUSE-*MICE*). Within the semi-regular words there were five plurals formed by *root+<es>*, three *final <f~fe>* → <ves> plurals and three *final <y>* → <ies> plurals.

The first analysis examined the nature of all *responses* and the second examined *misspellings*[6]. For the analysis of responses, spellings were categorised as Correct, Omission/Different Word and Misspelling (see Table 5.2). When a participant failed to give a response or provided a spelling that was clearly an attempt at a different word (e.g., **males* instead of *MEN*) this was categorised as *Omission/Different Word* (these errors were very rare and equally common in deaf and hearing children's responses). Other errors were categorised as *Misspellings*.

Table 5.2: Deaf and hearing children's responses to irregular and semi-regular plurals in Experiment 3a

	Correct		Omission/Different word		Misspelling	
	Deaf	Hearing	Deaf	Hearing	Deaf	Hearing
Irregular						
Internal	36/195	88/195	6/195	2/195	153/195	105/195
change	$\chi^2(1, N = 390) = 31.97, p < 0.001$		$p = 0.3$ [a]		$\chi^2(1, N = 390) = 26.39, p < 0.001$	
Invariant	23/195	49/195	10/195	6/195	162/195	140/195
	$\chi^2(1, N = 390) = 11.52, p = 0.001$		$p = 0.3$		$\chi^2(1, N = 390) = 7.10, p = 0.008$	
Semi-regular						
Root	85/195	73/195	4/195	2/195	106/195	120/195
+<es>	$p = 0.2$		$p = 0.5$ [a]		$p = 0.2$	
Final	22/117	11/117	2/117	1/117	93/117	105/117
<f~fe>	$\chi^2(1, N = 234) = 4.27, p = 0.039$		$p = 1.0$ [a]		$\chi^2(1, N = 234) = 4.73, p = 0.030$	
Final <y>	31/117	14/117	5/117	1/117	81/117	102/117
	$\chi^2(1, N = 234) = 7.95, p = 0.005$		$p = 0.2$ [a]		$\chi^2(1, N = 234) = 11.06, p = 0.001$	

Note. [a] Fisher's Exact Test because at least one cell had an expected value less than five.

Neither hearing nor deaf children produced omissions or different words very often, providing a first indication that deaf children are not merely using a visual-orthographic strategy. Furthermore, having seen that deaf children performed better than hearing children on semi-regular plurals and not as well as hearing children on irregular plurals,

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[6] Difference in responses and misspellings between deaf CI and non-CI participants approached significance for singular only errors on internal change plurals ($p = 0.057$). No other differences were significant ($p > 0.2$) and therefore the deaf were considered as a single group throughout these analyses.

Table 5.2 demonstrates that this was true for all subtypes of these plurals except for root+<es> semi-regular plurals, on which they did not differ.

Having seen that deaf and hearing children differed in the number of misspellings that they made (see Table 5.2), the question for the present analysis was whether deaf and hearing children also differed in the *nature* of these misspellings (i.e., whether they were phonetically or morphologically plausible). In an initial analysis, misspellings were divided into phonetic or non-phonetic renditions of the appropriate plural based on the spelling of the entire word, in order to examine whether children used knowledge of plural formation from speech to aid their spelling. This division revealed that a larger proportion of hearing children's misspellings of internal change and root+<es> plurals were phonetically plausible than deaf children's (hearing 13/105, 97/120; deaf 0/153, 71/106); $\chi^2(1, N = 258) = 19.95, p < 0.001$ and $\chi^2(1, N = 226) = 5.66, p = 0.017$. However, deaf and hearing children did not differ in the proportion of phonetically plausible misspellings on invariant, final <f~fe> and final <y> plurals (hearing 26/140, 1/105, 87/102; deaf 25/162, 0/93, 69/81; $p > 0.3$). Appendix 3a contains a complete list of misspellings categorised as phonetically plausible and implausible.

A second analysis examined the morphographic structure of the misspellings. All of the misspellings were coded according to whether they contained the singular root or not. Misspellings that did not contain the singular root were coded as *Other*. Misspellings which contained the singular root were subcategorised as Singular only, Singular+plural suffix and Singular+other graphemes. *Singular only* misspellings were replications of the singular root without any transformation. *Singular+plural suffix* misspellings included the singular root plus the plural suffix +<s> or +<es> (e.g., **mouses*). *Singular+other grapheme* misspellings added other graphemes to the singular root. These included adding non-plural suffixes (e.g., **gooseing*) and pseudo-suffixes (e.g., **scissorsmoth*).

Misspellings that did not retain the singular (other misspellings) indicate a failure to observe root+suffix structure. These other misspellings were rare for both deaf and hearing children on all types of plurals and an even smaller proportion of deaf children's misspellings were categorised as other than hearing children's (see Figure 5.5 and Figure 5.6). This difference was significant for irregular invariant and internal change as well as semi-regular root+<es> plurals (deaf 12/162, 16/153, 1/106; hearing 24/140, 27/105 and 17/120); $\chi^2(1, N = 302) = 6.78$, $p = 0.009$; $\chi^2(1, N = 258) = 10.44$, $p = 0.001$ and $\chi^2(1, N = 226) = 13.43$, $p < 0.001$. However, the difference on semi-regular final <f~fe> and final <y> plurals was not significant ($p > 0.3$); deaf 9/97 and 8/81; hearing 9/105 and 15/102. These findings suggest that deaf children (possibly even more so than hearing children) use a morphographic principle when spelling plurals–morphemes are invariantly spelled across morphologically related words.

Singular only misspellings were also rare. Increased rates of these errors would be consistent with the use of visual orthographic strategies. Generally, hearing children produced more singular only responses than deaf children (see Figure 5.5 and Figure 5.6). The difference was significant for semi-regular final <y> and irregular internal change plurals (note that this category is not relevant for invariant plurals, as such responses would have been correct); deaf[7] 1/80 and 5/153; hearing 8/102 and 19/105; Fisher's Exact Test[8] $p = 0.045$ and $\chi^2(1, N = 258) = 16.23$, $p < 0.001$. On root+<es> and final <f~fe> plurals deaf (8/106 and 5/93) and hearing (16/120 and 10/105) children did not differ in proportions of singular only misspellings ($p > 0.2$). Therefore, if anything, hearing children showed

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[7] The difference between deaf CI (3/28) and deaf non-CI (2/120) approached significance for singular only misspellings on internal change plurals; Fisher's Exact Test (FET) $p = 0.057$. However, follow-up tests revealed that both deaf CI and non-CI children produced fewer of these misspellings compared to their reading-age matched hearing counterparts (hearing CI 11/23, non-CI 8/82); $\chi^2(1, N = 54) = 10.01$, $p = 0.002$ and FET $p = 0.016$.

[8] At least one cell contained expected values of less than five and therefore, here and throughout the remainder of this chapter where this is the case, Fisher's Exact Test was used.

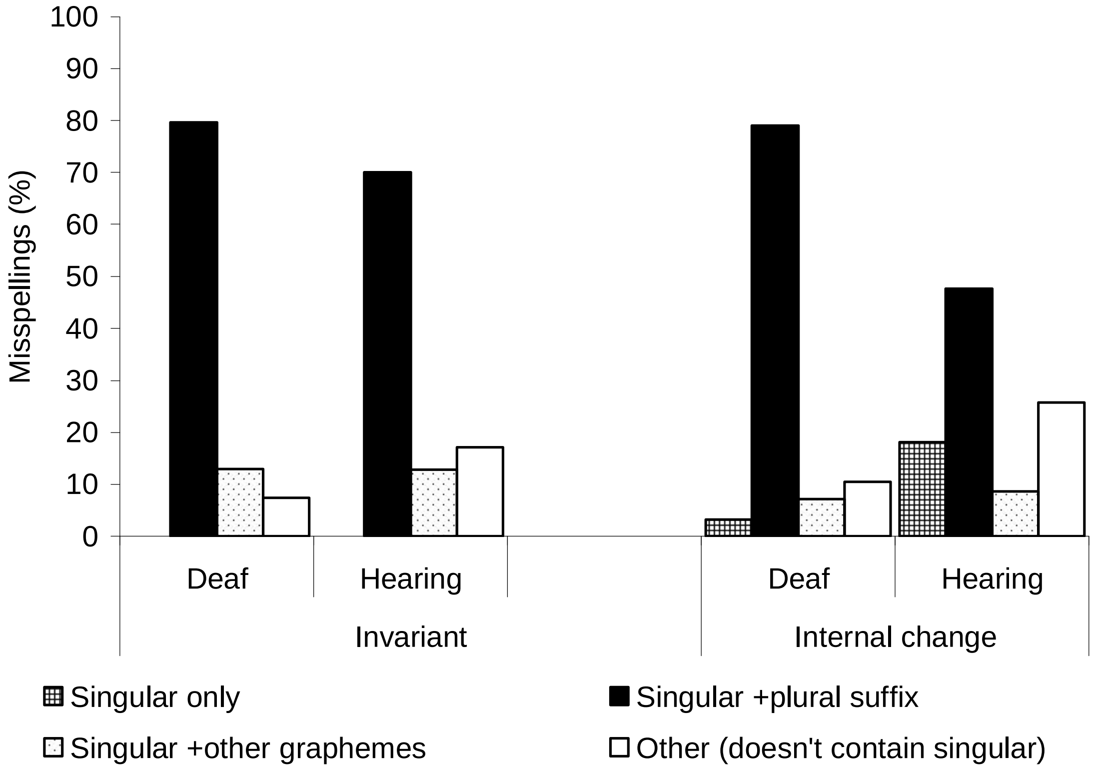

Figure 5.5: Analysis of deaf and hearing children's misspellings of irregular plurals (invariant and internal change) as a percentage of misspellings in Experiment 3a

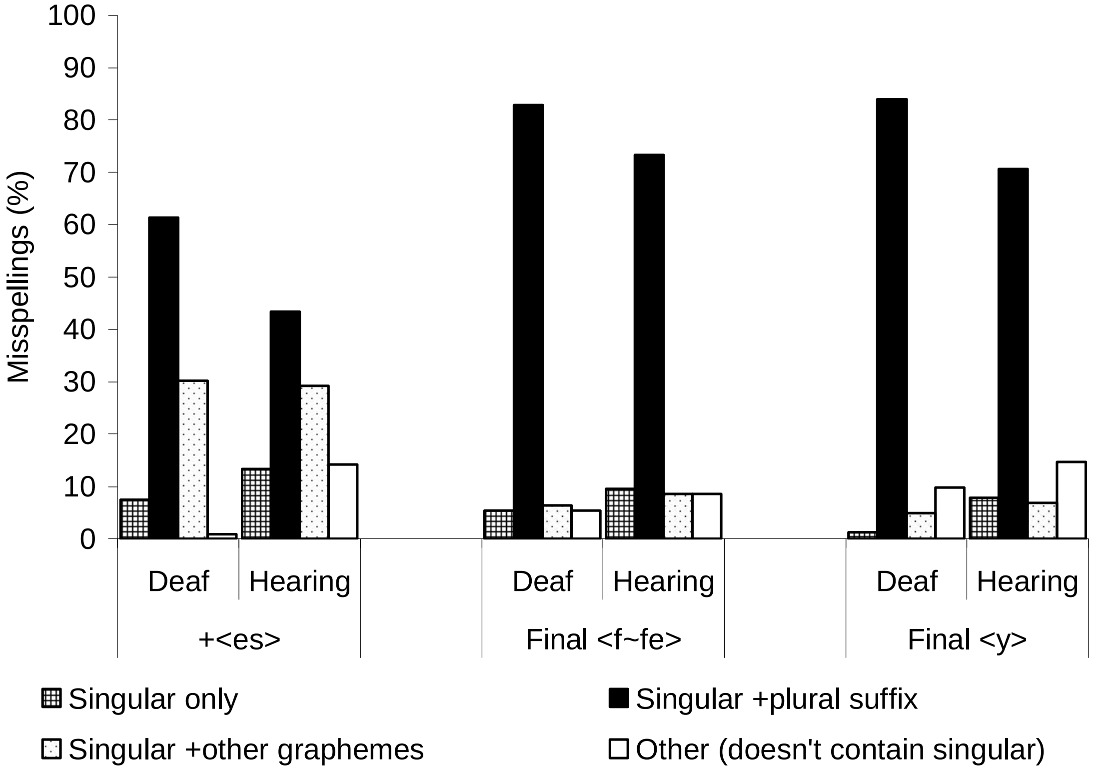

Figure 5.6: Deaf and hearing children's misspellings of semi-regular plurals (root+<es>, final <f~fe> and final <y>) as a percentage of misspellings in Experiment 3a

greater evidence for the use of visual-orthographic strategies than deaf children.

Singular+plural suffix misspellings are indicative of over-generalisation of morphological rules. A greater proportion of deaf children's misspellings were singular+plural suffix than hearing children's (see Figure 5.5 and Figure 5.6) and the differences were significant for all types of plural except final <f~fe> semi-regular plurals (deaf 77/88, hearing 77/96, $p = 0.11$); invariant deaf 129/162, hearing 98/140, $\chi^2(1, N = 302) = 3.73$, $p = 0.053$; internal change deaf 121/153, hearing 50/105, $\chi^2(1, N = 258) = 27.59$, $p < 0.001$; root+<es> (note that these singular+plural suffix misspellings were singular+<s>) deaf 65/106, hearing 52/120, $\chi^2(1, N = 226) = 7.29$, $p = 0.007$; final <y> deaf 68/81, hearing 72/102, $\chi^2(1, N = 183) = 4.48$, $p = 0.034$. Therefore, deaf children demonstrated greater use of morphological generalisation than hearing children (with the exception of the semi-regular final <f~fe> → <ves> rule).

Finally, singular+other grapheme misspellings were equally rare for both deaf and hearing children on all plural types ($p > 0.6$, see Figure 5.5 and Figure 5.6); internal change deaf 11/153, hearing 9/105; invariant deaf 21/162, hearing 18/140; root+<es> deaf 32/106, hearing 35/120; final <f~fe> deaf 6/93, hearing 9/105; final <y> deaf 4/81, hearing 7/102.

Although the rates of singular+other grapheme misspellings made by deaf and hearing children did not differ on any semi-regular or irregular transformation, the qualitative nature of these misspellings revealed differences between the groups. More of the deaf children's singular+other grapheme misspellings could be subcategorised as morphologically formed (i.e., adding a real English suffix) than hearing children's (see Table 5.3). Indeed, 70/74 of the deaf children's singular+other grapheme misspellings were morphological compared to only 43/78 of the hearing children's. Moreover, deaf children's singular+other grapheme misspellings were largely restricted to a small group of suffixes (+*ed, +*er, +*ers, +*est, +*ing, +*ings +*'s. Exceptions: *shelfies, *mousese*) and very few of these misspellings could be regarded as phonologically driven. In contrast, when hearing children's singular+other grapheme misspellings could be classified as having a morphological basis, they could nearly always also be classified as phonetically plausible renditions of the correct plural (_*box's, *bus', *busses, *church's, *dress', *dress's, *glassies, *glass's, *baby's, *lady's, *penny's_) or of an over-regularised plural (_*knife's, *leaf's, *shelf's, *mouseies,* deer's,* sheep's_. Exceptions: _*footet, *mansise, *deerise_). In other words, hearing children's singular+other grapheme misspellings may have resulted from a combination of morphological and/or phonological sources but deaf children's appeared to have only a morphological source. A complete list of misspellings categorised as morphological and non-morphological is provided in Appendix 3a.

Table 5.3: Proportions of deaf and hearing children's singular+other grapheme misspellings that had a morphological source (i.e., singular+suffix) in Experiment 3a

	Irregular		Semi-regular		
	Internal change	Invariant	Root +<es>	Final <f~fe>	Final <y>
Deaf	10/11	19/21	31/32	6/6	4/4
Hearing	5/9	11/18	17/35	5/9	5/7
	$p = 0.13$ [a]	$p = 0.055$ [a]	$\chi^2(1, N = 67) = 19.20, p < 0.001$	$p = 0.10$ [a]	$p = 0.5$ [a]

Note. [a] Fisher's Exact Test because at least one cell had an expected value less than five.

5.1.3 Discussion

In Experiment 3a, deaf children demonstrated a good understanding of plural noun formation and provided evidence that they had generalised the morphographic rules for plural formation rather than being constrained to using visual-orthographic strategies. Deaf children were as accurate as reading-age matched hearing children at spelling regular and semi-regular plurals, only under-performing on irregular plurals. By demonstrating superior performance on rule based (regular and semi-regular) plurals than exception words (irregular plurals), deaf children demonstrated that they had associated the singular and plural forms of these words (if they had not, performance would not be influenced by regularity). Furthermore, because deaf children's most frequent error on all types of semi-regular and irregular plurals was over-generalisation, deaf children demonstrated that they had generalised knowledge of plural formation. It is particularly interesting to note the high rates of over-regularisation on root+<es> semi-regular plurals. Here, sensitivity to orthographic structure should discourage over-regularisation (since the resultant word-final grapheme constellations <chs>, <xs> and <sss> virtually never occur in English). Although rates of singular+plural suffix misspellings were less frequent on these words compared to the other semi-regular and irregular plurals, they remained very common and, crucially, were produced more often by deaf children than hearing children, which is not consistent with the view that deaf children rely more heavily on orthographic features than hearing children. Following from this same argument, sensitivity to orthographic structure could result in children seeking to produce legal alternatives to the orthographically illegal over-regularisation, hence the elevated rates of singular+other grapheme misspellings on root+<es> semi-regular plurals. Nonetheless, it should be noted that deaf and hearing children did not differ quantitatively in these misspellings. Furthermore, this account does not explain why deaf children (and only deaf children) consistently produced other English suffixes rather than simply adding any other frequent word-final grapheme constellations.

Deaf children's particularly poor performance on irregular plurals indicated that they had difficulty learning exceptions. It is probably easier for hearing children to learn the exceptions because the exception is marked in both speech and spelling. Hearing children have the advantage of greater experience with spoken language (both heard and produced) to flag these plurals as irregular. Consistent with this argument, hearing children's errors on both semi-regular and irregular plurals were more frequently phonetic (e.g., *church-*churchis, goose-*geas*) than deaf children's, suggesting that hearing children were using phoneme-grapheme correspondences to convert plurals from their speech vocabulary into text.

Although we observed a quadratic pattern in the relationship between rates of over-regularisation and reading-age for hearing children (as predicted by no over-regularisations during the earliest stage of development and learning of the exceptions during the final stage of development), no such pattern was observed for deaf children. This is not to say that such a pattern does not exist, simply that it was not observed at the age tested. Although the deaf children demonstrated a particular difficulty spelling irregular plurals (i.e., learning the exceptions), it is also important to note that the deaf children with the lowest reading-ages were already producing many more over-regularisations than their hearing counterparts. This will be discussed further in the Summary and General Discussion of the present chapter (Section 5.4).

Analysis of the errors from Experiment 3a not only indicated that deaf children used morphology productively but actually suggested that deaf children relied on morphographic knowledge to a greater degree than their reading-age matched hearing counterparts. Deaf children produced significantly more over-generalisation (singular+plural suffix) misspellings than hearing children on every type of semi-regular and irregular plural (although the difference was not significant for final <f~fe> plurals). They also rarely changed the spelling of the singular root when forming a plural. Furthermore, although deaf and hearing children did not differ quantitatively in their singular+other grapheme misspellings, there were important qualitative differences. The vast majority of graphemes that hearing children added could be explained with reference to phonological or morphological strategies. In contrast, the deaf children's singular+other grapheme misspellings typically involved the addition of a non-plural real English suffix but this was very rarely phonologically plausible. Thus, the deaf children seemed to have an understanding that these graphemes had special status related to word formation and were often added to the ends of words but did not necessarily understand the meaning associated with them.

To summarise, the evidence from plural spelling when children were provided with the correct singular strongly suggests that deaf children had generalised the regular plural rule root+<s> and had begun to learn some of the less frequent, semi-regular plural rules, Experiment 3b examines the generation of nonword plurals to provide converging evidence that this understanding can be used productively.

5.2 Experiment 3b: Spelling plural nonwords

To ensure that the patterns of performance observed in Experiment 3a truly were the result of morphological generalisation and the use of productive mechanisms, the same children who participated in Experiment 3a also provided plural spellings for nonwords. Kemp and Bryant (2003) pointed out that even adults sometimes fail to make use of morphographic rules for plurals and for this reason, we also asked a group of hearing adults to produce the nonword plurals for comparison. If morphological generalisation has been achieved then responses should be consistent with morphographic rules and errors should be indicative of over-generalisation of the most common rules (e.g., root+<s>). On the other hand, if children were largely spelling from individually stored forms in Experiment 3a (consistent with the initial phase of normal development or the use of visual-orthographic strategies) then responses should not be consistent with morphographic rules. Instead, there should be a large number of omissions, singular only and other responses, since children would not know how to form a plausible plural nonword.

5.2.1 Method

5.2.1.1 Participants

The same deaf and hearing children from Experiment 3a participated in this experiment. In addition, twenty-five (12 male) hearing adults took part. These participants were native English speakers without any literacy, language or hearing impairments. Hearing adults had a mean age of 26-years (range 18 to 55-years) and were all highly literate–they were either current Undergraduates of the University of Birmingham or educated to or above degree level.

5.2.1.2 Stimuli and design

Thirty-three nonwords were devised by splitting each singular noun from Experiment 3a at the antibody boundary and recombining the parts (e.g., <ba> from *baby* and <rch> from *church* formed <barch>). A complete list of stimuli is provided in Appendix 3b. Nonwords were pronounceable and followed English phonotactic rules. Nonword singular images were sourced from the Tarr Lab Novel 2D Shapes and Possible Objects Library (Tarr, 2005). Plural images were produced and booklets compiled as in Experiment 3a. An example trial is illustrated in Figure 5.7.

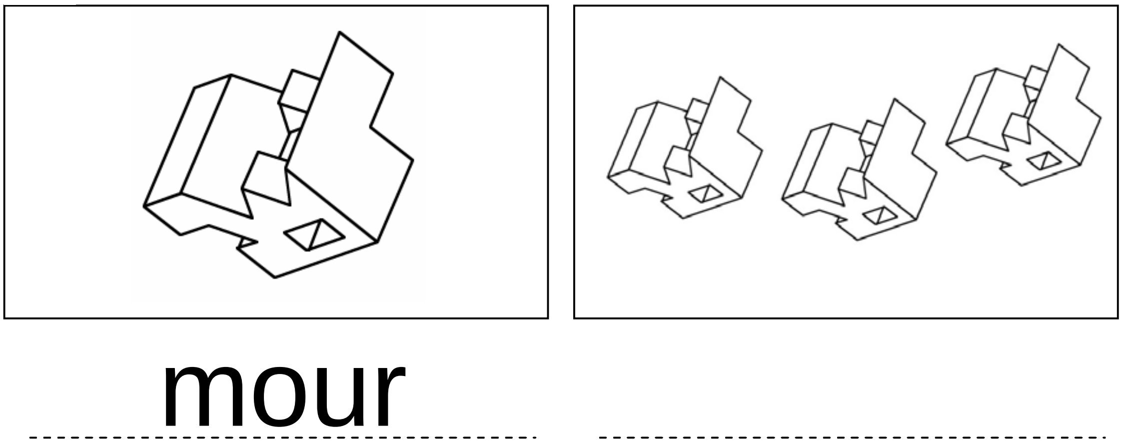

Figure 5.7: Example of a nonword plural spelling trial in Experiment 3b

There is not a correct way of inflecting nonwords. However, regular and semi-regular morphographic rules (outlined in Section 2.6.2.1 of Chapter Two) were used to predict behaviour. It was expected that 20 nonword plurals would be formed by adding <s> to the singular (henceforth *root+<s>*) and six by adding <es> (*root+<es>*). An adjustment to the root was anticipated for five stimuli; three singulars containing *final <f~fe>* were predicted to change to final <ves> and two singulars with *final <y>* were expected to change to final <ies>. Behaviour was less predictable for the remaining nonwords; LASSORS and HASERS were formed from the codas of plural invariant nouns. Attending to the final phoneme or grapheme alone (/z/ or <s>) suggests use of the semi-regular rule +<es>. However, a search of the CELEX Database (Baayen et al., 1993) revealed that final <rs> is virtually always a plural ending (the only exception being *mars*). Using the coda as the unit of analysis, participants may conclude that the nonword refers to an invariant noun and leave it unchanged. Because of this uncertainty, these stimuli were excluded from the analyses.

5.2.1.3 Procedure

The children completed the nonword plural spelling task immediately following completion of Experiment 3a. The previous spelling booklet was removed prior to administration to ensure that participants could not refer to prior responses. Procedure was as Experiment 3a with the exception that, although full instructions were provided on the booklet, verbal/signed instructions were abridged. Children were simply told that the task was "*the same as before, only this time the words are made up…*". They were reminded that the experimenter could not help with reading the words and that "*there is no right or wrong answer, just put whatever you think the spelling would be…*". Written instructions included a completed regular example (FOULK-*FOULKS*).

Hearing adults were given the list of singular nonwords without pictures and asked to pretend that they were real words and produce what they thought were the plurals. They were also provided with a completed regular example (BREW-*BREWS*).

5.2.2 Results

As in Experiment 3a, we examined both the nature of *responses* and the *misspellings*[9] (in the present experiment misspellings are referred to as *unexpected spellings* since you cannot technically misspell a nonword). The present results are entirely parallel to those of Experiment 3a, with deaf children over-generalising, producing few singular only responses and mainly morphologically driven unexpected errors.

In the response analysis, spellings were categorised as Expected, Omission or Unexpected spelling. *Expected* responses were spelled using the transformation predicted on the basis of the morphographic rules. Responses were categorised as *Omissions* when no response was given and all other responses were categorised as *Unexpected spellings* (see Table 5.1). Hearing adults produced a significantly greater proportion of expected responses than deaf children, who in turn produced a significantly greater proportion of expected responses than RA matched hearing children (see Table 5.4). Hearing adults virtually always applied the morphographic rules (expected responses accounted for over 85% of responses on all nonword types except final <f~fe>). Final <f~fe> nonword plurals were rarely produced as expected by any participant (hearing adults 19%, deaf children 3%, hearing children 0%), casting doubt on the psychological reality of this rule even in adult readers. Deaf and hearing children demonstrated the same pattern of difficulty with the different transformations, producing many responses as expected on root+<s> nonwords (69% and 61%), somewhat fewer on root+<es> nonwords (38% and

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[9] Throughout these analyses, the deaf CI and non-CI children performed similarly (as observed in Experiment 3a). For this reason, statistical tests were conducted on the combined CI and non-CI data. Differences are stated only where significant.

Table 5.4: Hearing adults, deaf and reading-age matched hearing children's responses to plural nonwords in Experiment 3b

	Expected			Omission			Unexpected spelling		
	HA	D	RA	HA	D	RA	HA	D	RA
Root +<s>	450/475	513/741	453/741	1/475	10/741	2/741	24/475	218/741	286/741
HA vs. D	$\chi^2(1, N = 1216) = 114.28, p < 0.001$			$\chi^2(1, N = 1216) = 4.19, p = 0.041$			$\chi^2(1, N = 1216) = 107.82, p < 0.001$		
D vs. RA	$\chi^2(1, N = 1482) = 10.70, p = 0.001$			$\chi^2(1, N = 1482) = 5.38, p = 0.020$			$\chi^2(1, N = 1482) = 13.90, p < 0.001$		
HA vs. RA	$\chi^2(1, N = 1216) = 170.99, p < 0.001$			$p = 0.8$			$\chi^2(1, N = 1216) = 171.47, p < 0.001$		
Root +<es>	127/150	90/234	63/234	0/150	7/234	6/234	23/150	137/234	165/234
HA vs. D	$\chi^2(1, N = 384) = 79.40, p < 0.001$			$\chi^2(1, N = 384) = 4.57, p = 0.033$			$\chi^2(1, N = 384) = 70.23, p < 0.001$		
D vs. RA	$\chi^2(1, N = 468) = 7.08, p = 0.008$			$p = 0.8$			$\chi^2(1, N = 468) = 7.32, p = 0.007$		
HA vs. RA	$\chi^2(1, N = 384) = 121.92, p < 0.001$			$\chi^2(1, N = 384) = 3.91, p = 0.048$			$\chi^2(1, N = 384) = 111.37, p < 0.001$		
Final <f~fe>	14/75	3/117	0/117	0/75	3/117	0/117	61/75	111/117	117/117
HA vs. D	$\chi^2(1, N =192) = 14.68, p < 0.001$			$p = 0.2$			$\chi^2(1, N = 192) = 8.98, p = 0.003$		
D vs. RA	$p = 0.081$			$p = 0.08$			$\chi^2(1, N = 234) = 6.16, p = 0.013$		
HA vs. RA	$\chi^2(1, N = 192) = 23.56, p < 0.001$			$p = 1$			$\chi^2(1, N = 192) = 23.56, p < 0.001$		
Final <y>	72/75	25/117	7/117	0/75	1/117	0/117	3/75	91/117	110/117
HA vs. D	$\chi^2(1, N = 192) = 101.84, p < 0.001$			$p = 0.4$			$\chi^2(1, N = 192) = 99.55, p < 0.001$		
D vs. RA	$\chi^2(1, N = 234) = 11.73, p = 0.001$			$p = 0.3$			$\chi^2(1, N = 234) = 12.74, p < 0.001$		
HA vs. RA	$\chi^2(1, N = 192) = 152.93, p < 0.001$			$p = 1$			$\chi^2(1, N = 192) = 152.93, p < 0.001$		

Note. HA: Hearing adults. D: Deaf. RA: Reading-age matched hearing children.

27%) and final <y> nonwords (21% and 6%) and the least on final <f~fe> nonwords (3% and 0%).

Omissions were rare for all three groups of participants (accounting for a maximum of 3% of responses on any transformation), although they appeared to be slightly more common for the deaf than either group of hearing participants (see Table 5.4). On root+<s> nonwords, deaf children made proportionately more omissions than either group of hearing participants but hearing children and adults did not differ. For root+<es> nonwords, hearing adults made proportionately fewer omissions than deaf or hearing children but the two groups of children did not differ significantly. All three groups of participants made the same proportion of omissions on final <f~fe> and final <y> nonword plurals.

The analysis of unexpected spellings examined the orthographic structure of responses. Hearing adults very rarely produced unexpected spellings and therefore their data is not included in this analysis. The only exception was the final <f~fe> nonword plurals, for which all groups produced very few expected responses and therefore this transformation will be examined separately, with the deaf and hearing children's data presented alongside the hearing adults' data. Unexpected spellings were recoded according to whether they contained the singular root. Spellings which did not contain the singular root were categorised as *Other*. Unexpected spellings containing the singular root were subcategorised according to the graphemes that were added. When no graphemes were added the response was *Singular only*. *Singular+plural suffix* spellings added the plural suffix +<s> or +<es> to the singular root (i.e., generalisation of the most common morphographic rules). Finally, *Singular+other grapheme* spellings added other graphemes to the singular, including non-plural suffixes and pseudo-suffixes.

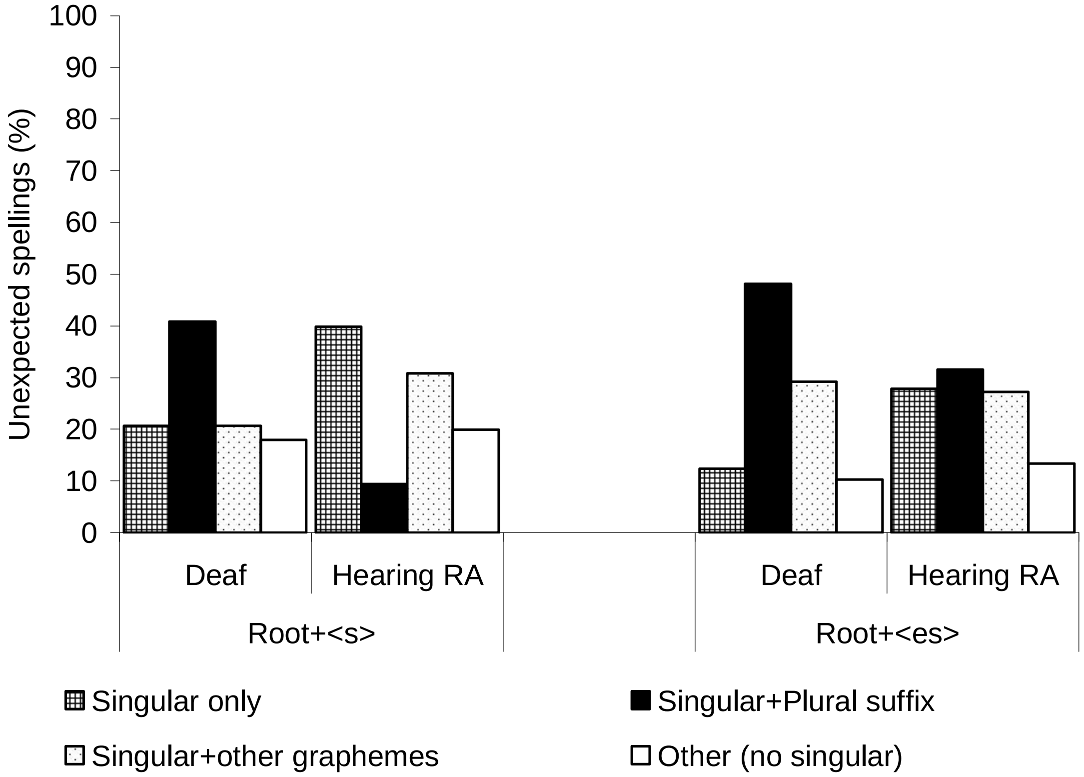

Figure 5.8: Deaf and hearing children's unexpected spellings of root+<s> and root+<es> nonwords in Experiment 3b

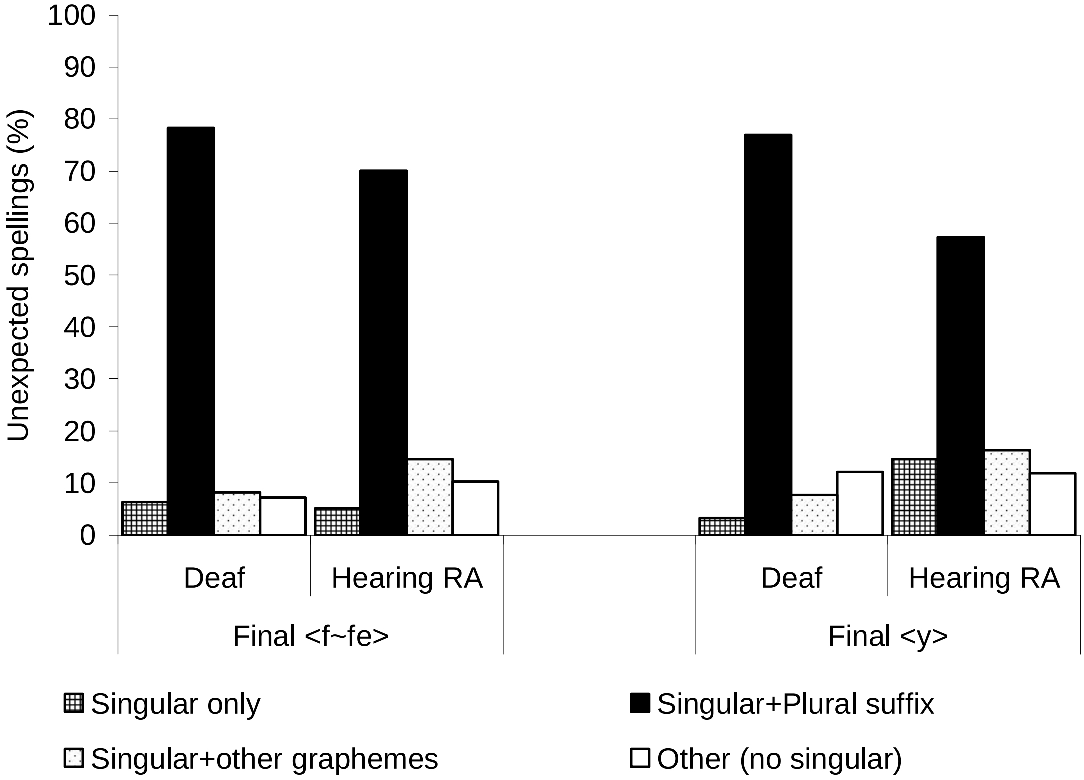

Figure 5.9: Deaf and hearing children's unexpected spellings of final <f~fe> and final <y> nonwords in Experiment 3b

Analyses of unexpected spellings revealed that the vast majority of all participants' responses retained the singular root (see Figure 5.8 and Figure 5.9). Furthermore, on root+<s>, root+<es> and final <y> plural nonwords, deaf[10] (39/218, 14/137 and 11/91) and hearing children (57/286, 22/165 and 13/110) did not differ in the proportion of their unexpected spellings that failed to retain the singular root (i.e., other spellings. See Figure 5.8 and Figure 5.9, $p > 0.4$). Indeed, if anything, the hearing children produced more other responses than deaf children, confirming the finding of Experiment 3a that deaf children obey the morphographic principle of invariantly spelling a morpheme in related words.

The most common unexpected spelling was to produce singular+plural suffix responses, which is indicative of generalisation of morphological rules. For root+<s> and root+<es> nonword plurals, singular+plural suffix unexpected spellings involved the alternative plural suffix (i.e., +<es> and +<s> respectively), whilst for final <y> nonwords these responses may have involved either suffix. On root+<s>, root+<es> and final <y> nonword plurals, deaf[11] children (89/218, 66/137, 70/91) produced more singular+plural suffix unexpected spellings than RA matched hearing children (27/286, 52/165, 63/110) and the difference was significant in all cases; $\chi^2(1, N = 504) = 68.77$, $p < 0.001$; $\chi^2 = (1, N = 302) = 8.73$, $p = 0.003$; $\chi^2(1, N = 201) = 8.59$, $p = 0.003$. Therefore, deaf children demonstrated greater use of morphographic rules than hearing children.

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[10] Deaf CI and non-CI children differed in their rates of other spellings for all nonword transformations; root+<s> $\chi^2(1, N = 218) = 21.59$, $p < 0.001$; root+<es> FET $p = 0.003$; Final <f~fe> FET $p = 0.056$; Final <y> FET $p = 0.048$. Nonetheless, for root+<es>, final <f~fe> and final <y> plurals, differences between deaf and hearing children were not significant for neither CI or non-CI participants ($p > 0.2$). The story was not so simple for root+<s> nonwords, where non-CI deaf children produced more other spellings than hearing children, whereas CI deaf children produced more other spellings than hearing children; non-CI deaf 19/168, hearing 44/212, $\chi^2(1, N = 380) = 6.05$, $p = 0.014$; CI deaf 20/50, hearing 13/74, $\chi^2(1, N = 124) = 7.69$, $p = 0.006$.

[11] Deaf CI and non-CI children differed in their rates of singular+plural suffix spellings on final <y> nonwords; FET $p = 0.036$. Deaf CI and matched hearing children did not differ significantly (11/19 and 9/22, $p = 0.3$), however the deaf CI children produced more of these type of responses than hearing children (59/72 and 54/88); $\chi^2(1, N = 160) = 8.09$, $p = 0.004$

Singular only responses were rare for deaf children. Hearing children generally produced more of these responses than deaf children and the difference was significant on root+<s>, root+<es> and final <y> nonword plurals; hearing 114/286, 46/165, 16/110; deaf[12] 45/218, 17/137, 3/91; $\chi^2(1, N = 504) = 21.16$, $p < 0.001$; $\chi^2(1, N = 302) = 10.85$, $p = 0.001$ and $\chi^2(1, N = 201) = 7.36$, $p = 0.007$.

Singular+other grapheme spellings accounted for the remaining responses. Generally, deaf children produced fewer singular+other grapheme responses than hearing children. The difference was significant for root+<s> plural nonwords, approached significance for final <y> but was not significant for root+<es> nonword plurals; deaf[13] 45/218, 7/91 and 40/137; hearing 88/286, 18/110 and 45/165; $\chi^2(1, N = 504) = 6.53$, $p = 0.011$; $\chi^2(1, N = 201) = 3.44$, $p = 0.064$ and $p = 0.7$. Nonetheless, as observed in Experiment 3a, a greater proportion of deaf children's singular+other grapheme unexpected spellings were morphological (i.e., they retained the root and added a real English suffix) than the hearing children's. The difference was significant for root+<s> and root+<es> but not for final <y> nonword plurals; deaf 40/45, 36/40, 6/7; hearing 61/88, 29/45, 14/18; $\chi^2(1, N = 133) = 6.24$, $p = 0.012$; $\chi^2(1, N = 85) = 7.69$, $p = 0.006$; Fisher's Exact Test $p = 1.0$.

Recall from the response analysis that final <f~fe> nonword plurals were rarely produced as expected. Indeed, final <f~fe> unexpected spellings occurred with such high frequency within the hearing adults' responses that it was worthwhile to include their data

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[12] The difference between deaf CI and non-CI children in their rates of singular only spellings on root+<s> nonwords approached significance; FET $p = 0.085$. Nonetheless, both CI and non-CI deaf children (6/50 and 39/168) produced fewer singular only responses than hearing children (34/74 and 80/212); $\chi^2(1, N = 124) = 15.74$, $p < 0.001$ and $\chi^2(1, N = 380) = 9.19$, $p = 0.002$.

[13] On root+<s> nonwords deaf CI and non-CI children differed in their rates of singular+other grapheme responses; $\chi^2(1, N = 218) = 8.49$, $p = 0.004$. Deaf CI children produced significantly fewer singular+other grapheme responses than hearing children (3/50 and 22/74); $\chi^2(1, N = 124) = 10.44$, $p = 0.001$. However, deaf non-CI children did not differ from hearing children (42/168 and 66/212, $p = 0.19$).

in the analysis of unexpected spellings alongside that of deaf and hearing children. The analyses of unexpected spellings on final <f~fe> nonword plurals revealed that unexpected spellings that failed to retain the singular root (i.e., other spellings) were equally rare for all participants (deaf 8/111, hearing children 12/117, hearing adults 2/61, $p > 0.4$). Singular+plural suffix unexpected spellings (+<s> or +<es>) accounted for the vast majority of responses made by all participants, as observed for the other transformations. However, the proportion of singular+plural suffix unexpected spellings was significantly greater for hearing adults (58/61) than deaf or hearing children, who did not differ from one another (87/111 and 82/117, $p = 0.2$); $\chi^2(1, N = 94) = 9.04$, $p = 0.003$; $\chi^2(1, N = 113) = 3.88$, $p = 0.049$. Singular only responses were particularly rare on final <f~fe> nonwords. Hearing adults produced no such spellings, while deaf and hearing children did not differ in their rates (7/111 and 6/117, $p = 0.7$). Finally, singular+other grapheme responses accounted for the remaining responses. Hearing children produced significantly fewer of these responses than hearing adults (17/117 and 1/61); $\chi^2(1, N = 178) = 7.33$, $p = 0.007$. However, deaf children (7/111) did not differ from either group of hearing participants ($p > 0.1$).

5.2.3 Discussion

In Experiment 3b, deaf children demonstrated that their understanding of plural formation was productive, by creating plausible plural nonword spellings that were consistent with the morphographic rules. The only exception was final <f~fe> nonwords, which even hearing adults rarely spelled in accordance with the morphographic rule final <f~fe> → <ves>. This suggests that even skilled readers do not necessarily abstract this morphographic rule. Anecdotally, final <f~fe>→<ves> seems to be disappearing from use not only in its orthographic form but also in speech. For example, *hoofs* and *hooves* are now both acceptable plural forms for *hoof*. Nonetheless, across all nonword plurals, hearing adults produced the greatest proportion of spellings as expected on the basis on morphographic rules, hearing children produced the least and deaf children performed intermediate between these two extremes. Thus, deaf children's use of productive morphology was significantly greater than reading-age matched hearing children's.

In addition to successful production of nonword plurals in accordance with morphographic rules, further evidence for morphographic generalisation was provided by the nature of unexpected spellings. As observed in Experiment 3a, singular+plural suffix responses accounted for the vast majority of unexpected spellings. Regular root+<s> and semi-regular root+<es> are the two most common plural noun transformations and therefore the high frequency of singular+plural suffix unexpected spellings is consistent with over-generalisation of the most common rules to cases where less frequent transformations would be appropriate (notice, also, that expected spellings were produced more frequently for root+<s> and root+<es> than final <y> or final <f~fe> nonword plurals). Not only were singular+plural suffix unexpected spellings highly common in the deaf corpus but, on every type of nonword plural, deaf children actually produced significantly more singular+plural suffix unexpected spellings than RA matched hearing children. As argued in the Discussion of Experiment 3a (p125), on root+<es> nonwords the use of an orthographic strategy should have discouraged singular+<s> unexpected spellings (because the resultant word-final grapheme constellations <chs>, <xs> and <sss> are virtually nonexistent in English) and encouraged singular+other grapheme unexpected spellings. However, the results from Experiment 3b support those from 3a, indicating that any influence of orthographic sensitivity was equal for both deaf and hearing children, since they did not differ quantitatively in their rates of singular+other grapheme responses on these words. In addition, singular+plural suffix unexpected spellings on root+<es> nonwords remained more frequent in the deaf corpus than the hearing children's.

Furthermore, despite a lack of quantitative differences in deaf and hearing children's singular+other grapheme unexpected spellings, deaf children produced more singular+other grapheme spellings that were morphologically constructed (i.e., adding a real English suffix to the root) than hearing children and followed the morphographic principle of keeping the root spelling constant. Therefore, consistent with the findings from Experiment 3a, in Experiment 3b deaf children demonstrated generalisation of morphographic rules that enabled productive use of morphology in a nonword spelling task.

5.3 Experiment 3c: Spelling singular and plural nouns

The findings from Experiments 3a and 3b strongly indicate that deaf children use morphographic rules to aid plural spelling and that they are able to use these rules generatively. A final test to compare the use of visual-orthographic memory strategies and morphographic rules is to establish whether plural spelling is dependent on spelling of the singular root. In Experiment 3c, participants were therefore asked to spell both singular and plural form. The use of visual-orthographic memory strategies predicts that accuracy on singular and plural words should be independent, since each word is learned separately. However, the use of morphographic rules predicts that plural accuracy is dependent on being able to spell the singular accurately, since the singular is transformed to create the plural. Children should also be more inclined to use the relationship between singular and plural forms to aid their spelling when this relationship is transparent and least inclined when the relationship is unusual. Therefore, the difference in performance between Experiment 3a and 3c should be larger for regular plurals than irregular plurals.

5.3.1 Method

5.3.1.1 Participants

The majority of the children who participated in Experiments 3a and 3b also completed Experiment 3c. However, several of the children in the deaf and hearing CI groups were unable to complete the final spelling task due to time constraints. For this reason, the deaf CI children and their RA matched hearing counterparts were removed from this experiment. In addition, one of the deaf non-CI participants failed to complete Experiment 3c and so he and his RA matched hearing control were removed from the analysis. In total, data from 30 deaf children and 30 RA matched hearing children were entered into the analysis of Experiment 3c.

5.3.1.2 Stimuli and design

The stimulus booklet was identical to that used in Experiment 3a, with the exception that singular spellings were removed and the children were required to produce both singular and plural words (see Figure 5.10).

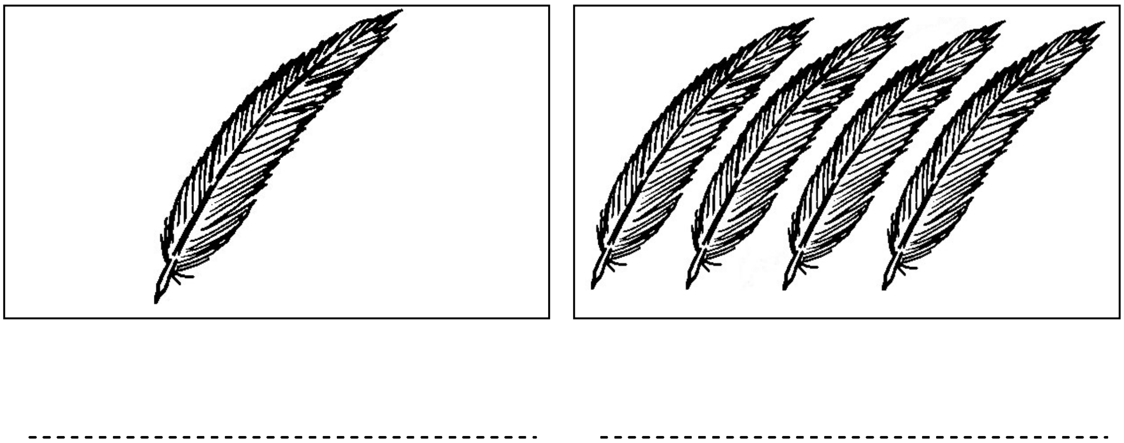

Figure 5.10: Example of a singular and plural spelling trial for Experiment 3c

5.3.1.3 Procedure

The singular and plural word spelling booklet was administered immediately following completion of the nonword spelling booklet (Experiment 3b). The previous booklets were removed prior to commencing Experiment 3c. Children were asked to spell both the singular and plural forms of the word (instructions were provided in the booklet and reiterated verbally or in BSL as necessary).

5.3.2 Results

The first analysis examined the relationship between singular and plural accuracy in Experiment 3c to test whether plural accuracy was dependent on singular accuracy. The second analysis examined the difference between plural accuracy in Experiment 3c (where the correct singular spelling was not provided) and Experiment 3a (where the correct singular spelling was provided) to test whether providing the singular improved plural accuracy selectively for regularly inflected words.

5.3.2.1 The effect of singular accuracy on plural accuracy

For the singular words, deaf children produced more correct spellings than hearing children (deaf mean 72%, *SD* 25; hearing mean 56% *SD* 25); $F(1,58) = 6.20$, $p = 0.016$, partial $\eta^2 = 0.10$. However, deaf and hearing children did not differ significantly on plural spelling (deaf mean 39%, *SD* 25; hearing mean 32%, *SD* 22; $p = 0.3$). For both groups of participants, performance is far worse on plurals than on singulars.

To examine whether plural accuracy was dependent on singular accuracy, the accuracy of producing plurals having spelled the singular correctly was examined separately from when the singular was spelled incorrectly. Figure 5.11 illustrates clear floor effects when the singular was spelled incorrectly–it was very rare for children to produce the correct plural if they spelled the singular incorrectly[14] (mean 2%, *SD* 3).

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[14] Comparing each data point against zero indicated that deaf children's performance differed from zero for irregular plurals only; $F(1,29) = 12.43$, $p = 0.001$, partial $\eta^2 = 0.30$. Hearing children differed from zero on regular and irregular plurals; $F(1,29) = 9.43$, $p = 0.005$, partial $\eta^2 = 0.25$ and

Children produced the correct plural far more frequently having spelled the singular correctly (mean 34%, *SD* 22). The combination of floor effects when the singular was spelled incorrectly and the difference in variance in these two circumstances made it inappropriate to conduct an omnibus analysis on these conditions. Nonetheless, it was possible to examine the effect of regularity and hearing group when the singular was spelled correctly. The main effect of hearing group was not significant ($p = 0.2$) but the main effect of regularity and the interaction between regularity and hearing group were significant; $F(2,116) = 61.74$, $p < 0.001$, partial ŋ^2 = 0.52 and $F(2,116) = 13.18$, $p < 0.001$, partial ŋ^2 = 0.19.

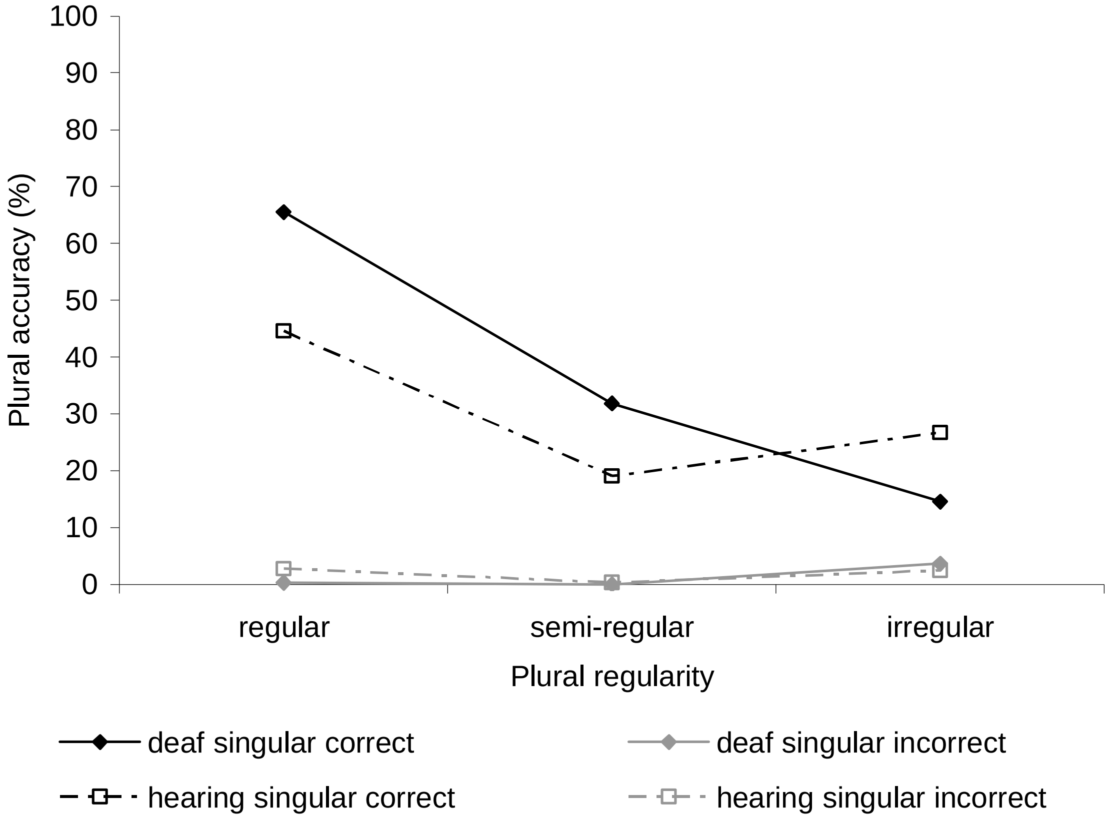

Figure 5.11: Deaf and reading-age matched hearing children's accuracy on plurals, as a function of singular accuracy (correct, incorrect) and plural regularity (irregular, semi-regular, regular) in Experiment 3c

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$F(1,29) = 7.86$, $p = 0.009$, partial ŋ^2 = 0.21 respectively. However, hearing children's performance on regular plurals did not differ from that on irregular plurals ($p = 0.8$).

To further understand the different regularity effects in deaf and hearing children, the effect of regularity when the singular was spelled correctly was examined for each hearing group independently. A Bonferroni-adjusted alpha level of 0.05/3 = 0.0167 was applied. The patterns of performance were very similar to those observed in Experiment 3a (see p116). For deaf children, plural spellings were most accurate for regular plurals, least accurate on irregular plurals and intermediate on semi-regular plurals (regular > semi-regular > irregular) and all differences were significant; regular vs. semi-regular *F*(1,29) = 30.52, *p* < 0.001, partial η^2 = 0.51; semi-regular vs. irregular *F*(1,29) = 10.52, *p* = 0.003, partial η^2 = 0.77; regular vs. irregular *F*(1,20) = 95.66, *p* < 0.001, partial η^2 = 0.77. For hearing children, plural spellings were most accurate on regular plurals, least accurate on semi-regular plurals and intermediate on irregular plurals (regular > irregular > semi-regular). However, the difference between semi-regular and irregular plurals did not quite reach the Bonferroni-adjusted criterion level (*p* = 0.02); regular vs. semi-regular *F*(1,29) = 42.95, *p* < 0.001, partial η^2 = 0.60; regular vs. irregular *F*(1,29) = 18.19, *p* < 0.001, partial η^2 = 0.39. Furthermore, despite the means suggesting numerical differences between deaf and hearing children on all levels of regularity (see Figure 5.11), univariate ANOVAs with the between-participants factor of hearing group (deaf, hearing) indicated that differences were significant for regular and irregular plurals; *F*(1,58) = 8.17, *p* = 0.006, partial η^2 = 0.12 and *F*(1,58) = 5.84, *p* = 0.019, partial η^2 = 0.09 but not for semi-regular plurals *F*(1,58) = 2.47, *p* = 0.12, partial η^2 = 0.04. Therefore, having spelled the singular correctly, hearing children produced significantly more correct irregular plural spellings than deaf children (deaf mean 15%, *SD* 18; hearing mean 27%, *SD* 21). However, deaf children produced significantly more correct regular plural spellings than hearing children (deaf mean 65%, *SD* 30; hearing mean 23%, *SD* 27) and there was also a (non-significant) trend for deaf children to be more accurate at spelling semi-regular plurals than hearing children (deaf mean 32%, *SD* 38; hearing mean 19%, *SD* 24).

5.3.2.2 Comparing plural accuracy in Experiment 3c to Experiment 3a

In a second analysis, the results from Experiment 3a (where the correct singular spelling was provided to the child) were compared to those from Experiment 3c (where the singular spelling was not provided, see Figure 5.12). If children understand root morphology then plural accuracy should be higher when the correct singular spelling is provided to child (i.e., Experiment 3a). This is particularly important for regular plurals, where there is no adjustment to the root when forming plurals.

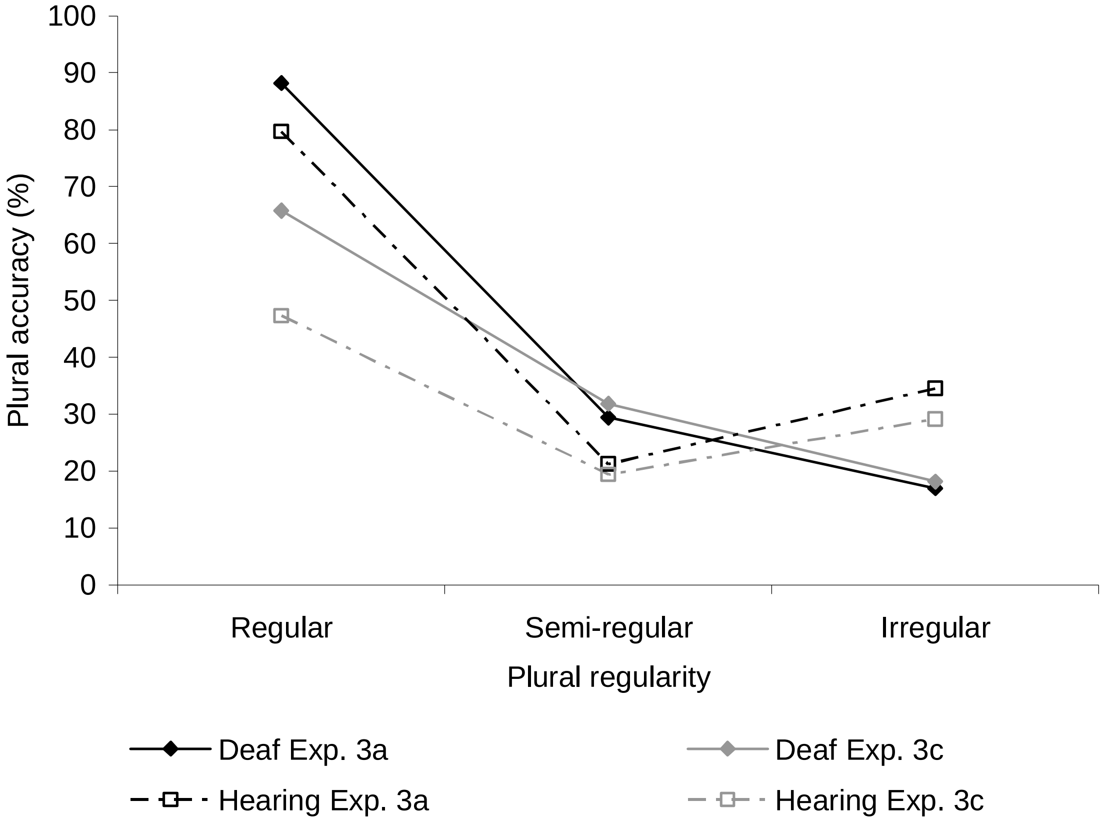

Figure 5.12: The effect of regularity (regular, semi-regular, irregular) on deaf and hearing children's accuracy (percent correct) in Experiments 3a and 3c

A split-plot ANOVA with the within-participants factors of regularity (regular, semi-regular, irregular) and Experiment (3a, 3c) and the between-participants factor of hearing group (deaf, hearing) was conducted on the dependent variable plural accuracy (percent correct). The main effect of hearing group was not significant ($p = 0.5$) indicating that deaf and hearing children's plural accuracy was very similar overall. The main effects of regularity and experiment were both significant; $F(2,116) = 143.94$, $p < 0.001$, partial $\eta^2 = 0.71$ and $F(1,58) = 45.42$, $p < 0.001$, partial $\eta^2 = 0.44$. However, these main effects were mediated by significant two-way interactions. There was a significant interaction between regularity and hearing group, reflecting different patterns of performance across levels of regularity for deaf and hearing children (as discussed on p116 for Experiment 3a and p140 for Experiment 3c); $F(2,116) = 12.19$, $p < 0.001$, partial $\eta^2 = 0.17$. The interaction between experiment and hearing group was significant, indicating that the effect of experiment differed for deaf and hearing children; $F(1,58) = 5.81$, $p = 0.019$, partial $\eta^2 = 0.09$. Furthermore, the significant interaction between regularity and experiment indicated that experiment mediated the effect of regularity; $F(2,116) = 50.42$, $p < 0.001$, partial $\eta^2 = 0.47$. The three-way interaction between regularity, experiment and hearing group was not significant ($p = 0.6$).

To further understand the two-way interactions, follow-up analyses were conducted on each level of regularity independently, using a Bonferroni-adjusted alpha level of 0.05/3 = 0.0167. On irregular plurals, there was only a main effect of hearing group, indicating that hearing children were more accurate than deaf children; $F(1,58) = 7.51$, $p = 0.008$, partial $\eta^2 = 0.12$. Neither the main effect of experiment ($p = 0.2$) nor the interaction with hearing group were significant ($p = 0.03$). For semi-regular plurals, there was neither a main effect of hearing group ($p = 0.2$), experiment ($p = 0.9$) nor an interaction between hearing group and experiment ($p = 0.2$). For regular plurals, there were significant main effects of hearing group and experiment; $F(1,58) = 6.19$, $p = 0.016$, partial $\eta^2 = 0.10$; $F(1,58) = 68.42$, $p < 0.001$, partial $\eta^2 = 0.54$. The interaction between hearing group and experiment was not significant ($p = 0.1$). Therefore, regular spellings were more accurate in Experiment 3a than in Experiment 3c and overall, deaf children (Experiment 3a mean 88%, *SD* 13; Experiment 3c mean 66%, *SD* 30) were more accurate than hearing children (Experiment 3a mean 80%, *SD* 24; Experiment 3c mean 47%, *SD* 29). In contrast, experiment did not influence performance on semi-regular and irregular plurals.

To summarise the results from Experiment 3c, both deaf and hearing children produced more accurate plurals after spelling the singular word correctly. Overall, there was no difference in deaf and hearing children's plural accuracy, although deaf children were better at spelling regular plurals than hearing children and hearing children were better at spelling irregular plurals than deaf children. Deaf and hearing children differed in their patterns of performance across levels of regularity, demonstrating the same orders of difficulty as observed in Experiment 3a (see p116; deaf children regular > semi-regular > irregular, hearing children regular > irregular >= semi-regular). A comparison of the results from Experiment 3c to the same participants' responses to Experiment 3a revealed that regular spellings were more accurate when children were provided with the correct singular spelling (Experiment 3a) than when they had to produce both the singular and plural themselves (Experiment 3c).

5.3.3 Discussion

The aim of Experiment 3c was to establish whether plural accuracy was dependent on singular accuracy. If children use visual-orthographic memory strategies then performance on singular and plural words could be independent. If, on the other hand, children use morphographic rules to produce plurals, then plural accuracy should be dependent on either knowing or being provided with the correct singular spelling.

Both deaf and reading-age matched hearing children were more likely to spell the plural correctly if they had spelled the singular correctly. Likewise, both deaf and hearing children were more accurate at producing plural spellings when they were provided with the correct singular word (Experiment 3a) than when they had to produce both the singular and plural spellings themselves (Experiment 3c). The difference in performance was largely accounted for by responses to regular plurals–there was very little difference in performance on semi-regular and irregular plurals in the two experiments. This suggests that the children used the relationship between singular and plural forms when spelling regular plurals but that performance on semi-regular and irregular plurals was more dependent on having learned the plural forms as separate, exceptional forms (or perhaps the less frequent rules in the case of semi-regular plurals). Nonetheless, it should be noted that the contribution of orthographic strategies to this effect cannot be entirely ruled out, since the singular and plural forms share orthographic features in addition to morphological features. This will be discussed further in the Summary and General Discussion of the present chapter (see p147).

Deaf children produced significantly more correct regular plural spellings than hearing children in Experiment 3c, suggesting that deaf children may make greater use of morphological generalisation than hearing children. However, as observed in Experiment 3a, deaf children produced significantly more errors on irregular plurals than hearing children, indicating that they have difficulty learning the exceptions. This clearly implies that both deaf and hearing children used the relationship between singular and plural words in their spellings. Note that performance was worst on Experiment 3c than Experiment 3a. Because the children produced the same plural spellings in Experiment 3a and 3c, it could have been argued that the children merely referred back to their memory from Experiment 3a rather than generating spellings online. Although the decline in performance between the two tasks does not fully address this argument, it does reduce the likelihood of such an explanation.

Deaf children were more accurate at spelling singular words than hearing children, although the two groups did not differ overall in terms of plural accuracy. Nonetheless, finding the difference on singular words supports the suggestion that deaf children's spelling abilities are less delayed than their reading abilities (Gates & Chase, 1926; Meadow, 1980; Templin, 1948).

5.4 Summary and General Discussion

The evidence from Experiment 3 suggests that deaf children have an awareness of the relationship between morphologically related words and use morphological generalisation productively to assist plural spelling. Experiments 3a and 3c supported the tentative conclusion from Chapter Four that deaf children associated morphologically related words, by revealing that plural spelling was dependent on singular spelling. In Experiment 3c, deaf (and hearing) children's plural accuracy was shown to be dependent on singular accuracy. Furthermore, comparisons between performance on Experiment 3a (where children were provided with the correct singular form) and Experiment 3c (where they had to produce both the singular and plural themselves) revealed that it was the plural spellings of the regular plurals that were more accurate when children (deaf or hearing) were provided with the correct singular. This is consistent with regular plurals being formed by rule from the singular and semi-regular and irregular plurals being memorised using visual-orthographic strategies. For irregular plurals, exception words must be learned as individual items. In the case of semi-regular plurals, the less frequent rules must be learned as exceptions to the dominant root+<s> morphographic rule. However, there remains the possibility that the interdependence of singular and plural spelling was due to orthographic overlap between these words rather than morphology. Whilst this still reflects awareness that these words are related, it could be based on awareness of orthographic relationships not morphology.

In all three experiments deaf children generalised the plural endings at least as much as their reading-age matched hearing counterparts, if not more. Deaf children spelled regular and semi-regular plural nouns at least as accurately as RA matched hearing children in Experiments 3a and 3c, only under-performing on irregular plurals. Furthermore, deaf children's errors on semi-regular and irregular plurals in Experiment 3a were more commonly indicative of morphological generalisation than hearing children's. Similarly, in Experiment 3b, deaf children produced more nonword plurals as expected on the basis of morphographic rules than hearing children (although not as frequently as hearing adults).

The nature of the deaf and hearing children's misspellings of plural nouns in Experiment 3a and unexpected spellings of plural nonwords in Experiment 3b revealed further differences in their spelling strategies. Hearing children's errors were more commonly phonologically plausible than deaf children's. Therefore, hearing children were more likely than deaf children to make use of their knowledge of plural formation in speech and then apply phoneme-grapheme correspondences to produce the spelling of the plural. Furthermore, although deaf and hearing children produced a similar number of singular+other grapheme misspellings/unexpected spellings, the qualitative nature of these responses differed between the groups. The majority of hearing children's singular+other grapheme responses were morphological constructions (i.e., a real English suffix added to the root morpheme) but, crucially, these were usually also phonologically related to the plural. In contrast, the deaf children's were morphologically constructed but were often completely divergent from phonological information. It is also interesting to note that the vast majority of deaf children's singular+other grapheme misspellings were restricted to a very small range of common and productive non-plural suffixes (the suffixes *+ed, +er, +ers, +est, +ing, +ings + 's* accounted for all but two). These findings suggest that deaf children rely more heavily on morphographic strategies than hearing children. However, this knowledge is not always fully developed and there are cases where the child has noticed that certain letter combinations are frequently added to words in certain positions but have not yet learned the meaning associated with these affixes.

In Experiment 3a, analyses of spelling accuracy and rates of over-regularisation as a function of reading-age revealed a U-shaped pattern of development amongst the hearing children but not the deaf. Spelling accuracy increased linearly with reading-age at a very similar rate for both groups of children but they differed in terms of over-regularisations. Hearing children with a low reading-age produced many errors but few over-regularisations, those with a high reading-age produced few errors and few over-regularisations and hearing children with a reading-age of around 8 to 10-years produced a moderate number of errors and these were mainly over-regularisations. This is a similar age to when hearing children have previously been observed making high rates of over-regularisations on past-tense verbs (Nunes, Bryant, & Bindman, 1997a; 1997b). It is interesting to note that the five hearing children that produced the fewest over-regularisations in Experiment 3a (always accounting for under 7% of errors) collectively produced only 17/165 nonword plurals in the form predicted based on morphographic rules and in fact, two of them never did so. Nonetheless, in Experiment 3c three of these children demonstrated that they were reasonably competent at spelling the singular roots (two participants were removed from Experiment 3c. The remaining three participants spelled 43/99 singulars correctly).

The deaf children did not demonstrate the U-shaped pattern of development in their rates of over-regularisation. Deaf children with a low reading-age were already producing very high rates of over-regularisation and this rate did not reduce significantly with reading-age, even though accuracy improved. This is not to say that the deaf children do not show a U-shaped pattern of development, just that we did not observe this pattern in the group of children who participated. This may have been because of the chronological age of the children. It seems highly implausible that deaf children should know that the regular plural is formed by root+<s> from the earliest stages of reading and writing. Even the youngest deaf children that participated in the present task had already received around five-and-a-half years of education and therefore it is likely that they had received specific education on plural formation. Nonetheless, this does not alter the implications of the present study. The important finding here is that deaf children are able to learn morphographic rules and apply them productively in spelling.

Generally then, deaf children demonstrated good understanding of plural formation throughout the experiments in the present chapter. The only exception was that deaf children had poor understanding of irregular plurals (the exceptions to the rules) compared to their RA matched hearing counterparts. This may be due to differences in deaf and hearing children's experience with spoken language. For irregular English plurals the exception is marked similarly in speech as well as spelling. In fact, it could be argued that for irregular plurals the spelling is more likely to be correct if phoneme-grapheme correspondences are used instead of morphographic rules. Plural suffixes are often virtually invisible from lip patterns alone and therefore irregular plurals do not necessarily appear to be unusual in the spoken language experienced by deaf children. Hearing children will have the advantage of greater experience with spoken language (both heard and produced) to flag irregular plurals as unusual and may also be more inclined to use phoneme-grapheme correspondence to provide them with the correct spelling. Finding that hearing children's errors on semi-regular and irregular plurals were more commonly phonetic (e.g., *church-*churchis, goose-*geas*) than deaf children's provides further support for this claim. Nonetheless, it is encouraging to note that only two deaf children (and no hearing child) produced singular+<s> responses for all 33 responses. Most children had learned at least some exceptions to singular+<s> and furthermore, a strategy of simply adding <s> to all responses without morphological awareness was not contaminating results. In addition, considering that there are very few irregular plurals in English, additional education on these exceptions seems feasible (at least for high frequency plurals). Hearing children may also benefit from such intervention, since they too were far from perfect at spelling irregular and semi-regular plurals.

Although Chapter Four suggests that deaf children may have an awareness of morphological relationships and Chapter Five indicates that deaf children are able to apply morphographic rules to spell plural nouns, the question remains whether deaf children are able to use their knowledge about plural formation at the single-word level to aid comprehension at the sentential level. Chapter Six will address this question by examining deaf children's understanding of subject-verb number agreement at the sentence level.

CHAPTER SIX

MORPHOLOGY IN COMPREHENSION

In Experiment Two (Chapter Four), deaf children appeared to demonstrate an awareness of the relationship between morphologically related words (although the possibility that these relationships were based on the combined effects of orthographic and semantic overlap could not be ruled out). Experiment Three (Chapter Five) provided further evidence that deaf children have the ability to use morphology productively. However, whilst the results so far suggest that deaf children have some awareness of inflectional relations at the single-word level, they do not tell us whether they use this knowledge in understanding of morpho-syntactic relationships at the sentence level. To achieve the next level of morphological awareness necessary for full mastery of English literacy, children must apply their knowledge of single-word inflection to the sentence and demonstrate awareness of morpho-syntactic constraints. Continuing the theme of number marking, the present chapter is concerned with understanding subject-verb number agreement. Experiment 4a assesses knowledge of plural formation at the single-word level, using a pencil-and-paper plural noun reading task and the stimuli from Experiment 3a, to ensure that the present participants had morphological awareness at this basic level. The same participants then completed Experiment 4b and 4c. Experiment 4b examines awareness of subject-verb number agreement using a self-paced reading paradigm and Experiment 4c tests explicit manipulation of number markers in a pencil-and-paper agreement judgement task.

6.1 Introduction to morphology and reading comprehension

The focus of reading education typically changes around the age of 9 to 10-years from single word decoding to reading for comprehension (Gaustad & Kelly, 2004). It is interesting to note that this coincides with the reading-age at which deaf children commonly fail to progress. Any problems that a child experiences with processing individual words will be compounded when they attempt to read sentences. Not only must the child deal with decoding multiple words but they must also keep this information available for long enough to integrate meaning within and between sentences. According to capacity theory (Just & Carpenter, 1992), if single-word decoding is laborious then only a limited amount of capacity will remain for sentence processing. However, knowledge of morphology and syntax may ease some of the burden of sentence processing. Indeed, morphological awareness has been found to relate to reading comprehension more than single-word reading (Deacon & Kirby, 2004; Mahony et al., 2000). This may be because morphological agreement is a source of redundancy within sentences and redundancy increases reading speed (Rayner & Pollatsek, 1989) which in turn improves comprehension (Just & Carpenter, 1992; Perfetti, 1992).

Subject-verb number agreement is one example of morphological redundancy. In English, number markers on the subject and verb must match and, therefore, number is marked in more than one place across the sentence. For example, in the sentence *"the **apples grow** on the tree"* the plural marker +<s> on the noun informs us that there is more than one apple, whilst the lack of a suffix on the verb indicates that more than one thing is growing (contrast this with the markers in *"the **apple grows** on the tree"*). Note that the nature of the marking on the noun and verb are opposite–the suffix +<s> marks a plural noun but a singular verb. Attending to the presence of the suffix +<s> is not sufficient, readers must also attend to whether it is attached to a verb or a noun to understand its function (and therefore noun+<s> and verb+<s> are understood as different suffixes). When markers on the subject and verb contradict, number marking of the sentence is ambiguous. For example, the sentences *“the **apples grows** on the tree”* or *“the **apple grow** on the tree”* are ambiguous as to whether there are one or several apples growing. To reconcile the problem, we must choose to ignore one of the number markers. Previous research has shown that mature readers slow down when they read sentences that contain disagreeing number markers. In fact, in self-paced reading tasks, increased reading times are observed not only on the verb where the anomaly is initially apparent but also on the word immediately after the verb (Deevy, 2000; Pearlmutter, Garnsey, & Bock, 1999). These spill-over effects demonstrate that, although mature readers recognise the anomaly immediately, they continue processing syntax in the background while beginning to read the next word. If children have not developed an awareness of subject-verb number marking, one would not expect them to slow down following an anomaly.

The effect of subject-verb number agreement described above is a grammatical effect quite different from semantic or plausibility anomaly. For example, it is still possible to understand the implausible sentence *“the car smiles at her mother”*, even though we know that cars do not smile. There is evidence from eye-tracking studies that semantic anomalies also increase reading times in mature readers. When the anomaly is severe, longer total gaze durations are observed on the anomalous word and the likelihood of regressing (looking back to the anomaly) increases. However, the effect becomes increasingly delayed as the degree of the semantic anomaly reduces–relatively minor anomalies affect regressions and total gaze durations but not initial fixations (Rayner, Warren, Juhasz, & Liversedge, 2004). De Vincenzi (2003) used a self-paced reading technique to distinguish semantic anomaly from subject-verb agreement effects in Italian. Mature readers demonstrated subject-verb agreement effects on the anomaly and the word immediately afterwards, whereas reading times for semantic anomalies did not increase until a later point (affecting reading times two words after the anomaly but not on the anomaly itself).

Understanding number marking on noun and verb is clearly a prerequisite to understanding subject-verb number agreement. Nonetheless, it does not necessarily follow that a child with understanding of number marking at the single-word level will have an awareness of subject-verb number agreement, since this is a more advanced level of morphological awareness (as discussed in Chapter Two). To put this another way, noticing that *cat* is related to *cats* (necessary for plural formation) is quite different to noticing that *cats* is related to *play* (and *cat* to *plays*). Thus, at the sentence level, inflectional morphology extends beyond the lexicon to the syntactic system. Hearing children demonstrate understanding of agreement in speech from around 3 to 5-years-old (Keeney & Wolfe, 1972) and since the rules for number agreement are the same in speech and spelling, provided that hearing children have knowledge of number at the single-word level, they should be able to apply pre-existing knowledge of subject-verb agreement to reading. However, deaf children probably will not have acquired knowledge of agreement from speech.

Previous research has shown that deaf children have a particular difficulty with syntactic processing. For example, Quigley conducted two large scale research programmes during the 1970s in which he examined several hundred deaf children's knowledge of various syntactic structures. This research culminated in the design and norming of the Test of Syntactic Abilities (see Quigley & King, 1980 for a review). Although deaf children (10 to 18-years-old from USA, Canada and Australia) and hearing children (8 to 10-years-old) demonstrated the same pattern of difficulty across different syntactic structures, deaf children were substantially delayed–18-year-old deaf children performed significantly worst than 8-year-old hearing children on every type of syntactic structure (see Quigley & King, 1980). Furthermore, deaf children's performance on the Test of Syntactic Abilities correlates well with reading-age (Waters & Doehring, 1990).

Evidence from Hebrew and Italian speaking deaf populations suggests that the syntactic errors that are made by the deaf are largely inflectional in nature and further suggest that agreement may pose a particular problem. For example, Tur-Kaspa and Dromi (2001) demonstrated that Hebrew-speaking children with hearing-impairments (severe-profound hearing loss) made more grammatical errors, particularly in their written language, than children with normal hearing. These errors most commonly took the form of omissions of obligatory morphological markers. The second most common error was failure to obey rules of agreement (subject-verb and noun-adjective), which affected around 22% of written clauses. Volterra and Bates (1989) conducted a detailed case study of a 32-year-old deaf Italian who was a native signer and highly competent in written and spoken language. She demonstrated excellent lexical abilities and used sentences that were of equal syntactic complexity to those used by hearing adults with a postgraduate education. Nonetheless, this participant also demonstrated a particular difficulty with grammatical morphology, which most commonly manifested itself as omissions or substitutions of free function words and long distance agreement errors. Fabbretti, Volterra and Pontecorvo (1998) demonstrated a similar pattern of errors in a larger sample of Italian deaf adults. However, agreement is more complex in both Hebrew and Italian (where verbs must be marked for number, gender and tense) than in English (where verbs are marked for number and tense only). No research to date has explicitly examined deaf children's knowledge of agreement in English.

Experiment Four therefore examined subject-verb number agreement in reading for comprehension. Experiment 4a assessed deaf and hearing children's knowledge of plurals in a plural noun reading task (with the stimuli from Experiment 3a), to ensure that the present participants have this basic understanding of morphology at the single-word level. Experiment 4b compared the effects of an agreement anomaly to plausibility anomaly using a self-paced reading paradigm. Hearing adults, deaf adolescents and reading-age matched hearing children read sentences containing agreeing or disagreeing subject-verb number markers and plausible or implausible subject-verb pairs. The comparison between plausible and implausible sentences provides information about the effect of semantic anomaly, whereas the comparison between agreeing and disagreeing sentences provides information about morpho-syntactic anomaly. If these effects differ, then the effect of morpho-syntactic anomaly is not simply due to semantic anomaly.

Hearing adults should slow down following an agreement anomaly and this effect should be distinguishable from the plausibility effect. The majority of research into the effect of semantic anomaly comes from eye-tracking studies. Although non-cumulative self-paced reading results typically mirror observations from eye-tracking (Ferreira & Clifton, 1986; Ferreira & Henderson, 1990; Just, Carpenter, & Woolley, 1982; Pearlmutter et al., 1999), the specific nature of semantic anomaly effects may make the differences less visible in the self-paced reading paradigm. In Experiment 4b, the self-paced reading paradigm does not allow regressions and therefore, since semantic anomaly effects are typically observed in regressions and total gaze durations (rather than initial gaze durations), the effects may be weaker in this paradigm. Nonetheless, plausibility anomaly offers an adequate control to test whether agreement anomaly influences reading times in a manner that is distinct from semantics.

If deaf and hearing children have an awareness of agreement, then they too should demonstrate increased reading times on sentences containing disagreeing subject-verb number markers in Experiment 4b. However, reading times reflect the difficulty experienced processing text and decrease with reading proficiency (Rayner, 1998 reviews). Child participants can be expected to read more slowly. Therefore, the agreement effect may be observed over a different time course. Hearing adults are able to process multiple words concurrently and demonstrate spill-over effects (the agreement effect is observed on the anomaly and the word afterwards). In contrast, children may read in a more word-by-word manner, which might reduce spill-over effects (i.e., the effect may be observed on the anomaly only). If children are not aware of subject-verb number agreement, then reading times will not increase on sentences containing disagreeing subject-verb number markers. If the deaf and hearing children are well matched on the basis of reading-age, then their raw reading times should be about equal and differences in the time courses of the agreement effect will not be due to reading proficiency per se. Such differences would have to be related to the integration of the morpho-syntactic information provided in the verbs' number marking.

In contrast to the implicit measure of agreement in the self-paced reading experiment in Experiment 4b, Experiment 4c investigated participants' explicit knowledge of subject-verb number marking. Participants were asked to explicitly state whether there were errors in sentences containing agreeing or disagreeing number markers. If they thought that a sentence contained an error, they were asked to correct the mistake. Accurate performance required them to explicitly state that sentences containing disagreeing number markers were incorrect and further, required them to explicitly manipulate number markers on subject and/or verb in order to correct the mistake.

Developmentally, implicit knowledge often precedes explicit knowledge (e.g., Critten, Pine, & Steffler, 2007). Therefore, it is possible that participants with partial understanding of morpho-syntax would demonstrate implicit awareness of agreement in the self-paced reading task (Experiment 4b) but will not have explicit understanding of the source of the error, or the ability to correct the error in the agreement judgement task (Experiment 4c). Meanwhile, evidence from second language acquisition suggests a contrast between these two experiments which may be of particular relevance to the deaf children (since the present sample were primarily BSL users and therefore could be considered to be analogous to ESL hearing adults). Jiang (2004) demonstrated that native Chinese speakers (a language which does not have subject-verb number agreement) had explicit understanding of English subject-verb agreement in a written judgement task but did not demonstrate increased reading times for sentences containing disagreeing subject-verb number markers in a word-by-word self-paced reading task. Similarly, ERP studies have shown that bilingual L2 English-speakers often fail to show components of syntactic anomaly effects (Hahne, 2001; Hahne & Friederici, 1999; Ojima, Nakata, & Kakigi, 2005; Weber-Fox & Neville, 1996), even though they are sometimes better at noticing agreement anomalies in explicit judgement tasks (Ojima et al., 2005). In contrast, semantic anomalies still elicit effects in the ERP signal for bilingual adults (Ojima et al., 2005; Weber-Fox & Neville, 1996; Weber-Fox & Neville, 2001). Thus, explicit knowledge of subject-verb number agreement rules does not necessarily lead L2 English-speaking adults to use this information in reading comprehension.

6.2 Experiment 4a: Plural noun reading

Knowledge of plural formation at the single-word level is a prerequisite to understanding subject-verb number agreement. To check that participants had this level of morphological awareness, Experiment 4a assessed plural noun reading.

6.2.1 Method

Prior to completing the self-paced reading task, the 19 deaf and hearing children who participated in Experiments 4b and 4c completed a paper-and-pencil plural noun reading task based on the stimuli from Experiment 3a. Any participants who were also involved in Experiment 3 had completed the spelling tasks at least six months previously.

6.2.1.1 Participants

Deaf participants

All 19 deaf children (14 male) were profoundly deaf and had been deaf since before they were 3-years-old. They had a mean BEA of 109dB (range 93-120dB), a mean reading-age[1] (RA) of 8;0 years (range 6;4–>11) and a mean chronological age (CA) of 13;9 years (range 11;9–16;3). All but one of the children attended a Secondary School located on a campus comprising of Primary, Secondary and Post-16 specialist day and residential provision for deaf children. These children were educated using BSL and English. The remaining deaf child attended a large campus-based mainstream Secondary School, spending at least one day a week within a specialist Hearing Impairment Unit where they were taught by a Teacher of the Deaf using BSL or Sign Supported English (an MCE approach, see Chapter Two). For the remainder of the week this child attended mainstream classes with the support of a signing Teaching Assistant.

The parents of participating children were asked to complete a short questionnaire detailing their own hearing status and communication with their child at home. Four parents did not complete this part of the consent form. All of the remaining parents reported communicating with their child using BSL or a combination of BSL and English. Four of the children had two deaf parents. One child had a mother who was hard of hearing and a hearing father. The remaining children were born to hearing parents. None of the children had any additional special educational needs.

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[1] Reading-ages were measured using the NFER-Nelson Group Reading Test II Form B (Group Reading Test, 1997) which has a lower bound of 6-years and an upper bound of 11-years. One deaf child reached ceiling (>11 years) therefore was matched to a hearing child on the basis of their raw score.

Reading-age matched hearing participants

The 19 reading-age matched hearing children (seven male) had normal hearing and were native, monolingual English speakers. On the consent form, parents confirmed that these children had not been diagnosed with any language, learning or literacy impairments. The hearing children were reading appropriately for their age and were matched on an individual basis to the deaf children by reading-age. They had a mean RA of 8;3 years (range 6;4–>11) and a mean CA of 8;6 years (range 5;11–11;2). Eighteen of the children attended a Junior School in Berkshire and one attended a Primary School in Warwickshire, England.

6.2.1.2 Stimuli and design

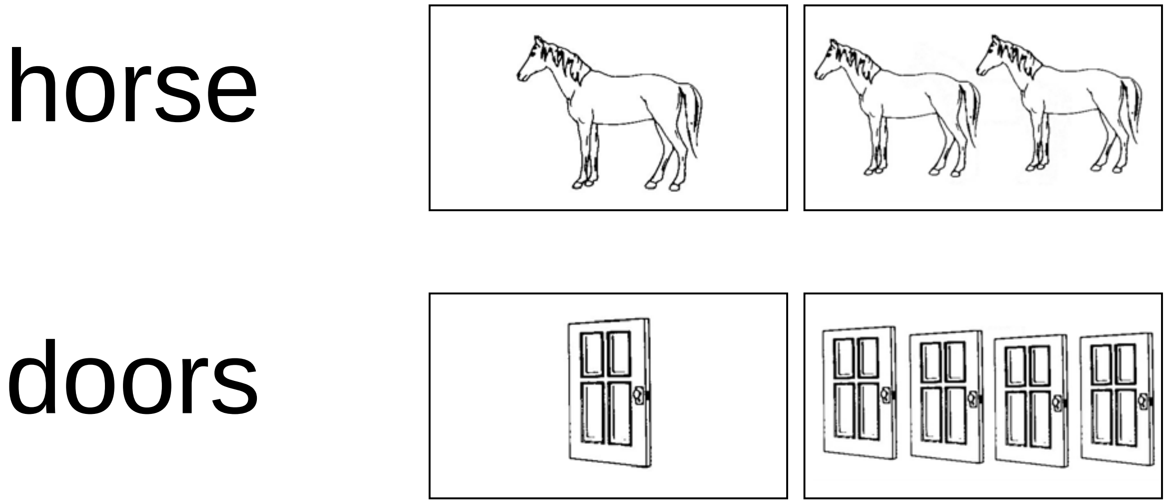

Figure 6.1: Example of the reading plural noun stimuli for a singular and regular plural trial in Experiment 4a

The stimuli were identical to those used in the plural noun spelling task (Experiments 3a and 3c). Children were presented with two booklets containing both singular and plural forms of all 33 nouns (11 regular plurals, 11 semi-regular plurals and 11 irregular plurals). To test recognition knowledge of each word, the word was presented adjacent to two pictures depicting the singular and plural forms (the singular image was always located on the left), the child had to place a tick next to the picture that "*best matched*" the word. Figure 6.1 illustrates a singular and regular plural trial.

6.2.2 Results and discussion

Deaf and hearing children performed very well on the plural noun reading task. On singular nouns, both deaf and hearing children's mean accuracy was 80% (deaf *SD* 12, hearing *SD* 7). On plural nouns, deaf children achieved a mean of 71% correct (*SD* 8) and hearing children achieved 70% correct (*SD* 26). Not only did both groups of participants demonstrate good knowledge of singular and plural nouns, univariate ANOVAs revealed that deaf and hearing children did not differ from one another in their overall performance on singular or plural nouns ($p > 0.9$). Considering performance on regular plurals only (since these will be the focus of Experiments 4b and 4c), deaf and hearing children did not differ in performance on singular (deaf mean 96%, *SD* 13, hearing mean 95%, *SD* 10) or plural nouns (deaf mean 96%, *SD* 8, hearing mean 86%, *SD* 31; all $p > 0.2$). Therefore, both deaf and hearing children demonstrated good knowledge of plural noun formation in general and regular plural noun formation in particular.

6.3 Experiment 4b: Subject-verb agreement in self-paced reading

In Experiment 4b, a self-paced reading task was utilised to measure reading times on sentences containing agreeing and disagreeing subject-verb number markers and on sentences containing plausible and implausible noun and verb combinations. If participants know about subject-verb agreement then reading times should increase when sentences contain disagreeing number markers, as participants notice the grammatical violation. If the agreement effect truly is due to grammatical factors rather than semantics then the effect of semantic anomaly and agreement anomaly should differ. Differences in the magnitude and time course of these effects in hearing adults, deaf children and reading-age matched hearing children will demonstrate differences in each group's integration of morphological and syntactic structure.

6.3.1 Method

6.3.1.1 Participants

After completing the plural noun reading task (Experiment 4a) the same deaf and hearing children also completed the present study. In addition, twenty-five native, monolingual English-speaking undergraduates from the University of Birmingham (two male) participated for partial course credit or £3. Participants had a mean age of 21-years (range 19 to 36-years), normal or corrected to normal vision and did not have any literacy, language or learning impairments.

6.3.1.2 Stimuli and design

Two types of sentences were presented; 28 probing singular-plural agreement and 20 probing semantic plausibility. The anomaly (whether agreement or plausibility) could be detected from the mismatch between the noun and verb. For each of the 28 agreement sentences, four variations were created, fully crossing number markers on the subject and verb (e.g., *the **apples grow** on the tree, the **apple grows** on the tree, the **apples grows** on the tree, the **apple grow** on the tree*). Twenty plausible sentences were designed for the plausibility anomaly condition and matched to twenty implausible sentences. The implausible sentences were semantically anomalous but grammatically correct. Plausible-implausible pairs contained identical nouns but differed from the verb onwards (e.g., *the **car drives** along the road, the **car smiles** at her mother*). Half of the plausibility sentences contained plural nouns and half contained singular nouns. A complete list of agreement and plausibility sentences is provided in Appendix 4b.

All of the sentences were structured [the] [noun] [verb] [3–5 word completion]. The average number of words in the completion was matched between conditions (see Table 6.1, $p > 0.5$). The subject (noun) and verb were always morphographically regular (i.e., root+<s>) and the noun, verb and first two words following the verb (henceforth *completion 1* and *completion 2*) were matched between conditions for word frequency[2] (based on the CELEX Database–Baayen et al., 1993 and the CERV–Stuart et al., 2003) and number of letters (see Table 6.1, independent sample *t* tests, $p > 0.1$).

Twenty native English-speaking hearing adults educated to degree level or above provided plausibility ratings for the agreeing, plausible and implausible sentences. Ratings were provided on a Likert scale of 1 (unlikely to occur in the real world) to 7 (very likely to occur in the real world) and confirmed that the agreeing and plausible sentences were equally plausible (independent samples *t* tests, $p = 0.1$) and significantly more so than the implausible sentences; $t(74) = 39.0$, $p < 0.001$ and $t(38) = 34.4$, $p < 0.001$.

The 28x4 agreement sentences and 20x2 plausibility sentences were divided into four lists of stimuli, each containing 48 sentences. Across the four lists, all four types of agreement sentence occurred once and each plausibility sentence occurred twice but on each individual list, each sentence occurred in only one variation (i.e., only one of the four variations of agreement sentences and only one of the plausible or implausible pairs). Furthermore, within each list the number of trials per condition was controlled such that each list contained 14 agreeing sentences (seven singular, seven plural), 14 disagreeing sentences (seven singular verb, seven plural verb), 10 plausible sentences (five singular, five plural) and 10 implausible (five singular, five plural) sentences. Deaf and hearing

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[2] Frequencies were missing from the CERV (Stuart et al., 2003) for four nouns and three verbs in the agreement sentences, two nouns and two verbs in the plausible sentences and two nouns and two verbs in the implausible sentences. For the remaining words, independent samples *t* tests confirmed that word frequencies in agreement, plausible and implausible sentences did not differ on the noun, verb, completion 1 or completion 2 ($p > 0.1$).

children completed only one list each. Hearing adults completed all four stimulus sets but the data presented in this chapter is from the first list that was presented and is, therefore, fully comparable to the children's data.

Table 6.1: Matching agreement and plausibility sentences in Experiment 4a

Word	Measure	Condition		
		Agreement	Plausible	Implausible
		M (*SD*)	*M* (*SD*)	*M* (*SD*)
Noun	CELEX Frequency	721 (951)	814 (1201)	814 (1201)
	CERV Frequency	70 (96) [a]	83 (132) [b]	84 (131) [c]
	Number of letters	5 (2)	5 (1)	5 (1)
Verb	CELEX Frequency	633 (741)	719 (973)	710 (794)
	CERV Frequency	52 (119) [a]	37 (43) [b]	47 (111) [c]
	Number of letters	5 (1)	5 (1)	5 (1)
C1	CELEX Frequency	314643 (372032)	465633 (447320)	434715 (399625)
	CERV Frequency	3935 (5151)	6919 (7233)	5520 (5689)
	Number of letters	3 (2)	3 (1)	3 (2)
C2	CELEX Frequency	740254 (491914)	684981 (526075)	622901 (538680)
	CERV Frequency	11253 (7933)	10684 (8487)	9871 (8594)
	Number of letters	3 (1)	4 (1)	4 (2)
Plausibility rating		6.4 (1.3)	6.1 (1.5)	1.3 (0.9)
Number of words in completion		3.4 (0.7)	3.3 (0.6)	3.5 (0.8)

Note. C1: Completion 1. C2: Completion 2. CELEX Frequency: Based on 17.9 million token text corpus taken from the CELEX Database (Baayen et al., 1993). CERV Frequency: Based on 268,028 token children's text corpus taken from the Children's Early Reading Vocabulary database (Stuart et al., 2003).

[a] CERV frequencies were missing for four nouns, and three verbs out of the 56 items for the agreement sentences. [b] CERV frequencies were missing for two nouns and three verbs out of the 20 items in the plausible sentences. [c] CERV frequencies were missing for two nouns and two verbs out of the 20 items in the implausible sentences.

6.3.1.3 Procedure

After the plural noun reading task, participants received instructions explaining that they would read sentences on the computer screen but would only be able to see one word at a time. They were told to read carefully because sometimes they would have to choose a picture to match the sentence that they had just read. Participants were told that they should use the spacebar to move through the sentence in their own time but that once they moved on from a word they would not be unable to see that word again. Adults were provided with written instructions which were briefly reiterated verbally. Deaf and hearing children received instructions in written, spoken and signed formats (as appropriate) and also completed four practice trials with experimenter support prior to commencing experimental trials.

An HP Pavilion dv1000 notebook computer ran the experiment using e-prime™ (version 1.1.4.4 SP3, 2002) software to control stimulus presentation and record responses. Background colour was white with text presented in black 16pt Courier New font. Sentences were presented using a non-cumulative word-by-word moving window paradigm, without permitting regressions. Throughout each trial, dashes provided visual representations of any words that were not visible, with one dash replacing each letter in the words (see Figure 6.2). Trial order was randomised and after each picture trial participants viewed a “scoreboard” screen with a score based on the speed and accuracy with which they selected the picture.

Start of trial:	`--- ----- ----- - ---- -- --- ----`
After key press 1:	`the ----- ----- - ---- -- --- ----`
key press 2:	`--- birds ----- - ---- -- --- ----`
key press 3:	`--- ----- build - ---- -- --- ----`
key press 4:	`--- ----- ----- a ---- -- --- ----`
key press 5:	`--- ----- ----- - nest -- --- ----`
key press 6:	`--- ----- ----- - ---- in --- ----`
key press 7:	`--- ----- ----- - ---- -- the ----`
key press 8:	`--- ----- ----- - ---- -- --- tree`

Figure 6.2: Text presented with each button press for “the birds build a nest in the tree” in Experiment 4a

On each list, 16 of the sentences (four agreeing, four disagreeing, four plausible and four implausible) were followed by a picture trial, in which participants had to choose which"*best matched the sentence*". These trials were included to ensure that participants were reading for comprehension. Each picture trial contained two images. For agreement sentences, one image depicted the sentence in its singular form whilst the other depicted the plural (see Figure 6.3A). For the plausibility sentences, one image depicted the plausible sentence and the other the implausible (see Figure 6.3B). The left-right order of images was counterbalanced between trials. Images included black-and-white and colour photographs and drawings.

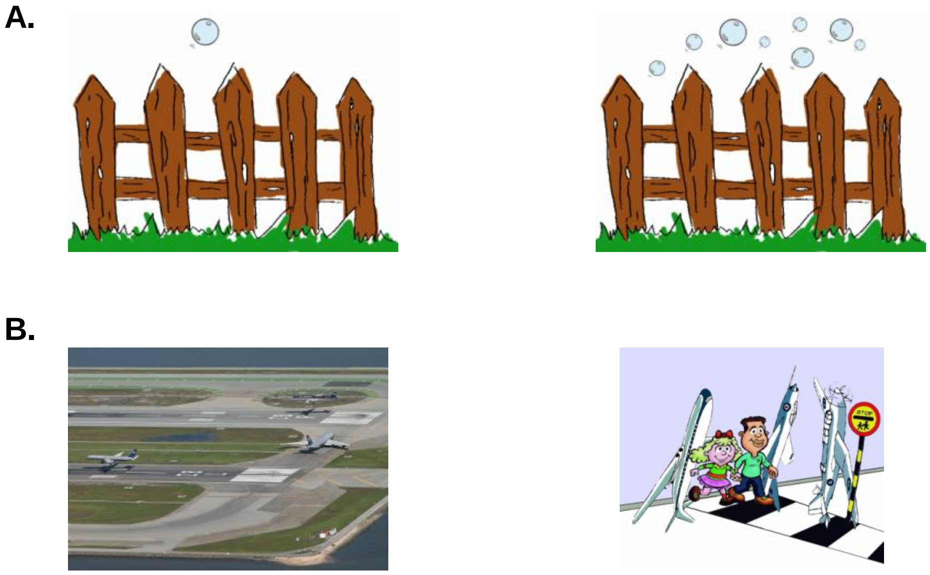

Figure 6.3: Examples of images used in the picture trials in Experiment 4a. A) Agreement sentences "the bubble(s) blow(s) over the fence". B) Plausibility sentences "the planes land at the airport/the planes help the children cross the road"

6.3.2 Results

To ensure that participants were indeed reading for comprehension, the initial analysis assessed performance on the picture trials. The second set of analyses examined self-paced reading times to test whether participants demonstrated awareness of subject-verb number agreement and/or semantic anomaly.

6.3.2.1 Picture trials

To establish whether participants were attending to the sentences, performance on the picture trials was assessed (Table 6.2). Since there is not a correct response for the disagreeing sentences, responses to these sentences were not examined[3]. The analyses focus on the agreeing, plausible and implausible sentences.

Table 6.2: Accuracy on picture trials following agreeing, plausible and implausible sentences in Experiment 4a

Hearing group		Sentence type		
		Agreeing	Plausible	Implausible
Deaf children	*M* (*SD*)	2.16 (1.07)	3.95 (0.23)	3.26 (1.05)
	Range	0–4	3–4	0–4
Hearing children	*M* (*SD*)	2.84 (0.90)	3.84 (0.50)	3.68 (0.82)
	Range	1–4	2–4	1–4
Hearing adults	*M* (*SD*)	3.56 (0.51)	4.00 (0.00)	4.00 (0.00)
	Range	3–4	4–4	4–4

A split-plot ANOVA with the within-participants factor of picture trial (agreeing, plausible, implausible), the between-participants factor of hearing group (hearing adults, hearing children, deaf children) and the dependent variable of correct responses (counts) revealed that both the main effects of picture trial and hearing group were significant; $F(2,120) = 51.74$, $p < 0.001$, partial $\eta^2 = 0.46$ and $F(2,60) = 15.64$, $p < 0.001$, partial $\eta^2 = 0.34$. Furthermore, there was a significant interaction between hearing group and picture trial; $F(4,120) = 6.68$, $p < 0.001$, partial $\eta^2 = 0.18$. Univariate ANOVAs were conducted on each type of picture trial separately (using a Bonferroni-adjusted criterion level of $p =$

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[3] Each participant completed two picture trials with a singular noun and plural verb, and two pictures trials with a plural noun and singular verb. Although this is insufficient trials to ascertain statistically whether participants had a preference for the number marker on the noun or the verb in selecting the singular or plural picture, it is still worth looking at the raw data. The hearing adults generally demonstrated a noun preference, with 17/25 selecting the singular picture when the noun was singular and plural when it was plural, 1/25 showed a verb preference and only 7/25 showed no preference. The two groups of child participants did not show such a clear preference for nouns. Amongst the deaf children, 5/19 had a noun preference, 6/19 had a verb preference and 8/19 showed no preference. Amongst the hearing children, 7/19 had a noun preference, 6/19 had a verb preference, 8/19 showed no preference.

0.05/3 = 0.0167), revealing that hearing group (hearing adults, deaf and hearing children) did not effect accuracy on plausible sentence picture trials ($p = 0.2$), which is likely to be due to ceiling effects. However, the effect of hearing group was significant on agreeing and implausible picture trials; $F(2,60) = 15.57$, $p < 0.001$, partial $\eta^2 = 0.34$ and $F(2,60) = 5.53$, $p = 0.006$, partial $\eta^2 = 0.16$.

Follow-up tests on agreeing and implausible picture trials examined which groups differed from one another (applying a Bonferroni-adjusted criterion level of 0.05/3 = 0.0167). Deaf and hearing children did not differ significantly on either agreeing ($p = 0.04$) or implausible ($p = 0.2$). However, hearing adults produced significantly more correct responses than deaf children on both agreeing and implausible picture trials; $F(1,42) = 33.40$, $p < 0.001$, partial $\eta^2 = 0.44$ and $F(1,42) = 12.51$, $p = 0.001$, partial $\eta^2 = 0.23$. Furthermore, although the difference did not reach significance for implausible sentences ($p = 0.06$), hearing adults were more accurate than hearing children on agreeing sentences; $F(1,42) = 11.30$, $p = 0.002$, partial $\eta^2 = 0.21$. Thus, while hearing adults produced more correct responses to the picture trials than deaf or hearing children (particularly on agreeing and implausible sentences), deaf and RA matched hearing children did not differ in terms of accuracy on the picture trials. This confirms that the deaf and hearing children were well matched but that the hearing adults were better readers than either group of children. It is interesting to note that both groups of children performed worse on the sentences that demanded a grammatically based distinction (i.e., the agreeing sentences) than those based purely on the semantics of the sentence (i.e., plausible and implausible sentences, see Table 6.2).

Comparisons against chance revealed that deaf and hearing children's performance on plausible and implausible picture trials were significantly better than chance; deaf $F(1,36) = 1369.00$, $p < 0.001$, partial $\eta^2 = 0.97$; $F(1,36) = 27.72$, $p < 0.001$, partial $\eta^2 =$

0.44; hearing $F(1,36) = 2578.81$, $p < 0.001$, partial $\eta^2 = 0.99$; $F(1,36) = 912.84$, $p < 0.001$, partial $\eta^2 = 0.96$. However, deaf children's accuracy did not differ from chance for agreeing sentences ($p > 0.5$). Hearing children's accuracy on agreeing sentences was significantly greater than chance; $F(1,36) = 552.00$, $p < 0.001$, partial $\eta^2 = 0.94$. The results from the plausible and implausible picture trials clearly indicate that the participants were attending to and comprehending the sentences. However, the findings for the agreeing sentences suggest that the deaf children had difficulty recognising and/or fully processing the number markers in the sentences.

6.3.2.2 Reading times

The first reading time analysis examined the effect of hearing group on raw reading times in order to compare the reading speed of the different participant groups. Because this analysis indicated large differences in the reading times of adults compared to children, the second reading time analysis was conducted on z-scores of raw reading times and examined the influence of hearing group on the plausibility and agreement effects.

Z-scores of reading times (ms) were calculated for each participant (and therefore independently for each group), on each word. Trials with z-scores greater than three (i.e., 3*SD*s from the mean) on the verb, completion 1 or completion 2 were considered to be outliers and were removed from the analyses. Since the anomaly could not be recognised until the verb, analyses focus on the verb, completion 1 and completion 2 but the noun (subject) is included in figures for illustrative purposes.

Having removed the outliers, a split-plot ANOVA was conducted with raw reading times on normal sentences as the dependent variable (i.e., the mean reading times on the verb, completion 1 and completion 2 on agreeing and plausible sentences combined). The main effect of hearing group was significant; $F(2,60) = 9.40$, $p < 0.001$, partial $\eta^2 = 0.24$. Tukey HSD post hoc tests revealed that the reading times of deaf (mean 668.94 ms, *SD*

234.32) and hearing (mean 733.45 ms, *SD* 251.83) children did not differ significantly (p = 0.6). However, hearing adults (mean 481.38 ms, *SD* 115.70) read significantly faster than deaf or hearing children (p = 0.018 and p = 0.001). This analysis is presented word-by-word in Appendix 4b.

Because of the differences in raw reading times between the child participants and the hearing adults, z-scores of reading times were recalculated for each participant (and therefore independently for each group), on each word (having removed the outliers). Z-score differences were then calculated. In the agreement condition, each participant's mean z-score on disagreeing sentences was subtracted from their mean z-score on agreeing sentences. In the plausibility condition, each participant's mean z-score on implausible sentences was subtracted from their mean on plausible sentences. The remaining analyses were conducted on these z-score differences on each word.

A split-plot ANOVA with the within-participants factors anomaly (agreement and plausibility) and word (verb, completion 1 and completion 2) and the between-participants factor of hearing group (hearing adults, deaf and hearing children) revealed no significant main effects on z-score differences (hearing group p = 0.2, anomaly p = 0.7, word p = 0.09). Furthermore, the interaction between hearing group and anomaly was not significant (p = 0.2). However, the two-way interactions between word and hearing group and between word and anomaly were significant; $F(4,120) = 5.65$, $p = 0.001$, partial $\eta^2 = 0.16$ and $F(2,120) = 3.20$, $p = 0.050$, partial $\eta^2 = 0.05$. Moreover, the three-way interaction between word, anomaly and hearing group was significant; $F(4,120) = 2.54$, $p = 0.050$, partial $\eta^2 = 0.08$. This three-way interaction justifies separate analyses on each anomaly condition, applying a Bonferroni-adjusted criterion level of 0.05/2 = 0.025.

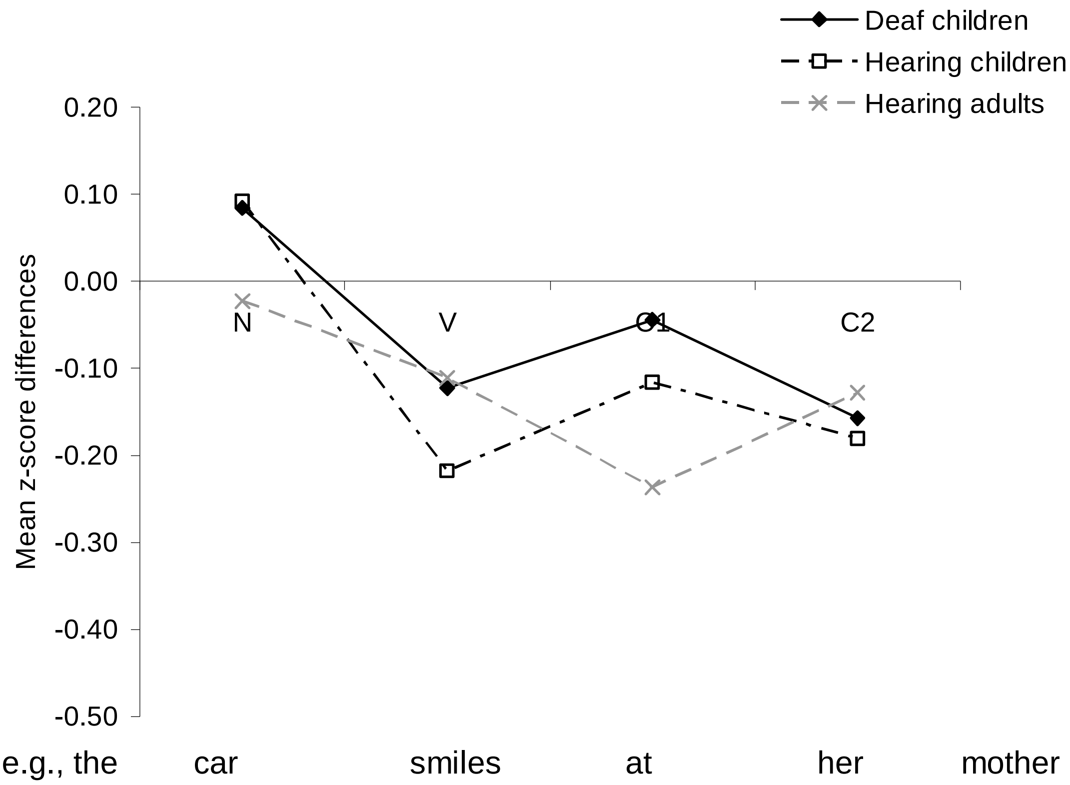


Figure 6.4: Z-score differences on plausibility sentences (i.e., plausible – implausible) in Experiment 4a

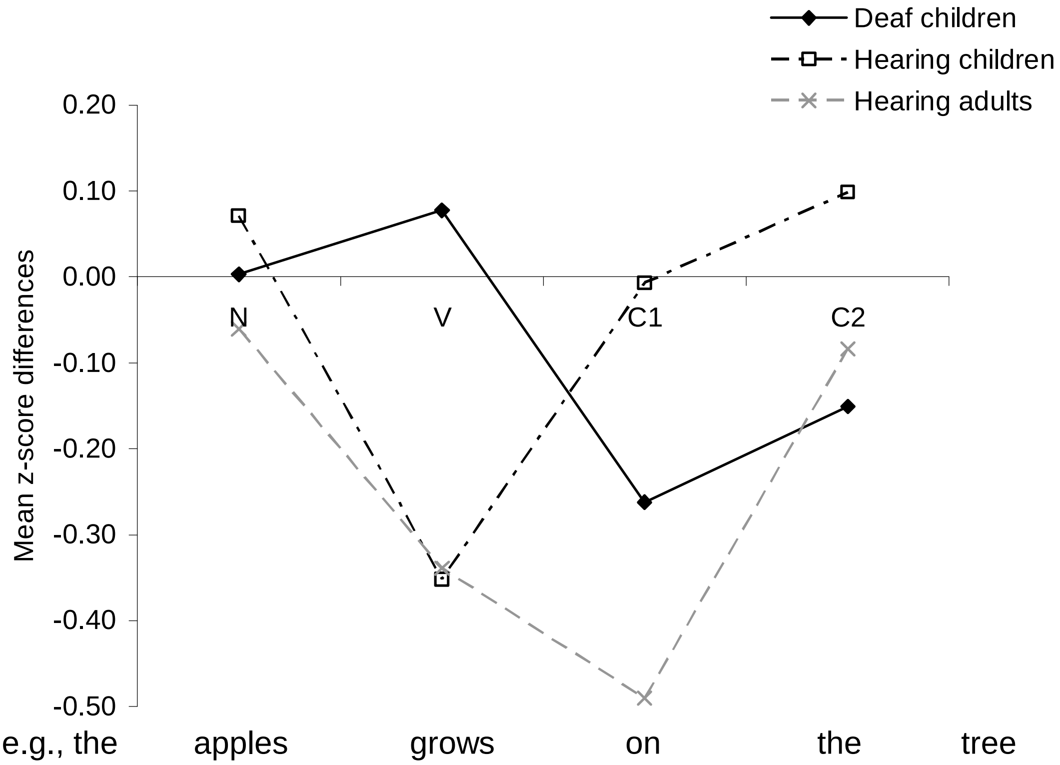


Figure 6.5: Z-score differences on agreement sentences (i.e., agreeing – disagreeing) in Experiment 4a

Plausibility effects

Figure *6.4* illustrates the mean z-score differences for hearing adults, hearing children and deaf children. Examining the plausibility anomaly condition first, a split-plot ANOVA with the within-participants factor of word (verb, completion 1 and completion 2) and the between-participants factor of hearing group (hearing adults, hearing children and deaf children) revealed that neither the main effects of word or hearing group, nor the interaction between word and hearing group were significant ($p > 0.3$). This suggests that the effect of plausibility was minimal on all words, for all participants.

To establish whether any of the participant groups slowed down significantly on any word, each participant groups' z-score differences on each word were compared to zero (using a Bonferroni-adjusted criterion of 0.05/3 = 0.0167). These analyses revealed that deaf children did not slow significantly on any of the words ($p > 0.13$). The difference between hearing children's z-score differences and zero indicated a non-significant trend towards slowing down on the verb and completion 2; $F(1,36) = 3.25$, $p = 0.08$, partial ŋ^2 = 0.08 and $F(1,36) = 3.68$, $p = 0.06$, partial ŋ^2 = 0.09; but were far from significant on completion 1 ($p = 0.3$). Hearing adults did not differ from zero on the verb ($p = 0.2$) but slowed significantly on completion 1 and demonstrated a weak trend on completion 2; $F(1,48) = 12.74$, $p = 0.001$, partial ŋ^2 = 0.21 and $F(1,48) = 3.05$, $p = 0.09$, partial ŋ^2 = 0.06. Thus, only adults slowed significantly for plausibility sentences, where they demonstrated significantly longer reading times on completion 1.

Agreement effects

Turning to the agreement anomaly condition (see Figure 6.5), a split-plot ANOVA on the z-score differences with the within-participants factor of word (verb, completion 1 and completion 2) and the between-participants factor of hearing group (hearing adults, hearing and deaf children) revealed that the main effects of word and hearing group were both significant; *F*(2,120) = 4.68, $p = 0.015$, partial $ŋ^2 = 0.07$ and *F*(2,60) = 3.21, $p = 0.047$, partial $ŋ^2 = 0.10$. However, these main effects were mediated by a significant interaction; *F*(4,120) = 5.77, $p = 0.001$, partial $ŋ^2 = 0.16$.

Follow-up analyses examined the effect of hearing group on each word individually, applying a Bonferroni-adjusted criterion level of 0.05/3 = 0.0167. The main effect of hearing group was significant on the verb and completion 1; *F*(2,60) = 4.80, $p = 0.012$, partial $ŋ^2 = 0.14$ and *F*(2,60) = 6.39, $p = 0.003$, partial $ŋ^2 = 0.18$; but not on completion 2 ($p = 0.2$). Simple effects analyses examined which participant groups differed from one another and, to establish whether participants slowed down significantly, each participant group's z-score differences were compared to zero. A Bonferroni-adjusted criterion level of 0.05/3 = 0.0167 was applied to these analyses. All groups slowed down following the disagreeing number markers but the point where slowing occurred varied between groups. On the verb, hearing children and adults slowed down significantly more than deaf children who, if anything, appeared to speed-up slightly (although z-score differences were not significantly different from zero, $p = 0.3$); *F*(1,36) = 1.75, $p = 0.005$, partial $ŋ^2 = 0.20$ and *F*(1,42) = 8.37, $p = 0.006$, partial $ŋ^2 = 0.17$. Hearing adults and children did not differ from one another ($p = 0.9$) and both groups of hearing participants slowed down significantly on the verb (i.e., z-score differences were significantly below zero); *F*(1,36) = 7.86, $p = 0.008$, partial $ŋ^2 = 0.18$ and *F*(1,36) = 8.92, $p = 0.004$, partial $ŋ^2 = 0.16$. On completion 1, deaf children differed from neither hearing adults or children ($p > 0.07$) but hearing adults slowed significantly more than hearing children; *F*(1,42) = 10.78, $p = 0.002$, partial $ŋ^2 = 0.20$. Comparisons against zero revealed that hearing children did not slow down significantly on completion 1 ($p = 1.0$) but deaf children and hearing adults did; *F*(1,36) = 11.55, $p = 0.002$, partial $ŋ^2 = 0.24$ and *F*(1,36) = 26.93, $p < 0.001$, partial $ŋ^2 = 0.36$. Deaf children's z-score differences were significantly below zero on completion 2; $F(1,36) = 6.15$, $p = 0.018$, partial $\eta^2 = 0.15$; whereas hearing children ($p = 0.3$) and adults ($p = 0.4$) did not slow down significantly. Nonetheless, the main effect of hearing group was not significant on completion 2, indicating that any differences between groups on this word were small. To summarise, hearing adults slowed down on the verb and the following word. Hearing children slowed down only on the verb and returned to baseline by completion 1. Deaf children did not slow down on the verb. Instead, they slowed down later, on completion 1.

6.3.3 Discussion

In Experiment 4b, a self-paced reading task was utilised to compare reading times on sentences containing agreeing and disagreeing subject-verb number markers to sentences containing plausible and implausible noun-verb combinations. Hearing adults were superior readers compared to deaf and hearing children, as demonstrated by faster reading times on normal (agreeing and plausible) sentences and greater accuracy on the picture trials (comprehension test). Deaf and RA matched hearing children were well matched, demonstrating similar reading times (in addition to having demonstrated similar ability to read plural nouns in Experiment 4a), although only hearing children were sensitive to the grammatical number marking of the sentences when they were required to pick a corresponding picture.

Plausibility anomalies had little effect on participants' reading times in a self-paced reading task. Only hearing adults showed significant slowing at any point during these sentences and this occurred on the word following the anomalous verb. This suggests that subject-verb semantic anomaly has little influence on reading times, particularly for less proficient readers. Previous research has found increased rates of regression and gaze durations for severe semantic anomalies using eye-tracking paradigms (e.g., Rayner et al., 2004). However, regressions were not permitted in the present task and, because sentences had to be pictureable to enable comprehension testing in the form of picture trials, the semantic anomaly was relatively minor. Nonetheless, finding that the plausibility effect was largely insignificant suggests that the agreement effect is a syntactic effect rather than due to semantics alone.

In contrast to the null effect of plausibility, the agreement effect was strong for all three groups of participants, although there were time course differences. The results for hearing adults replicated previous findings that used more complex syntactic structures (e.g., Deevy, 2000; Pearlmutter et al., 1999). Hearing adults demonstrated increased reading times on the verb (where the anomaly could first be detected) and the following word, but returned to normal reading times by the word thereafter. Interpreting this finding within the context of their relatively fast reading times suggests that the spill-over effects observed on the word following the verb are the result of hearing adults performing syntactic integration in the background whilst continuing to process the rest of the sentence. ERP studies have shown that both subject-verb number agreement errors and semantic anomalies are recognised very quickly. Subject-verb number agreement errors elicit a left anterior negativity at around 250–500ms post-onset, followed by enhanced late posterior-parietal positivity at around 600ms. These are referred to as the LAN and P600 effects (Coulson, King, & Kutas, 1998; De Vincenzi et al., 2003; Kutas & Hillyard, 1983; Osterhout & Mobley, 1995). Semantic anomalies lead to right central-posterior negativity at around 400ms post-onset, referred to as the N400 effect (De Vincenzi et al., 2003; Kutas & Hillyard, 1983). The present findings add to this research by suggesting that although anomalies may be detected early, integration might take place later, since both the semantic anomaly effect and the subject-verb agreement effect were present on the word after the verb.

Hearing children read more slowly than hearing adults and showed the agreement effect on the verb only, recovering to normal reading times by the word following the verb. This suggests that hearing children were reading in a more word-by-word fashion. Instead of performing syntactic integration whilst simultaneously reading the next word, hearing children did not move on until they had not only accessed the word but had also integrated number marking on the verb.

Deaf children read as slowly as RA matched hearing children but deaf children were slower to show the agreement effect. Instead of slowing down on the verb they slowed on the next word. Hearing children take extra time on the verb to perform syntactic integration whereas deaf children do not do this until the word after the verb. In addition, deaf children's accuracy on agreeing picture trials (where the child was required to choose between pictures differing only in number) was not significantly different from chance. This result was, however, based on only four picture trials per participant. Therefore, caution should be taken in drawing strong conclusions from this result. Nonetheless, this does suggest that deaf children might not fully process grammatical number up to a semantic level. This result also contrasts with their good performance on the plural noun reading task in Experiment 4a. If deaf children indeed have problems fully processing grammatical number up to a semantic level, they seem to have this problem only in sentence comprehension, not when processing individual nouns. Nonetheless, by slowing down at any point in sentences containing disagreeing subject-verb number markers, deaf children did demonstrate sensitivity to agreement and therefore must have been processing the number markers in the sentence on some level.

6.4 Experiment 4c: Subject-verb agreement judgement

Immediately after completing the self-paced reading task (Experiment 4b), deaf and hearing children completed a pencil-and-paper judgement task on the agreement sentences that they had viewed in the self-paced reading task. In addition, a new group of 19 hearing adults completed the same judgement task. The purpose of this task was to test whether participants could use awareness of subject-verb agreement explicitly.

Although deaf and hearing children demonstrated implicit awareness of subject-verb number agreement in Experiment 4b, this will not necessarily transfer to explicit ability to make judgments on the correctness of sentences or enable manipulation of subject-verb number markers to correct the error. Nonetheless, a fully mature awareness of subject-verb agreement requires the presence of these skills.

6.4.1 Method

6.4.1.1 Participants

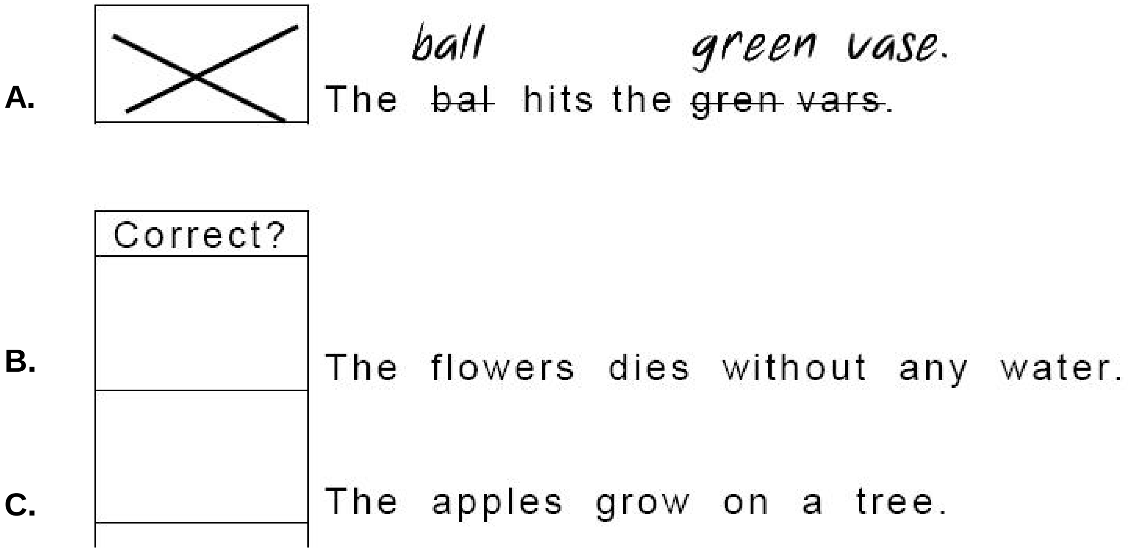
The 19 deaf and 19 hearing children who participated in Experiment 4a and 4b completed the agreement judgement task (Experiment 4c). In addition, 19 hearing adults (six male) made judgements on the same items. The hearing adults were current undergraduates or postgraduates at the University of Birmingham, were monolingual English speakers and had a mean age of 22 years (range 18 to 27).

6.4.1.2 Stimuli and design

The agreement sentences from Experiment 4b were used as stimuli in the agreement judgement task. They were divided into the same four lists, with each list containing 28 sentences (14 containing agreeing subject-verb number markers and 14 containing disagreeing number markers). Participants were assigned to the same stimulus list as in Experiment 4b and therefore at no point in Experiment 4b and 4c were individual participants presented with the same sentence in both its correct and anomalous form.

6.4.1.3 Procedure

The agreement judgement task consisted of a list of sentences with tick boxes located to the left of each sentence. Participants were instructed to read the sentences and decide whether they contained an error. If the sentence was incorrect they were told to put a cross in the box and, if possible, to try and correct the sentence like a teacher would. If the sentence was correct they were told to place a tick in the box. The worksheet included a completed example of an incorrect sentence (illustrated in Figure 6.6A). Figure 6.6B and Figure 6.6C demonstrate a disagreeing and agreeing trial respectively.



A. ☒ The ~~bal~~ hits the ~~gren vars~~.

ball green vase.

Correct?

B. ☐ The flowers dies without any water.

C. ☐ The apples grow on a tree.

Figure 6.6: A) Example of an incorrect sentence that has been corrected as provided to participants and B) a disagreeing and C) an agreeing trial from the agreement judgement task (Experiment 4c)

6.4.2 Results

The first set of analyses examined the accuracy with which hearing adults, deaf and hearing children were able to mark the sentences as correct or incorrect. The second set of analyses examined the changes that participants made to the sentences.

6.4.2.1 Accuracy

In order to compare accuracy on the agreement judgement task, *d'* values were calculated for each participant from counts of ticks and crosses on sentences containing agreeing and disagreeing subject-verb number markers[4]. From these it was clear that hearing adults were always highly sensitive to the agreement anomaly (mean *d'* 3.33, *SD* 0.53, mean bias 0.04); 97% of agreeing sentences were correctly accepted and 98% of disagreeing sentences were correctly rejected. Hearing children were somewhat less sensitive compared to the adults and demonstrated a general bias to accept the sentences as being correct. Nonetheless, hearing children were still very sensitive (mean *d'* 1.57, *SD* 1.01, mean bias -0.60); 90% of agreeing sentences were correctly accepted and 56% of disagreeing sentences were correctly rejected. In contrast, deaf children were not at all sensitive to the agreement anomaly and had a strong bias to produce ticks (mean *d'* -0.01, *SD* 0.69, mean bias -0.75); 73% of agreeing sentences were correctly accepted but only 27% of disagreeing sentences were correctly rejected. Furthermore, only 6/19 deaf children achieved *d'* values greater than zero, whereas only one hearing child (and no hearing adults) had such low sensitivity. Therefore, only a real minority of deaf children could perform this task reliably.

Statistical significance was tested using hierarchical log-linear analysis with the factors hearing group (deaf children, hearing children and adults), sentence type (agreeing, disagreeing) and response (tick, cross). Sensitivity is indexed by the interaction between sentence type and response (i.e., the tendency for the agreement anomaly to modify

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[4] Omissions accounted for 6 of the deaf children's responses to disagreeing sentences as well as 10 of the deaf children's responses to agreeing sentences and 2 of the hearing children's responses to agreeing sentences (none of the hearing adults' responses were omissions). Because of how *d'* and log-linear analyses are calculated, these omissions are simply removed from this analysis.

response). Including all of the participants in this analysis[5] revealed that hearing group had a significant effect on sensitivity; Hearing group*Sentence type*Response $G^2(2) = 295.59$, $p < 0.001$. Follow-up analyses compared each pair of hearing groups, revealing that deaf children had significantly lower sensitivity than hearing children or adults; $G^2(1) = 60.53$, $p < 0.001$ and $G^2(1) = 295.30$, $p < 0.001$. Furthermore, hearing adults had significantly greater sensitivity than hearing children; $G^2(1) = 88.48$, $p < 0.001$.

6.4.2.2 Changes to disagreeing sentences

A correct response to a disagreeing sentence would be to mark it as incorrect and then to change the sentence to correct the disagreeing subject-verb number markers, this represents explicit awareness of agreement. Differences in the nature of these changes may provide further evidence of differences between participant groups. If participants are unable to make any changes to the sentence or make an unexpected change (such as changing the completion) this indicates a lack of explicit awareness of agreement (although this may represent some level of implicit awareness, since they are aware that there is an error in the sentence but could not correct the error). Accordingly, accurate responses to sentences containing disagreeing subject-verb number markers were recategorised as agreeing present tense, other change and no change. *Agreeing present tense* responses involved a deletion or addition of the suffix +<s> to the noun/verb to produce the grammatically correct singular or plural form of the sentence. Responses were categorised as *Other change* when an alteration had been made that was not consistent with the

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[5] Repeating the analyses having removed the participants with *d'* =< 0 (leaving 6/19 deaf children, 18/19 hearing children and 25/25 hearing adults) revealed the same pattern of results; Hearing group*Sentence type*Response $G^2(2) = 117.26$, $p < 0.001$. Follow-up analyses comparing each pair of hearing groups once again revealed that deaf children had significantly lower sensitivity than hearing children or adults; $G^2(1) = 10.51$, $p = 0.001$ and $G^2(1) = 92.56$, $p < 0.001$. Furthermore, hearing adults had significantly greater sensitivity to agreement than hearing children; $G^2(1) = 65.62$, $p < 0.001$. Therefore, even the minority of deaf children who were able to perform the agreement judgement task reliably were less sensitive to agreement than the hearing children.

intended singular or plural sentence. These included changes that were grammatical (such as changing the tense of the sentence) and ungrammatical (such as changing a different part of the sentence). *No change* responses were responses for which the participant had managed to accurately mark the sentence as incorrect but had not attempted to change the sentence in any way. Counts of each hearing group's responses were analysed using nonparametric tests (chi-square) because, as established in the accuracy analysis, the participants differed in the number of accurate responses to disagreeing sentences (individual data is provided for the deaf participants in Appendix 4c).

Table 6.3: Changes made to disagreeing sentences in Experiment 4c by hearing adults and deaf and hearing children

Change to sentence	Hearing group		
	Deaf children	Hearing children	Hearing adults
Didn't try to correct	41/71 (58%)	35/149 (23%)	0/260 (0%)
Agreeing present tense	20/71 (28%)	75/149 (50%)	239/260 (92%)
Changed noun	5	6	71
Changed verb	15	69	168
Changed other	10/71 (14%)	39/149 (26%)	21/260 (8%)

Table 6.3 illustrates the rates of each type of correction to disagreeing sentences. The most apparent difference between hearing groups was on no change responses, which accounted for significantly more of the deaf children's responses than hearing children's or adults'; $\chi^2(1, N = 220) = 24.96$, $p < 0.001$ and $\chi^2(1, N = 331) = 171.37$, $p < 0.001$. Hearing children produced more no change responses than hearing adults; $\chi^2(1, N = 409) = 66.79$, $p < 0.001$. Responses categorised as agreeing present tense were also very common, particularly for the hearing adults. Hearing adults produced significantly more of these responses than hearing or deaf children; $\chi^2(1, N = 409) = 91.87$, $p < 0.001$ and $\chi^2(1, N = 331) = 133.18$, $p < 0.001$. Deaf children produced even fewer agreeing present tense responses than hearing children; $\chi^2(1, N = 220) = 9.63$, $p = 0.002$. Finally, other change

responses[6] accounted for the remaining responses. Deaf children did not differ from hearing adults in the proportion of their responses that were of this type (p = 0.12) but hearing children produced significantly more other change responses than deaf children or hearing adults; $\chi^2(1, N = 220) = 4.06$, $p = 0.044$ and $\chi^2(1, N = 409) = 24.78$, $p < 0.001$.

To gain further insight into the nature of the changes that were made, the agreeing present tense responses were subcategorised according to whether the noun or the verb was altered (see Table 6.3). This revealed that all three groups of participants typically changed the verb rather than the noun. The deaf children and hearing adults did not differ in the proportion of their responses that changed the verb (p = 0.7). However, the hearing children changed the verb more frequently than hearing adults or deaf children; $\chi^2(1, N = 314) = 14.53$, $p < 0.001$ and Fisher's Exact Test[7] $p = 0.05$.

6.4.3 Discussion

In Experiment 4c, a pencil-and-paper judgement task was used to assess knowledge of subject-verb number agreement. Hearing adults were able to perform these judgements without difficulty and typically corrected disagreeing subject-verb number markers on the verb to produce a grammatically correct sentence that was in the same tense as the original. Therefore, hearing adults made explicit use of their awareness of subject-verb number agreement. Hearing children were less successful than hearing adults at noticing when a sentence contained disagreeing subject-verb number markers but, nonetheless,

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[6] Some of the other change responses made the sentence grammatical, for example, by changing the verb into its past-tense form (e.g., *the nurses tied the bandage in a bow*). Although the resulting sentence is grammatical, the processes involved seem quite different to when the number markers are manipulated and the change categorised as agreeing present tense. Grammatical sentences were formed in 4/10 of the deaf children's other change responses, 27/39 of the hearing children's and 21/21 of the hearing adults' other change responses. Adding these responses to the agreeing present tense sentences did not alter the pattern of results. Hearing adults changed the sentence into a grammatical form more frequently than hearing children, who did so more frequently than deaf children (260/260, 102/149, 24/71); $\chi^2(1, N = 409) = 92.66$, $p < 0.001$ and $\chi^2(1, N = 220) = 23.60$, $p < 0.001$.

[7] At least one cell contained expected values less than five therefore Fisher's Exact Test was used.

demonstrated awareness of agreement. In contrast, deaf children failed to demonstrate an explicit awareness of subject-verb agreement and demonstrated a strong bias towards giving a "yes" response regardless of the accuracy of this response. The deaf children found the agreement judgement task very difficult. Not only were they less successful but they found it hard to understand what was required of them and needed more encouragement to attempt the entire worksheet. Hearing children did not appear to have these problems.

The changes that participants made to sentences containing disagreeing subject-verb number markers that had been accurately marked as incorrect revealed further differences between participants. Very often, deaf children failed to change any part of the sentence, suggesting that even when they were aware that something was wrong, their knowledge of subject-verb agreement was not sufficient to enable them to correct the sentence (or that they could not decide whether to change the noun or the verb). Deaf children failed to change the sentence more frequently than hearing children who, in turn, failed to change the sentence more frequently than hearing adults. The difference between hearing children and adults suggests a developmental trend, whereby an implicit understanding of agreement precedes the explicit ability to correct ungrammatical sentences. As previously stated, the most common response by hearing adults was to change the sentence into its singular or plural form. This type of response reflects the most explicit knowledge of agreement, where participants are able to change an ungrammatical sentence into its grammatical form with minimal adjustment. Hearing children produced significantly fewer of these responses than hearing adults and deaf children produced even fewer.

6.5 General Discussion

Experiment Four examined subject-verb number agreement in reading for comprehension. Hearing adults were more advanced readers than deaf and hearing children, as demonstrated by more accurate performance on the comprehension trials of the self-paced reading task (the picture trials) and faster raw reading times on normal (agreeing and plausible) sentences. Hearing adults demonstrated not only implicit but also explicit awareness of subject-verb number agreement, demonstrated by accurate judgement and correction of disagreeing sentence. In the self-paced reading task, hearing adults slowed down on both the verb and the following word of disagreeing sentences, demonstrating that syntactic integration took place whilst simultaneously processing the subsequent word. The agreement effect was distinguished from the effect of plausibility anomaly, which was weaker and caused adults to slow down only on the word following the verb. Hearing adults also demonstrated a preference for changing the number markers on the verb in the agreement judgement task.

Hearing children were less proficient readers than hearing adults but nonetheless demonstrated implicit awareness of agreement as well as some degree of explicit knowledge. In the self-paced reading task (Experiment 4b) hearing children read more slowly and appeared to read in a more word-by-word manner. Agreement effects (i.e., increased reading times on disagreeing sentences) were observed on the verb only, indicating that hearing children had an implicit awareness of agreement but that syntactic integration was completed prior to processing the subsequent word–the agreement anomaly was dealt with prior to moving on. The agreement effect was distinguished from the plausibility effect, since a plausibility anomaly did not result in a significant increase in reading times. In the agreement judgement task (Experiment 4c) hearing children demonstrated some degree of explicit awareness, although this was not as developed as the hearing adults. Hearing children were very accurate at judging agreeing sentences to be correct but were far less accurate at judging disagreeing sentences to be incorrect, although this was still above chance. Hearing children failed to attempt to correct disagreeing sentences far more frequently than hearing adults and even when they did, hearing children changed the number markers on the noun and verb less frequently than adults. This suggests that although hearing children were often able to see that subject-verb number markers disagreed, they were not always able to manipulate these markers.

Deaf children were matched to hearing children in terms of reading ability. They were initially matched on the basis of reading-age but also demonstrated similar performance on a test of plural noun knowledge (Experiment 4a) and read at a similar speed (based on raw reading times on normal sentences in Experiment 4b). However, deaf children's knowledge of subject-verb number agreement was less advanced than hearing children's. In the self-paced reading task (Experiment 4b), deaf children did show the agreement effect but this was delayed. Instead of slowing down on the verb, deaf children slowed down on completion 1. Nonetheless, the agreement effect was distinguished from the plausibility anomaly, which did not result in significant increases in reading times, so the agreement effect is not due to slowing caused by the semantic anomaly that the disagreement creates. Although deaf children demonstrated an awareness of subject-verb agreement, syntactic integration was delayed. In the agreement judgement task (Experiment 4c) deaf children's explicit knowledge of agreement was very weak. Accuracy of explicit judgements of agreement were far worst than those made by hearing children or adults and revealed a bias to accept sentences as correct regardless of the number markers. Furthermore, even when deaf children successfully noticed that the disagreeing sentences contained an error, it was very rare for them to be able to make any changes to sentences. Additionally, deaf children's performance on agreeing picture trials in the self-paced reading task (where comprehension was tested by distinguishing between two pictures differing only in number) was not significantly different from chance, suggesting that they might not fully process number marking on a semantic level. However, although this supports the result from the agreement judgement task, caution must be taken in drawing conclusions from this, since it is based on a small number of items (four trials per participant).

Together the results suggest that although deaf children may have implicit awareness of agreement, they did not demonstrate explicit understanding. This finding is consistent with previous research that has shown that deaf adolescents have a general impairment in syntax and grammar in tasks that explicitly require participants to demonstrate this knowledge (e.g., Quigley & King, 1980). Furthermore, the present findings add to evidence from samples of deaf adults' written prose in Hebrew and Italian which has similarly indicated a particular difficulty with agreement (Fabbretti et al., 1998; Tur-Kaspa & Dromi, 2001; Volterra & Bates, 1989).

Finding that the deaf children could not explicitly manipulate the number markers on subject and verb to correct disagreeing sentences is particularly compelling given that the same children were able to accurately identify singular and plural nouns. Despite understanding plural formation at the single-word level, these children apparently did not have an explicit understanding of the syntactic role that these number markers play at the level of the sentence. Knowledge of number marking on the verb was not assessed separately and it has been suggested that deaf children's spelling of third person singular verb inflections is worst than their knowledge of plural noun formation (Burman, 2004). Therefore, one source of the difficulty with subject-verb agreement might be number marking on the verb. Deaf children's difficulty identifying the picture with the right grammatical number in the self-paced reading study, however, suggests that this might not be the only source (if the problem was purely due to lack awareness of verb number marking, the correct picture could have been selected simply by using the noun marker alone).

The reasons why the deaf children demonstrated awareness of subject-verb agreement on the self-paced reading task but not on the agreement judgement task are difficult to ascertain. They also seem to contradict evidence from second language learners who have shown good explicit understanding of agreement rules but weaker implicit effects. For example, components of the agreement effect are commonly missing from ERP responses (Hahne, 2001; Hahne & Friederici, 1999; Ojima et al., 2005; Weber-Fox & Neville, 1996) and are not typically observed in self-paced reading (Jiang, 2004).

Despite some similarities between deaf children and bilingual hearing adults, there are also many contrasts. One important difference is that the deaf children are acquiring English in a more native-like environment–they are engulfed in the language and will not necessarily be explicitly taught the rules of agreement. Therefore, deaf children are more likely to show the developmental progression of implicit knowledge gradually becoming more explicit (by learning about agreement in this way they may never be able to explicitly state the rules of agreement but this is most likely also true of native English-speaking hearing adults). In contrast, it is very likely that bilingual adults will have explicit education on the rules of agreement and it is through first learning these rules that they gradually begin to use agreement more automatically.

There are also differences in the tasks used in Experiment 4b and 4c which may have implications for the expression of awareness of agreement. There are several reasons why the children were more likely to be motivated to read more carefully and to read for comprehension in the self-paced reading task (Experiment 4b) compared to the agreement judgement task (Experiment 4c). Firstly, the children simply seemed more engaged with the computer-based self-paced reading task. Secondly, they needed to comprehend the sentences in order to perform the picture trials in Experiment 4b (the use of scores based on accuracy on these trials seemed to motivate them to perform well). Finally, the self-paced reading paradigm has been shown to slow down the normal reading process (Rayner, 1988). By being forced to attend to each word in the sentence and to read more slowly, perhaps they were more likely to notice the agreement error. In contrast, in the agreement judgement task (Experiment 4c) stating that the sentence was correct was the easy option. If participants said the sentence was incorrect then they had to attempt to correct the sentence. Marking the sentence as correct enabled the child to complete the task more quickly. Even if the deaf children noticed the agreement errors in this task, if they didn't know how to correct the error they might have preferred to say that the sentence was correct. Finally, the example provided for the agreement judgement task did not draw attention to morpho-syntactic errors. Instead, the example illustrated a spelling error that had been corrected (see Figure 6.6A). This may have led the deaf children to simply look for words that were spelled incorrectly rather than to read the sentences and check the grammar (although this explanation seems unlikely given that only 6 of the changes that deaf children produced were of this type). It is possible that a task which explicitly drew deaf children's attention to agreement anomalies would reveal greater understanding of agreement than was observed in Experiment 4c. Nonetheless, in the real world, when deaf children read back their own writing they do not have their attention explicitly drawn to subject-verb agreement errors in this way and therefore, it is important that they learn to check and correct these errors for themselves. Perhaps education in agreement could help to develop this awareness to a level that would enable deaf children to prevent and correct agreement errors.

To conclude, deaf children demonstrated some awareness of subject-verb agreement in the self-paced reading task. However, reading times on this task also indicated that deaf children were somewhat delayed in performing syntactic integration compared to their reading-age matched hearing peers. Furthermore, deaf children were not able to explicitly manipulate subject-verb number markers in order to correct sentences containing disagreeing markers. Therefore, although the deaf children may have a weak understanding of agreement, this does not appear to be sufficient to assist reading and it seems highly unlikely that deaf children will be able to use this knowledge to correct their own writing.

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

The present thesis examined deaf children's knowledge of inflectional morphology. In English, morphology is a source of regular text-to-meaning relationships, which are visible in the orthography and should therefore be available to the deaf through their experience with text. Morphological awareness is also important in hearing children's literacy acquisition. Although hearing children have the advantage of knowledge of morphology from speech prior to literacy acquisition (Gaustad et al., 2002), morphological rules in the orthography and phonology do not always correspond (as discussed in Chapter Two, Section 2.6.2.1) and therefore hearing children also need to acquire awareness of morphology that is specific to written language. There are several ways in which morphological awareness can aid literacy, which can be described along a continuum of complexity; awareness of morphological relationships, productive morphology and morpho-syntax. The present thesis set out to examine whether deaf secondary school children demonstrate all of these levels of morphological awareness. The present chapter evaluates the evidence obtained within this thesis for each level of awareness, alongside the educational implications for deaf children.

7.1 Evidence for each level of morphological awareness

In Chapter Two, the levels of morphological awareness necessary for a child to use morphology effectively in literacy were described. Before examining the evidence I will summarise these levels again.

Prior to the development of any degree of morphological awareness, morphologically related forms will exist within the lexicon as isolated words. They will be learned as individual items and associations between related words will be orthographic (and/or phonological) rather than morphological.

The first level of morphological awareness is reached when children have an awareness of the relationship between morphologically related words and associate words on the basis of morphological features in addition to orthographic overlap.

The second level of awareness involves the productive use of morphology. There are multiple stages to the development of this level of awareness. First children must recognise that systematic changes in form co-occur with changes in meaning, then they must generalise their knowledge of these rules and finally they must learn the exceptions to these rules.

Finally, in order to have a fully mature understanding of morphology, as necessary for competent literacy, children must extend their understanding of morphology at the single-word level to the sentence, developing an awareness of morpho-syntax.

7.1.1 Evidence for awareness of morphological relationships

In order for morphology to influence literacy, the reader must first become aware of the relationship between morphologically related words. Chapters Three and Four examined whether deaf children had achieved this first level of morphological awareness– specifically, awareness of the relationship between root and inflected words. A novel short-term memory (STM) probe task was designed to assess whether deaf children had an awareness of the relationship between root and inflected words. Participants viewed a list of words followed by a probe word. The task was to state whether the probe was present on the preceding list or not. For half of the trials the probe was indeed present on the list. For the remaining trials the probe was not present on the list but the relationship between the probe word and a critical list word was manipulated to examine how different types of overlap influenced rates of false-positive errors. In Chapter Three, the utility of the STM probe paradigm was tested with hearing adults, who demonstrated significantly more false-positives for morphologically related words than words sharing an equal degree of orthographic or semantic overlap. Furthermore, accuracy for morphologically related words was worse than predicted by summing the effects of orthographic and semantic overlap, thus the morphological effect was distinguished from the combined effects of overlapping orthographic and semantic form. The STM probe paradigm does not tell us anything about the location of the morphological effect (e.g., whether morphology influences short-term storage, retrieval or lexical organisation) and cannot distinguish between full-listing and full-parsing accounts of morphological representation. Nonetheless, the evidence from Chapter Three indicated that the STM probe paradigm allows us to distinguish the effects of morphological overlap from semantic and orthographic components and, therefore, this paradigm is suitable for measuring awareness of morphological relationships.

In Chapter Four, the STM probe was applied to deaf and reading-age matched hearing children to examine whether they, like hearing adults, associated morphologically related words. Deaf children's performance was virtually identical to hearing children. In Experiment 2a, both deaf and hearing children produced more false-positives for morphologically related words than words sharing the same degree of orthographic overlap, indicating that the association between morphologically related words was not simply due to overlapping form. Neither deaf nor hearing children confused orthographically related words any more often than unrelated words, suggesting that children did not use visual-orthographic properties to code the words in this task.

However, semantic overlap was not considered in this experiment and therefore it was possible that the morphological effect was actually due to shared semantic features.

In Experiment 2b, the STM probe paradigm was applied to distinguish the effects of overlapping morphology, orthography and semantics. Both deaf children and reading-age matched hearing children demonstrated that they associated morphologically related words in a manner that was distinct from semantics. However, whereas in Experiment 2a false-positives were equally frequent on words that shared orthographic overlap and those that were unrelated, in Experiment 2b false-positives were more frequent on words sharing orthographic overlap. Furthermore, the frequency with which false-positives occurred on orthographically related words was indistinguishable from the rate for morphologically related words (although numerically there appeared to be more false-positives when there was morphological overlap, the difference was not significant). Further examination of the two STM probe experiments with deaf participants revealed that children were generally more accurate in Experiment 2b compared to 2a (i.e., performance on unrelated and morphologically related words improved). However, performance on words sharing orthographic overlap was worst in Experiment 2b. In the General Discussion of Chapter Four (Section 4.4), I argued that differences in the design of the two experiments resulted in participants focusing on orthographic features more in Experiment 2b compared to 2a. Therefore, deaf children demonstrated that they were able to use orthographic and semantic coding strategies flexibly, focusing more heavily on the features that led to the least confusion. Although it was not possible to distinguish the effect of morphological overlap from both overlapping orthographic and semantic features in a single study, the evidence from the two STM probe experiments suggested that it was possible to distinguish morphology from each factor individually. Nonetheless, it may be premature to conclude based on this evidence alone that deaf children have an awareness of morphological relationships, since it is possible that the morphological effect remains in both cases because of the remaining orthographic/semantic overlap. This could not be argued for the hearing adults since the morphological effect was stronger than the summed effects of overlapping orthography and semantics. Nonetheless, in both Experiment 2a and 2b the pattern of performance for deaf children was indistinguishable from that of reading-age matched hearing children. Therefore, deaf children demonstrated associations that were reading-age appropriate and any ambiguity that exists as to whether these associations are truly based on morphological overlap holds for both the deaf and hearing child populations.

Although the results from the STM probe tasks alone may not have been sufficient to have persuaded the skeptic that deaf children had an awareness of morphologically related words, combining this evidence with evidence from Chapter Five provides a more convincing account. Experiment 3c in Chapter Five revealed that the accuracy with which deaf children produced plural noun spellings was dependent on their spelling of the singular – it was very rare for a child to be able to spell a plural if they were unable to spell the singular. Furthermore, a comparison of performance on Experiments 3a and 3c indicated that deaf children were more accurate at spelling regular plurals when they were provided with the correct spelling of the singular than when they had to produce the singular for themselves, whereas this did not influence performance on semi-regular or irregular plurals. Together these findings suggest plurals (particularly regular forms) are dependent on (and therefore associated with) singulars. The finding that providing the correct singular spelling increased plural accuracy more for regular than semi-regular or irregular plurals reinforces the conclusion that the singular/plural dependency is mediated by productive knowledge of inflection, since the exceptions to the rules (i.e., semi-regular and irregular plurals) are more likely to be learned individually using visual-orthographic memory strategies, which should result in weaker dependency between singular and plural accuracy. However, the evidence from Experiments 3a-3c that supports an awareness of morphological relationships cannot be presented without caveats. Singular and regular plural nouns share not only root morphology but also the orthographic features of the root. Therefore, the contribution of overlapping orthography cannot be distinguished from that of morphology.

In summary, the results from the STM probe tasks (Chapter Four) and the plural noun spelling tasks (Chapter Five) together suggest that deaf children acquire the first level of morphological awareness which is necessary for morphology to influence literacy. They successfully associate morphologically related words and the strength of the associations between words is as strong in the deaf as in reading-age matched hearing children. Nonetheless, it remains possible that these associations are based on the orthographic and/or semantic properties of words rather than morphology.

7.1.2 Evidence for the use of morphological generalisation

Awareness of the relationship between morphologically related words is not sufficient for children to use morphology productively to aid literacy acquisition (i.e., the second level of morphological awareness). Generalisation of morphological rules offers potential for substantial improvements in spelling and vocabulary since morphological generalisation enables the child to learn a whole set of related words when they acquire a new root (providing the suffixes have been learned). Therefore, it is *productive* use of morphology that is of particular interest. The following discussion examines the evidence from the present thesis that reveals the use of morphological generalisation by deaf children.

Chapter Five examined whether deaf children had generalised understanding of plural noun formation. Participants produced spellings of plural nouns varying in regularity (Experiment 3a and 3c), as well as plural nonwords (Experiment 3b). The findings indicated that the deaf children not only used morphology productively to aid their spelling but actually appeared to rely on morphological and morphographic rules even more than reading-age matched hearing children. In Experiments 3a and 3c, both deaf and hearing children were better at spelling regular plurals than irregular plurals. Furthermore, deaf children were at least as accurate as reading-age matched hearing children at spelling regular and semi-regular plurals, only underperforming on irregular plurals. In the General Discussion of Chapter Five (Section 5.4) I argued that a probable reason why hearing children outperformed deaf children on irregular plurals was that hearing children already know the spoken forms of the irregular plurals. Irregular plurals are marked as exceptions in both speech and spelling. Because hearing children have already stored the irregular forms and use them to inhibit regular plural formation in speech, it seems plausible that they could transfer this knowledge from speech without relearning which words are irregular. The deaf, on the other hand, are likely to be learning which words are irregular for the first time when they learn to read and write.

In Experiment 3b, deaf children demonstrated that they had generalised morphological rules for plural noun formation, since they were able to produce plausible plural spellings for nonwords. Indeed, deaf children produced plural nonwords as expected on the basis of morphographic rules significantly more frequently than reading-age matched hearing children (although not as often as hearing adults).

In addition to evidence based on accurate responses, several features of the unexpected spellings of plural nonwords in Experiment 3b and the misspellings of semi-regular and irregular plural nouns in Experiment 3a further suggested that deaf children had an increased tendency to rely on morphographic information compared to their reading-age matched hearing counterparts. Firstly, deaf children produced more over-generalisation errors than reading-age matched hearing children (i.e., singular+<s> or singular+<es> responses when an alternative transformation was necessary). Secondly, when deaf children added other graphemes to the singular root, they virtually always added a real English suffix and these very rarely corresponded to the phonology of the correct plural or its over-regularised form. This suggested that deaf children understood that these graphemes had special status and were often added to roots in word-final positions but had not yet learned the meaning associated with the suffixes. They also spelled the root of plural forms more often correctly than hearing children, indicating their knowledge of another morphographic principle, namely the invariant spelling of morphemes in related words. While deaf children seemed to rely heavily on their knowledge of morphographic regularities, hearing children seemed to rely more heavily on their knowledge of plural formation from speech. Compared to deaf children's errors, hearing children's were more frequently phonologically plausible versions of the whole word (e.g., *GEESE-*gees, DRESSES-*dressis*) and when they added other graphemes to the singular, the misspelling that was created was nearly always a phonologically plausible rendition of the correct or over-regularised plural, even if it could also have been the result of morphological processes (e.g., adding the possessive +<'s>).

In Chapter Five, developmental progression of plural formation was also examined by testing the relationship between rates of over-regularisation and reading-age. Hearing children demonstrated a U-shaped developmental curve. Initially (age 6), responses were highly error prone but hearing children produced very few over-regularisations. By around 8 to 10-years-old hearing children's plural accuracy had improved and many of their errors on semi-regular and irregular words were over-regularisations, indicating that they had generalised the morphological rule root+<s>. During the final stages of development, the exceptions to the rule were learned and as accuracy increases, rates of over-regularisation reduce. This pattern of over-generalisations mirrors the development of plural acquisition in speech (Marcus, 1995; Mervis & Johnson, 1991) and it is consistent with previous evidence regarding past-tense acquisition in spelling (Nunes et al., 1997a; Nunes et al., 1997b). Deaf children did not demonstrate this U-shaped pattern in their rates of over-regularisation. Although deaf children's plural accuracy improved with reading-age at the same rate as hearing children's, deaf children with the lowest reading-age produced much higher rates of over-regularisation in their errors than hearing children of the same reading-age. In fact, reading-age did not influence the rate with which deaf children produced over-regularisations. This is not to say that the U-shaped pattern of development could not be observed in the deaf population over a wider range of ages, simply that it was not observed in the group and for the age range of children tested in Experiment 3. However, there are several reasons to be cautious in drawing developmental conclusions based on this research, including the chronological age and educational experiences of the deaf children, as well as the fact that the present research had a cross-sectional rather than longitudinal design. These limitations will be discussed in some depth in Section 7.2 (p205).

The spelling tasks used in Chapter Five may over-estimate plural knowledge because children were explicitly told that they were going to spell plurals and then produced a total of 99 plural spellings in succession (33 plural nouns, 33 nonword plurals, 33 singular and 33 plural nouns). Therefore, the error rate in this sample is not necessarily representative of what would be observed in a naturalistic sample of their written prose. Nonetheless, these findings represent what the deaf children are capable of when their attention is drawn to plural formation and the results were not consistent with the claim that the children were applying artificial strategies unconnected to their morphological knowledge. For the most part, they did not simply produce singular+<s> spellings indiscriminately for all nouns (only two deaf children and no hearing child did so).

Together, the findings from Chapters Four and Five suggest that deaf children have knowledge of plural inflection at the single-word level that is at least equivalent to reading-age matched hearing children. In fact, if anything, deaf children appear to use morphographic correspondence to aid spelling to a greater degree than reading-age matched hearing children. This may be because hearing children are influenced strongly by competing evidence from speech. Hearing children must not only learn the morphographic rules but must also learn that, for morphologically regular words, morphographic correspondences supersede phoneme-grapheme correspondences (e.g., regular plurals +/s~z~əz/ are all spelled +<s>). To further complicate matters, hearing children have to disinhibit their knowledge from speech for irregular plurals, not only to help them to mark the written plural as irregular but also to produce the correct spelling (since irregular plurals are usually spelled with regular phoneme-grapheme correspondences). Thus, deaf children may actually have an advantage when spelling morphographically regular plurals–by lacking knowledge of plural formation in speech, they may be more able to focus on morphographic rules. Morphographically irregular plurals will be harder for deaf children, however, since they have to learn the exceptions from less input (i.e., written text but not speech) and are also likely to lack the phonemic representations necessary to enable them to sound out the spellings (since morphographically irregular plurals typically have transparent phoneme-grapheme relationships). Irregular plural nouns are very rare in English, accounting for less than 2% of noun types and 3% of noun tokens (Marcus, 1995). Therefore, it seems quite feasible that, alongside the teaching of the morphographic rules, the spelling of the exception words could receive additional, explicit educational attention (at least for high frequency words).

7.1.3 Evidence for awareness of morpho-syntax

Although generalisation of plural rules indicates that the children understand that number is marked morphologically on individual words, a fully developed awareness of morphology requires that they understand the role of inflectional morphology in morpho-syntax as well as on individual words. Thus, within the context of number inflection, the child must acquire awareness of subject-verb agreement, which was the focus of Chapter Six. Although understanding of plural formation (as demonstrated in Chapters Four and Five) is clearly a prerequisite to subject-verb number agreement, it does not necessarily follow that a child who has the relevant morphological awareness at the single-word level will be able to use this knowledge to aid sentence processing. Agreement involves applying understanding of morphology at the single-word level to morpho-syntactic relationships between words. In order to have awareness of number agreement in English, the child must learn which words in the phrase are systematically marked for number (i.e., noun and verb) and they must learn how these specific word types are marked (+<s> for plural nouns and +<s> for singular verbs). In addition, they must hold the number information in memory while processing the sentence and relate subject and verb with regards to number marking during syntactic integration. Notice that the associations that must be made between subject and verb (e.g. *cat-plays* and *cats-play* but not *cats-plays* or *cat-play*) are quite different to those made between singular and plural forms of the same word (e.g., *cat-cats* and *plays- play*). Subject-verb agreement relates words on a grammatical level, while singular-plural relations, at least on nouns, are semantic in nature.

The final series of experiments (Chapter Six) examined whether deaf children's knowledge of number marking at the single-word level had extended to the syntactic level to enable them to use subject-verb number agreement in sentence processing. Experiment 4a assessed children's knowledge of plural nouns using a reading version of the spelling task from Experiments 3a and 3c to ensure that the participants in Experiments 4b and 4c had basic understanding of plural noun number marking at the single-word level. Experiment 4b examined implicit awareness of subject-verb agreement in a word-by-word self-paced reading task, in which participants read sentences containing agreeing or disagreeing subject-verb number markers. Finally, Experiment 4c examined awareness of subject-verb agreement in a more explicit manner; participants were presented with sentences containing agreeing or disagreeing number markers and asked to mark any sentences which contained an error as incorrect and then to correct the sentence. Participants were not told that the task involved the manipulation of subject-verb number markers but in order for them to correct the sentences they had to use their understanding of agreement explicitly.

Deaf and hearing children performed very similarly in these experiments in terms of their comprehension level. Children were initially matched for reading-age but they also demonstrated similar plural noun reading ability (Experiment 4a) and raw self-paced reading times on normal sentences (Experiment 4b). The hearing children demonstrated both implicit awareness of subject-verb agreement in the self-paced reading task (Experiment 4b) and the explicit ability to not only notice when number markers contradicted but also to correct disagreeing sentences appropriately in the judgement task (Experiment 4c). In contrast, although the deaf children did demonstrate implicit awareness of agreement during self-paced reading, they slowed down later than hearing children and did not show any evidence for explicit awareness of agreement in the judgement task.

When reading sentences that contained disagreeing subject-verb number markers in the self-paced reading task (Experiment 4b), hearing adults slowed down on the verb and the word immediately after. This indicates that hearing adults were aware of agreement and also that they could continue processing morphology in the background whilst beginning to read the next word. Hearing children read slower than adults and demonstrated the agreement effect on the verb only. Therefore, hearing children were aware of agreement but read in a more word-by-word manner, performing syntactic integration prior to moving on to the next word in the sentence. Deaf children read as slowly as reading-age matched hearing children but instead of slowing down on the verb (where the subject-verb anomaly can first be detected), deaf children did not slow down until the word after. Therefore it was concluded that deaf children were slower to perform syntactic integration–they had moved on to the next word before they noticed that there was a problem with the sentence. Nonetheless, finding that deaf children slowed down at all when reading sentences containing disagreeing subject-verb number markers indicated that the deaf children did have some degree of awareness of agreement.

The agreement judgement task (Experiment 4c) revealed that hearing adults were aware of disagreeing subject-verb number markers and could use their understanding of agreement explicitly to correct these errors appropriately. Hearing children also demonstrated awareness of the error and corrected it appropriately, although less frequently than hearing adults. In contrast, despite having similar reading abilities to the hearing children, deaf children did not typically notice the problem in disagreeing sentences when asked to explicitly mark the error. Furthermore, even when deaf children realised that disagreeing sentences contained an error, it was very rare for them to successfully correct the sentence. Experiment 4c showed that the implicit awareness of subject-verb agreement that was evident in the deaf children's results from the self-paced reading task was probably insufficient to guide their own writing, since they were not able to make use of this knowledge explicitly in the judgement task.

The agreement judgement paradigm was only able to test explicit awareness of agreement up to a point. Participants' attention was never explicitly drawn to agreement errors (or indeed grammatical structure). Had the task have forced participants to attend to this part of the sentence, deaf children might have demonstrated awareness of agreement. Nonetheless, in real reading and writing environments, attention is not directed to errors in this manner. Furthermore, if participants had a fully mature understanding of agreement they would have noticed the error in the sentences that contained disagreeing number markers and would have corrected them, just as the hearing adults and children did. This is precisely the sort of skill children need to have in order to apply their understanding of morphology to literacy. An implicit awareness of morphology should enable more efficient processing during reading (since the number markers are redundant), while an explicit understanding will improve writing ability. Deaf children appear to require more education in how to coordinate their morphological awareness at the single-word level to sentence level processing, in order to enable their implicit awareness of agreement to emerge explicitly. Intervention will be the subject of further discussion in Section 7.2 (p208).

7.2 General limitations, implications and future directions

The present thesis found that deaf secondary school children had acquired some degree of awareness of number inflection at the single-word level but could not apply this understanding explicitly to subject-verb agreement at the sentence level. Finding that deaf children acquire morphographic awareness contradicts the view that deaf children are constrained to using only visual-orthographic strategies due to limited access to the phonological route (Aaron et al., 1998; Musselman, 2000; Sterne & Goswami, 2000), unless these authors would consider morphographic awareness to be a form of visual-orthographic strategy (since it is not based on sound). Morphographic strategies can be (and indeed are) applied without phonological mediation. This has implications not only for deaf children but also for hearing children with literacy impairments, such as phonological dyslexics who are similarly argued to have a phonological impairments (Brady, 1997; Ehri, 1993; Frith, 1985; Goswami & Bryant, 1990; Stanovich, 1992). Indeed, others have already begun to argue that morphology is an important alternative source of regularity for dyslexic children (e.g., Elbro & Arnbak, 1996). In addition, by demonstrating that morphological awareness can develop without complete phonological representations, the present findings provide yet another problematic result for strict stage theories of literacy acquisition, which typically claim that the ability to use alphabetic strategies (or phoneme-grapheme correspondences) must precede the integration of orthographic and morphological knowledge (e.g., Ehri, 1995; Frith, 1985). The present thesis suggests that the integration of morphological information into the child's growing literacy skill is not dependent on having complete phonological representations.

The present thesis used different samples of participants for each experiment (although there was some overlap between experiments, since some participants took part in more than one experiment, the battery of tests that each participant completed varied). There are several reasons to be cautious about drawing conclusions regarding developmental patterns from this research. Firstly, because different samples were used in different experiments, there is no guarantee that a participant in one experiment has the same level of morphological awareness as a different participant in a different experiment (even if they had exactly the same reading-age). Secondly, the data represent a cross-section of children each at specific points of development rather than the longitudinal development of a single group of participants. Performance of different people at different ages doesn't imply that a single person will pass through the same stages as they progress through the ages sampled by the cross-section. Future research should use a longitudinal design to plot developmental progression, to test whether children pass through the levels of morphological awareness, to establish whether regression to earlier stages occurs and to study whether it is necessary for each level of awareness to have developed fully prior to initiating acquisition of the next level of awareness. The present data does not enable us to establish a causal relationship between morphological awareness and reading achievement, since one cannot ascertain whether advanced morphological awareness precedes or follows a certain level of literacy skill. The answer to this question has important implications for education, because if morphological awareness is the result of literacy skill rather than a precursor, there would be little point in providing explicit education in morphology. Only intervention studies can disentangle the cause from the effect in this case (intervention studies will receive further attention on p208).

A second factor which leads to difficulty in drawing developmental conclusions from the evidence provided in the present thesis relates to the reading-age match design. Goswami and Bryant (1990) argue that positive results in reading level match designs (i.e., finding a difference between deaf and RA matched hearing children, as in Experiments 4b and 4c) provide an impressive argument that these are not simply the product of reading-age disparity. However, a negative result (i.e., no difference) is a problem for interpretation. For example, in the present thesis there were several measures of morphological awareness at the single-word level that revealed no differences between deaf and reading-age matched hearing children (e.g., Experiments 2a, 2b and accuracy on regular plurals in 3a). In these circumstances, the deaf children were substantially older than their matched hearing counterparts. This means that the deaf children had received many more years of education and were also likely to be more cognitively advanced and therefore were more likely to apply extraneous skills to enable them to perform better on the task (Goswami & Bryant, 1990). Finding no difference between deaf children and RA matched hearing children does not necessarily mean that the two groups have the same skills. Furthermore, even if one was able to conclude that they were applying the same strategies, this would represent a substantial delay given the deaf children's chronological age. Chronological-age matched hearing children were not included in the present thesis because, in most cases, hearing children of the same chronological age as the deaf children would have performed at ceiling (as indeed the eldest of the reading-age matched hearing children did in Experiment 3). Furthermore, the differences between deaf and chronological-age matched hearing children are far greater than just reading ability. For example, hearing children of the same chronological age will have far more receptive and expressive experience with spoken language than deaf children, which is also likely to have important implications on these tasks.

Another pertinent limitation to interpretation of the present results relates to whether the failure of deaf participants to demonstrate awareness of agreement represents a developmental delay which (although unquestionably not simply the result of their general literacy delay) will eventually be overcome or whether this awareness is a lasting difference seen also in deaf adults. Since deaf children have the component skills, it seems likely that it is possible for them to develop appropriate awareness of agreement. Whether they would do so without specific intervention is a different matter. A quick examination of the individual data from Experiment 4c (see Appendix 4c) revealed that only 6/19 deaf participants reliably noticed that there was an error in disagreeing sentences (i.e., $d' > 0$) and furthermore, only four deaf participants ever made the appropriate correction (three of whom actually did not reliably mark disagreeing sentences as incorrect but corrected sentences appropriately on at least one occasion when they noticed the problem). The children that did demonstrate some understanding of agreement were largely the better readers but even these children demonstrated weaker sensitivity to agreement than hearing children. Therefore, even if deaf children do eventually develop an explicit awareness of agreement, this is clearly substantially delayed and therefore specific intervention by teaching children how to use knowledge of inflection at the single-word level to aid sentence comprehension and production seems to be a clear recommendation from the present findings. Education in agreement should enable deaf children to check their own writing for errors and to correct these mistakes appropriately.

Previous evidence suggests that morphological awareness training can have significant implications for the literacy skills of hearing children. For example, Elbro and Arnbak (1996) demonstrated that morphological awareness training improved the reading comprehension skills of Italian dyslexic teenagers. Nunes, Bryant and Olsson (2003) also demonstrated that morphological awareness training had a positive impact on the use of morphological spelling rules by hearing British children. Nonetheless, previous research has focused on general morphological awareness training at the single-word level, such as teaching segmentation skills and the combination of morphemes in derivation, compounding and inflection. Furthermore, there has been a focus on the oral use of these skills, something which is not necessary helpful (or perhaps attainable) for deaf children. The present research focused on understanding of number inflection, which is typically early developing (Cazden, 1968; De Villiers & De Villiers, 1973; Mervis & Johnson, 1991) and considered to be one of the least complex morphological relationships. Deaf children acquired this simple morphological rule at the single-word level and generalised their knowledge to new words but, despite the apparent simplicity of the morphological process, awareness of agreement at the sentence level was not fully developed. Derivational morphology and compounding involve more complex rules of morpheme combination and are sometimes argued to involve processes and representations that differ from those used in inflection (Jackendoff, 1975; Miceli & Caramazza, 1988; Stanners et al., 1979). Therefore, the present findings cannot automatically be assumed to extend to these domains. Further research should examine deaf children's knowledge of these more complex forms of morphology. Nonetheless, the findings from the present thesis suggest that deaf children are capable of acquiring morphological generalisation and therefore education in the more complex rules of inflection, derivation and compounding may very well lead to substantial gains in the single-word reading, spelling and vocabulary attainment of deaf children. Further intervention studies are necessary to examine the effects of explicit training on morphographic rules and the exceptions to these rules within this population.

In addition to morphographic training at the single-word level, deaf children also need further help learning about the combination of these morphological features at the level of the sentence. If deaf children's understanding of a relatively simple morpho-syntactic structure such as subject-verb agreement is impaired, then it seems almost certain that further difficulties will be encountered with more complex syntactic structures (as indeed has been argued, e.g., Quigley & King, 1980). Preliminary findings from a recent intervention study with British deaf children suggest that general morphological awareness training does indeed have a positive impact on deaf children's literacy acquisition (Nunes et al., 2007). Future research should continue to examine the areas of morphology which deaf children find it particularly difficult to acquire, so that education can be targeted at training these topics.

Finally, a limitation to the present research which is inherent to all research into literacy in the deaf population but which is rarely discussed, relates to the use of group data. As discussed in Chapter Two (Section 2.2), the deaf population are a highly heterogeneous group of individuals and much of this variation is likely to impact on experience with spoken language and literacy skill. When conducting research within a variable population such as this, it is always necessary to weigh up the pros and cons of conducting detailed case studies versus group studies. Group studies of course have the advantage of greater power and external validity – the larger the sample size, the more representative of the population it should be. However, this will be at the expense of information relating to individual differences. In a variable population, it is possible that the properties of the "average" person (which data from group studies represents) is not actually representative of any real individual, or represents only a very small minority of the population. A heterogeneous population can result in non-significant results because of this wide variation between participants. Under these circumstances it cannot be stated that, for instance, none of the deaf individuals show an effect, only that for the most part deaf individuals do not show an effect. For example, in the agreement judgement task (Experiment 4c) the majority of deaf children showed no sensitivity to agreement, hence the nonsignificant effect of agreement. Nonetheless, as previously discussed, 6/19 participants did show awareness ($d' > 0$). Thus, there is an argument for the use of case studies within this population in order to increase the level of detail that is provided. Nonetheless, while case studies prevent the loss of detail inherent to group studies this comes at the expense of power (effects must be bigger in order to be significant). Furthermore, case studies have their own problems in terms of generalisability, since one cannot know how representative the individuals are compared to the population from which they are drawn. In order for research to have implications for the education of deaf children, it is necessary to find out what information the majority of the population is lacking. A sample from a group of participants indicates the basic pattern and can help to identify areas where heterogeneity might cause problems for inference. For this reason, the present thesis made use of group studies. Throughout the thesis, detailed participant descriptions provide the reader with substantial information regarding the communicative experiences of these children. Nonetheless, as a cautionary note for the generalisability of these findings, the reader should be aware that the vast majority of deaf children who participated were profoundly and prelingually deaf, communicating primarily with BSL and attending specialist schools for the deaf or well-established Hearing Impairment Units within mainstream schools. None of the children could be considered to communicate effectively through oral/aural language alone and their education always involved some level of signed support. Deaf children with particularly good oral/aural communication skills could easily demonstrate a different pattern of performance. How similar morphological development amongst oral deaf children is to hearing children will depend on how comparable their spoken knowledge of morphology is, which cannot be speculated upon without further research.

7.3 Conclusions

The limitations outlined above are merely caveats in terms of the generalisability of the present findings which provide suggestions for future research. None of these limitations seriously undermine the validity or interpretation of the present thesis. The present thesis indicated that deaf children who primarily communicate using BSL develop some awareness of number inflection but that this morphological awareness is clearly incomplete. Deaf children associate inflectionally related words (whether based on the combination of orthographic and semantic features or due to morphology) and are able to use morphological generalisation to produce plural noun spellings. Indeed, at the single-word level, deaf children demonstrate morphological awareness that appears to be equivalent to their reading-age matched hearing counterparts. Furthermore, deaf children demonstrate some degree of implicit awareness of subject-verb number agreement when reading for comprehension. However, deaf children's knowledge of morphology was not always appropriate for their reading-age. Specifically, deaf children demonstrated deficiencies with respect to their knowledge of irregular plural nouns and in explicit understanding of subject-verb agreement. Furthermore, since deaf children typically had a reading-age delay of around five or six years, having morphological awareness comparable to reading-age matched hearing children still represents a substantial chronological delay. Nonetheless, finding that deaf children can acquire understanding of morphographic relationships not only indicates that morphological awareness is not necessarily dependent on phonology but also provides hope that explicit education in morphographic rules will have a positive impact on literacy acquisition within the deaf population and perhaps also for other populations where access to the phonological route is impaired. For deaf children, training in morphological awareness should focus on both regular and irregular morphographic relationships but also provide explicit links between knowledge of morphology at the single-word level and application of this understanding at the morpho-syntactic level. Further research should compare understanding of different types of morphological and syntactic structures in order to establish which are particularly difficult to learn. Intervention studies should also be performed to examine the effectiveness of training in these different types of morphological relationships and the impact that improving this knowledge has on literacy skill.

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APPENDICES

APPENDIX 1A

Experiment 1a: STM probe with hearing adults, comparing the effects of morphological and orthographic overlap

Table A.1: Stimuli for Experiment 1a

Substring	Morphological superstring	Orthographic superstring	Unrelated probe present	Unrelated probe absent
arm	arms	army	feel	window
ban	banned	band	fairy	sink
bat	bats	batch	dig	sighed
bee	bees	beef	sigh	trips
blank	blanks	blanket	pillar	cab
car	cars	card	ideas	wall
cat	cats	catch	sunk	hearts
count	counted	county	ears	fun
doll	dolls	dollar	monkey	fork
hand	handed	handle	son	east
hat	hats	hatch	cuts	bowl
hip	hips	hippo	starred	lists
need	needed	needle	table	hero
pan	pans	panda	cute	tinned
pen	pens	pence	cans	hop
pet	petted	petal	gases	breadth
pick	picked	pickle	gravel	bells
pin	pinned	pinch	wink	sung
plan	planned	planet	tap	marks
rock	rocked	rocket	lived	sit
scar	scarred	scarf	rubbed	bin
sea	seas	seam	bush	diet
tail	tailed	tailor	barred	fan
tax	taxes	taxi	market	closed
ten	tens	tend	hot	come
top	topped	topic	mad	piece
war	wars	ward	met	single

APPENDIX 1B

Experiment 1b: STM probe with hearing adults comparing the effect of morphological, orthographic and semantic overlap

Table A.2: Stimuli for Experiment 1b

Morphological /Semantic substring	Morphological superstring	Semantic superstring	Orthographic /unrelated substring	Orthographic superstring	Unrelated superstring
tale	tales	story	sigh	sight	forms
bowl	bowls	dish	tent	tenth	cakes
net	nets	mesh	ear	earn	fold
boat	boats	ship	star	start	doors
law	laws	rule	son	song	west
ray	rays	beam	bee	beef	tune
seat	seats	chair	pain	paint	rope
sea	seas	ocean	came	camel	roses
cost	costs	price	plan	plant	board
shop	shops	store	fair	fairy	waves
shirt	shirts	blouse	plane	planet	shower
flower	flowers	blossom	cabin	cabinet	players
frog	frogs	toad	scar	scarf	ninth
hat	hats	cap	win	wing	dad
palace	palaces	castle	count	county	hidden
oven	ovens	stove	bell	belly	tooth

APPENDIX 2A

Experiment 2a: STM probe with deaf and reading-age matched hearing children, comparing the effects of morphological and orthographic overlap

Table A.3: Stimuli for Experiment 2a

Substring	Orthographic superstring	Morphological superstring
arm	army	arms
cat	catch	cats
count	county	counted
doll	dollar	dolls
hip	hippo	hips
pan	panda	pans
pen	pence	pens
sea	seam	seas
tax	taxi	taxes
war	ward	wars

APPENDIX 2B

Experiment 2b: STM probe with deaf and reading-age matched hearing children comparing the effect of morphological, orthographic and semantic overlap

Table A.4: Stimuli for Experiment 2b

Morphological /Semantic substring	Morphological superstring	Semantic superstring	Orthographic /unrelated substring	Orthographic superstring	Unrelated superstring
boat	boats	ship	star	start	doors
seat	seats	chair	pain	paint	rope
sea	seas	ocean	came	camel	roses
shirt	shirts	blouse	plane	planet	shower
flower	flowers	blossom	cabin	cabinet	players
frog	frogs	toad	scar	scarf	ninth
hat	hats	cap	win	wing	dad
oven	ovens	stove	bell	belly	tooth

APPENDIX 3A

Experiment 3a: Plural noun spelling

Stimuli for Experiment 3a: Plural nouns (in their singular form)

Regular:	root+<s>:	*book, chicken, cloud, door, feather, hand, horse, plate, skirt, snake, star*
Semi-regular:	root+<es>:	*box, bus, church, dress, glass*
	final <f~fe>:	*knife, leaf, shelf*
	final <y>:	*baby, lady, penny*
Irregular:	internal change:	*foot, goose, man, mouse, tooth*
	invariant:	*deer, fish, scissors, sheep, trousers*

Phonetically plausible and implausible misspellings in Experiment 3a

Deaf children

Phonetically plausible misspellings: Irregular: **scissores, *scissorss, *trouseres, *trouserse, *trouserses, *trouserss.* Semi-regular: **boxs, *buss, bus's, *churchs, *dresss, *dress's, *glasss, *glass's, *babyes, *babys, *ladyes, *ladys, * lady's, *pennyes, *pennys.*

Phonetically implausible misspellings: Irregular: **feets, *foots, *geeses, *goose, *goosed, *gooseing, *gooses, *man, *maned, *mans, *man's, *mens, *mices, *mine, *mouise, *mouse, *moused, *mousees, *mousse, *mouse's, *mousse, *teeths, *thooths, *tooth, *toothe, *toothed, *toothes, *toothing, *tooths, *dearers, *deef, *deeres, *deers, *fished, *fishers, *fishes, *fishing, *fishs, *fish's, *scissorred, *scissorsed, *scissorsers, *scisssorses, *scissoring, *scissors's, *sheeped, *sheepes, *sheeping, *sheeps, *sissorsed, *trouserers, *trouseresers, *trousersd, *trousersed, *trouserser, *trousersing, *trousers's, *trousesies.* Semi-regular: **box, *boxing, *bus, *bused, *buser, *busers, *busing, *busrs, *church, *dress, *dressed, *dresser, *dressing, *dressings, *glass, *glassed, *glassers, *glassest, *glassing, *gless, *knifed, *knifes, *knifies, *knifves, *leaf, *leafers, *leafes, *leafs, *leatle, *leave, *shelf, *shelfers, *shelfes, *shelfies, *shelfing, *shelfs, *babe, *babie, *babiles, *ladie, *ladiles, *ladyed, *penniest, *penniles, *penny, *pennyed.*

Hearing children

Phonetically plausible misspellings: Irregular: **gees, *gese, *mene, *mise, *miys, *teth, *theeth, *scissers, *scissor's, *scissorss, *sisas, *sisus, *sizzes, *trosas, *trouseres, *trouser's, *trouserses, *trousers.* Semi-regular: **boxis, *boxes, *box's, *bus', *busis, *buss, *bus's, *busses, *churchis, *churchs, *church's, *dreses, *dresis, *dress', *dressis, *dresss, *dress's, *glases, *glasis, *glassis, *glasss, *glass's,*

**leevs, *babs, *babyes, *babys, *baby's, *babyse, *lades, *ladiys, *ladys, *lady's, *penes, *pennes, *penneys, *penney's, *pennys, *penny's.*
Phonetically implausible misspellings: Irregular: **fooet, *foot, *footet, *footis, *foots, *geses, *goose, *gooseis, *gooses, *goose's, *goosis, *man, *mans, *man's, *mansise, *mens, *mises, *miuse, *mose, *mouse, *mouseies, *mouseis, *mouses, *mousis, *mrn, *teetheclore, *theathes, *tooth, *toothes, *tooths, *beer, *deeas, *deeres, *deerise, *deers, *deer's, *deeys, *ficshes, *fiseses, *fishes, *fishis, *fishs, *fish's, *fishse, *scissor, *scissoris, *scissorses, *scissorsmoth, *scissors's, *sepes, *sheeppise, *sheeps, *sheep's, *sissorses, *sisuses, *tazeses, *thasuseis, *trales, *trouser, *trousers's.* Semi-regular: **box, *bresies, *bus, *buse, *church, * churis, *dress, *glaiss, *glass, *glassies, *glrss, *shurchs, *hivss, *knife, *knifiods, *knifes, *knife’s, *knifs, *knivies, *leaf, *leafes, *leafis, *leafs, *leaf’s, *lerf, *levses, *self, *selfvs, *shelf, *shelfe, *shelfes, *shelfie, *shelfs, *shelf’s,*baby, *baiyes, *brdy, *labys, *ladires, *lady, *lagys, *lrdy, *penny, *pennyins.*

Morphological and non-morphological misspellings in Experiment 3a

Deaf children

Morphological misspellings: **boxing, *bused, *buser, *busers, *busing, *bus’s, *dressed, *dresser, *dressing, *dressings, *dress’s, *glassed, *glassers, *glassest, *glassing, *glass’s, *knifed, *leafers, *sheflsers, *shelfies, *shelfing, *ladyed, *lady’s, *pennyed, *goosed, *gooseing, *maned, *man’s, *moused, *mouse’s, *mousse, *toothed, *toothing, *fished, *fishers, *fishing, *fish’s, *scissorsed, *scissorsers, *scissoring, *scissors’s, *sheeped, *sheeping, *trousersed, *trouser, *trousersing, *trousers’s*
Non-morphological misspellings: **busrs, *toothe, *trousersd, *trouserse.*

Hearing children

Morphological misspellings: **box’s, *bus’, *busses, *church’s, *dress’, *dress’s, *glassies, *glass’s, *baby’s, *lady’s, *penny’s, *knife’s, *leaf’s, *shelf’s, *mouseies,*deer’s,* sheep’s,*footet, *mansise, *deerise.*
Non-morphological misspellings: **boxis, *buse, *busis, *churchis, *dressis, *glassis, *knifeiods, *leafis, *shelfe, *shelfie, *babyse, *pennyins, *footis, *gosseis, *mouseis, *fishis, *fishes, *scissorsmoth, *sheeppise.*

APPENDIX 3B

Experiment 3b: Plural nonword spelling

Stimuli for Experiment 3b: Plural nonwords (in their singular form)

Root+<s>: *chike, chup, clourse, deese, doother, feart, fild, foon, glat, hocken, leate, mour, plar, scik, shend, skith, snase, stad, trour*

Root+<es>: *barch, booss, chiss, knis, sheex, toosh*

Final <y>: *drenny, gooby, pedy*

Final <f~fe>: *bolf, bufe, maf*

Unknown: *hasers, lassors*

APPENDIX 4B

Experiment 4b: Self-paced reading task examining the effects of subject-verb number agreement and plausibility

Stimuli for Experiment 4b self-paced reading task

Agreement sentences

the balloon(s) float(s) over the lake
the flower(s) die(s) without any water
the whale(s) swim(s) in the sea
the bubble(s) blow(s) over the fence
the apple(s) grow(s) on a tree
the rabbit(s) eat(s) carrots in the garden
the teacher(s) stand(s) by the blackboard
the girl(s) make(s) a sand castle
the star(s) shine(s) in the sky
the stone(s) sink(s) in the water
the doll(s) ride(s) on a toy horse
the bird(s) build(s) a nest in the tree
the monkey(s) swing(s) through the trees
the goat(s) arrive(s) at the farm
the bell(s) hang(s) in the tower
the rat(s) hide(s) from the cat
the tree(s) burn(s) in the fire
the pill(s) roll(s) off the table
the nurse(s) tie(s) the bandage in a bow
the cat(s) feed(s) the young kittens
the shoe(s) fall(s) off the shelf
the fan(s) wave(s) at the pop star
the egg(s) break(s) on the floor
the pig(s) run(s) away from the farmer
the dog(s) lie(s) on the floor
the builder(s) leave(s) the tools on the floor

the gardener(s) plant(s) a tree in the park
the boy(s) look(s) in the box

Plausibility sentences (plausible / implausible)

the frog jumps out of the pond / the frog cooks dinner in the oven
the ball hits the green vase / the ball loves to eat ice cream
the houses flood in the storm / the houses boil on the stove
the car drives along the road / the car smiles at her mother
the stamp sticks to the envelope / the stamp walks through the forest
the lemons taste too sour for me / the lemons dust the shelves above the fire
the puppies sit in the dog basket / the puppies talk to the girl
the planes land at the airport / the planes help the children cross the road
the kittens chase the little mouse / the kittens ski down the mountain
the pens leak on the paper / the pens shut the front door
the river flows down the hill / the river folds in the middle
the ring fits the finger / the ring wears a blue jumper
the horses ride across the field / the horses cycle down the road
the snake attacks the old man / the snake flies towards the flower
the bear follows the path through the forest / the bear types a letter on the computer
the bridges cross the wide river / the bridges dance to the music
the bulls fight in the field / the bulls ring in the busy office
the truck turns at the traffic lights / the truck plays on the stage
the sign points to the toilet / the sign flowers in the summer
the tigers sleep in the shade / the tigers post a birthday card

Raw reading times on normal sentences by word

A split-plot ANOVA with the within-participants factor of word (verb, completion 1 and completion 2) and the between-participants factor of hearing group (hearing adults, hearing children and deaf children) was conducted on the dependent variable raw reading times on normal (agreeing and plausible combined) sentences. The main effects of word and hearing group were significant; $F(2,120) = 83.85$, $p < 0.001$, partial $\eta^2 = 0.58$ and $F(4,120) = 5.06$, $p = 0.005$, partial $\eta^2 = 0.14$. However, these main effects were mediated by a significant interaction between word and hearing group; $F(2,60) = 9.40$, $p < 0.001$, partial $\eta^2 = 0.24$. Table A.5 indicates that, for all participant groups, reading times reduced as the sentence progressed. Follow-up analyses examining the effect of hearing group on each word individually revealed that the main effect of hearing group was significant on every word; verb $F(2,60) = 9.55$, $p < 0.001$, partial $\eta^2 = 0.24$; completion 1 $F(2,60) = 9.55$, $p < 0.001$, partial $\eta^2 = 0.24$; completion 2 $F(2,60) = 7.41$, $p = 0.001$, partial $\eta^2 = 0.20$. Tukey HSD post-hoc tests revealed that deaf and hearing children's reading times did not differ on any word ($p > 0.4$) but that the reading times of hearing adults were significantly smaller than those of deaf or hearing children ($p < 0.02$). Therefore, hearing adults read all words significantly faster than deaf or hearing children, who did not differ from one another. The interaction is caused by the differences being greater on the verb and reducing through completion 1 and 2 (see Table A.5).

Table A.5: Raw reading times (ms) on agreeing and plausible sentences in Experiment 4a

Participants	Word *M* (*SD*)			
	Noun	Verb	Completion 1	Completion 2
Deaf children	815 (300)	762 (250)	654 (241)	591 (221)
Hearing children	1004 (444)	867 (353)	700 (217)	634 (204)
Hearing adults	563 (203)	537 (158)	466 (104)	441 (100)

APPENDIX 4C

Experiment 4c: Agreement judgement task

Table A.6: Individual deaf children's performance on the agreement judgement task

Participant details			*d'*	bias	Disagreeing sentences				
					Didn't try to correct	Did try to correct			
						Changed in an expected way		Changed other	
RA	BEA	CA				Changed noun	Changed verb	Grammatical	Ungrammatical
76	101	170	0.97 [a]	-0.48	6	0	0	0	1
79	112	157	-0.18	-0.43	4	0	0	0	0
87	108	145	-0.55	-1.56	0	0	0	0	0
88	113	144	-0.17	-0.08	6	0	0	0	0
88	118	150	0	-1.83	0	0	0	0	0
89	101	143	-0.39	0.53	7	0	1	0	1
89	95	185	-0.55	-1.56	0	0	0	0	0
90	105	167	-0.24	-0.85	0	0	0	1	1
90	103	153	0	-1.28	0	0	0	0	1
91	119	146	0.34 [a]	-0.17	7	0	0	0	0
94	104	184	-1.07	-1.06	0	0	0	0	0
94	93	156	0.80 [a]	-0.57	6	0	0	0	0
98	120	141	-0.52	-0.26	4	0	0	0	0
101	110	187	0	-1.28	0	1	0	0	0
101	104	152	0.39 [a]	-0.53	0	0	0	3	2
104	107	195	-1.11	-1.28	0	0	0	0	0
109	120	185	1.70 [a]	0.12	0	3	9	0	0
132	118	180	0.55 [a]	-1.56	1	0	0	0	0
133	113	187	-0.17	-0.08	0	1	5	0	0

Note. RA: Reading-age in months. BEA: Better Ear Average. CA: Chronological age in months.
[a] Reliably noticing an error ($d' > 0$).