Visual word recognition in bilingual deaf children

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Introduction

Chapter 1

For most deaf children, learning to read is a major obstacle (e.g., Goldin-Meadow & Mayberry, 2001; Harris & Beech, 1998; Knoors, 2001; Kyle & Harris, 2006; Musselman, 2000; Paul, 1996; Perfetti & Sandak, 2000; Waters & Doehring, 1990; Wauters, van Bon & Tellings, 2006). On average, the reading achievement of deaf students leaving high school is lower than that of hearing students, and comparable to 9- to 10 year old hearing students (Kelly, 2003; Wauters, van Bon, & Tellings, 2006; Wauters, van Bon, Tellings, & van Leeuwe, 2006). Furthermore, the growth rate of deaf children's reading is on average 0.3 grade level per year (Paul, 2003). Different causes of these reading difficulties need to get disentangled in order to improve reading achievement (Izzo, 2002; Marschark, Lang, & Albertini, 2002; Paul, 2003)

In reading, visual word recognition and adequate language comprehension are involved (Hoover & Gough, 1990; Vellutino, Fletcher, Snowling, & Scanlon, 2004). According to the Simple View of Reading (Hoover & Gough, 1990), neither visual word recognition nor language comprehension is sufficient, but both aspects are necessary to attain adequate reading levels. Deaf children generally encounter difficulties in visual word recognition as well as in the language comprehension of spoken and written sentences (Kelly, 2003; Merills, Underwood, & Wood, 1994; Wauters, van Bon, & Tellings, 2006). At the same time, there are deaf children who have good word recognition and language comprehension skills, but these children comprise only a small group. As yet, no clear answers are available concerning the grounds of these visual word recognition and language comprehension difficulties in deaf children. According to Perfetti and Sandak (2000), limited access to spoken languages implies restricted reading achievements, given that writing systems encode spoken languages.

1.1 *Word recognition*

The present thesis focuses on one of these main components of reading: visual word recognition. Different parts of visual word recognition are addressed. First of all, it is unclear what *codes* deaf children use during word recognition. Secondly, only limited information is available about the *variables* predominantly related to, and possibly underlying, word and text reading fluency of deaf bilingual children (Kyle & Harris, 2006).

1.1.1 *Hearing children*

Word recognition is one of the crucial components of reading comprehension (Gaustad, 2000; Hoover & Gough, 1990). For many years, the dual-route model has been the most broadly accepted model of printed word identification (Coltheart & Rastle, 1994; van Orden, 1987). According to a dual-route model, two separate routes can theoretically provide access to lexical representations. Via the first route, the direct access route (or lexical route), orthographic representations are mapped to lexical representations by means of a direct connection between spelling and meaning-phonology. Via the second route, the phonological mediation route (or non-lexical route), representations of graphemes are mapped onto representations of phonemes (Coltheart & Rastle, 1994). Currently, interest is mounting for various connectionistic network models (Bosman & van Orden, 2003). Phonological codes are found to be an early, important source of constraint during word reading (van Orden, 1987: p. 192; van Orden, Bosman, Goldinger, & Farrar, 1997). Phonology has been given such a prominent and pervasive role in reading that even a Universal Phonological Principle has been proposed (Perfetti & Sandak, 2000). Hearing children can read and understand new words once they can individually decode words, relying on the alphabetical principle (Verhoeven, 1994).

At least three components are involved in word recognition: orthography, phonology, and semantics (Bosman & van Hell, 2002; Bosman & van Orden, 2003). As Bosman and van Hell (2002) explained, connections between semantics and phonology are generally stronger than connections between semantics and orthography, resulting from the order in which children learn to speak and read; hearing children generally learn to speak before they learn to read.

1.1.2 *Bilingual children*

The process of word recognition by people who are familiar with two languages is referred to as bilingual word recognition. Similarly, word processing in deaf children who are familiar with a sign language and a spoken/written language can theoretically be seen from a bilingual perspective. Surveying the process of bilingual word recognition – also in hearing people – has only recently gained serious interest. Experimental bilingual studies have given rise to the assumption that for hearing bilinguals, lexical information from both languages becomes available while processing one language (de Groot, Delmaar, & Lupker, 2000; Dijkstra, Grainger, & van Heuven, 1999; Dijkstra & van Heuven, 2002; Dijkstra, van Heuven, & Grainger, 1998; Hermans, Bongaerts, de Bot, & Schreuder, 1998; Kroll & Stewart, 1994; Kroll, Bobb, & Wodniecka, 2006; van Hell, 2002). Dijksta and van Heuven (2002) introduced a Bilingual Interactive Activation+ (BIA+) model. In this BIA+ model, Dijkstra and van Heuven propose bilingual word recognition to occur in a *language non-selective* manner, with cross-linguistic integration in the bilingual lexicon. The recognition of words in one of the languages known by bilinguals appears to be automatically affected by lexical knowledge of the other language known by participants.

1.1.3 *Bilingual deaf children*

Thus far, printed word recognition in deaf people has received relatively little attention. This is particular true with regard to possible bilingual interactive activation during word recognition, i.e., the role for sign language activation during word recognition. Many deaf children grow up in a bilingual environment. One language is a sign language and the other language is a spoken/written language. Crucially, only approximately 5 % of deaf children have deaf parents (Mitchell & Karchmer, 2004). As a consequence, most deaf children, i.e., in particular deaf children who do not have deaf parents, do not have full access to a sign language during the first few years of their lives (Chamberlain & Mayberry, in press). Spoken language is generally not easily accessible for deaf children as a result of the hearing impairment. Initial language input, whether it is a spoken language or a sign language, is therefore reduced in many deaf children (Mayberry, 2002; Spencer & Lederberg, 1997). Nevertheless, before deaf children enter bilingual programs in schools for the deaf, the children are generally already exposed to both languages in early intervention programs.

Currently, one of the important questions to pose if we want to disentangle the cause of reading difficulties for deaf children is: What *codes* are being activated during word recognition by deaf children? Whereas a number of studies investigated *phonological coding* during word recognition by bilingual deaf children (e.g., Harris & Beech, 1998; Miller, 2006; Waters & Doehring, 1990), only very few studies investigated *sign coding* during reading by deaf children.

In particular for deaf children who are educated in bilingual programs, sign coding seems a realistic prospect. Visual word recognition can theoretically occur in a language non-selective manner in deaf signers if non-selective language access occurs for not only spoken languages with associated writing systems, but also for the combination of a signed language with a spoken/written language, and thus for two languages with minimal overlap. To gain insight in the word decoding processes of deaf children, it is important to examine whether signs and written words function in a non-selective way during word recognition.

Equally important to answer this same question of how deaf children decode written words is the extent deaf children use phonology of the spoken language during word recognition. Phonology has long been perceived as fulfilling a key role during word recognition in hearing children. Conflicting evidence was found between different studies into the role of phonology in deaf children. Phonological codes are evidently difficult to achieve for deaf children as a consequence of limited access to sounds (Beech & Harris, 1997; Knoors, 2001). There is a major difference between word recognition in hearing and in deaf children: generally, deaf children cannot easily access word meanings as soon as a grapheme-phoneme coupling skill is mastered. That is, deaf children often have no extensive spoken vocabulary to map the decoded written words on to, like hearing children do (Paul, 1996; Kelly, 2003).

As a consequence of the limited access to sounds for deaf children, the three components involved in reading: orthography, phonology, and semantics (Bosman & van Hell, 2002) might play a somewhat different role for bilingual deaf children compared to hearing children. In addition to these three components, a fourth component may affect word recognition in bilingual deaf children: sign.

In support of the possible involvement of signs, Perfetti and Sandak (2000) suggested that deaf readers who cannot profit sufficiently from phonological coding may use visual information (orthography), semantic information gained from context (semantics) and also sign information (sign) as back-up systems. According to Perfetti and Sandak (2000), sign coding can perhaps be considered as manual motor support during reading for deaf individuals, comparable to phonological coding serving the purpose of speech motor articulation support in hearing individuals.

The precise role for sign coding during visual word recognition in bilingual children is an important question to study. Additional important questions concern the contribution of spoken language phonology and semantics to visual word recognition by deaf children. Moreover, given the importance of fluent word and text reading, it is important to examine the way phonology, signs, and semantics interact during fluent word and text reading. In the following section on coding mechanisms, the possible roles of spoken phonology (1.2.1) and of sign language (1.2.2) are discussed in visual word recognition of deaf children, followed by the possible contribution of semantics (1.2.3).

1.2 *Coding mechanisms in deaf children*

1.2.1 *Phonological coding*

In hearing children, phonology is found to be the essential skill for achieving good reading proficiency levels (Perfetti & Sandak, 2000; van Orden, 1987). Whether this is also true for deaf children is still unclear. A number of studies investigated the possibility of applying phonological information during reading in deaf children, adolescents, and adults. These studies provide evidence that deaf students can indeed utilize phonology (Alegria, 1998; Hanson & Fowler, 1987; Transler, Gombert, & Leybaert, 2001). Although some older deaf children do use phonological coding during reading (Leybaert, 1993; Transler et al., 2001), the use of phonology by young deaf children appears to lag far behind the use of phonology by hearing children (Beech & Harris, 1998; Marschark et al., 2002; Waters & Doehring, 1990). Perfetti and Sandak (2000) argued that different findings of phonological coding mainly reflect differences in backgrounds of participants, in addition to differences between tasks in various studies.

To achieve phonological knowledge, in spite of the lack of auditory input, several possibilities have been mentioned in the literature, including speech-reading, articulation, residual hearing, finger spelling and cued speech (Alegria, 1998; Marschark et al., 2002). Both Waters and Doehring (1990) and Kelly (1995) indicate that deaf children can use phonological coding during printed word recognition. However, this ability of phonological coding was unrelated to reading achievement. In addition, whereas the degree of hearing loss is indicative of the degree of access to phonological information for children who are hard of hearing, this is not true for children who are profoundly deaf (Marschark et al., 2002).

Hermans, Knoors, Ormel, and Verhoeven (2008) argue that phonological coding during word recognition is expected to be beneficial not only for hearing children but for deaf children also, even though it may seem a parsimonious effort. At the same time, it is important to realise that phonological knowledge appears to be developing less effectively in deaf children compared to hearing children (Perfetti & Sandak, 2000). Phonological knowledge may be largely based on speech reading instead of based on sounds.

1.2.2 *Sign coding*

For deaf readers, there may be an additional component to orthography, phonology, and semantics: sign. If so, it is important to study the way signs may influence visual word recognition. Results of some studies that examined the activation of sign language knowledge during the reading process suggest that deaf signers use sign information when (sentence) reading (e.g., Mayberry, Chamberlain, Waters, & Hwang, 2003; Treiman & Hirsh-Pasek, 1987). However, contradictory results were found in other studies (e.g., Hanson & Feldman, 1989; 1991).

Signs may contribute to visual word recognition through lexical mediation, resulting from the connection between words and signs, but also through sub-lexical sign phonological mediation, as a result of competing lexical items with overlapping combinations of sub-lexical sign phonological features. Individual signs in all sign languages contain several phonological parameters. The most important and most frequently reported phonological parameters include hand shape, movement of hands and arms, location of hands towards the body, and hand-palm orientation (Emmorey & Corina, 1990). In various studies, evidence has been provided for the presence of sub-lexical sign information, analogous to sub-lexical phonological information. Stokoe, Caserline, and Croneberg (1965, in Klima & Bellugi, 1979) were pioneers in establishing the existence of sub-lexical sign information. Next, Klima and Bellugi (1979) uncovered the important role for (sub-lexical) sign phonology in the memory system for deaf people. In hearing people, the phonological loop is an important component of the memory system. In deaf people, a similar loop has been found using (sub-lexical) sign phonology for deaf signers (Emmorey & Corina, 1990; Wilson & Emmorey, 1997). Additional evidence for the use of sub-lexical sign features in memory was provided by showing that signs are recognized faster when there was an overlap between certain combinations of sign phonemes and sign morphemes (Dye & Shi, 2006; Hildebrandt & Corina, 2002).

Hanson and Feldman (1989) investigated possible sign activation during visual word recognition. One of the aims of their study was to examine the lexical organisation of the spoken language, in their case English, in connection to American Sign Language. No evidence was found for sub-lexical sign activation during visual word recognition. Because of the small number of studies in this area of research and the conflicting results, no clear-cut conclusions about the activation of sign during visual word recognition may be drawn.

Not only sign phonology should be taken into account in studying the contribution of signs during visual word recognition, iconicity could be another important variable. In iconic signs, there is considerable transparency between form of the sign and meaning, e.g., related to a form characteristic of an object or to the function of an object. In spoken languages, onomatopoeia are examples of iconic words. According to Emmorey (2002) and van der Kooij (2002), parts of signs are more directly related to meaning than spoken words. Strongly iconic signs may therefore be processed differently from non- or weakly iconic signs. Thus, if sign iconicity plays a role during visual word recognition, words with strong iconic sign translation equivalents might be processed differently from words with non- or weak iconic sign translation equivalents.

If signs are activated while reading Dutch, the implication is that deaf children activate word meanings in a language non-selective way. The study of language non-selectivity in the case of word recognition processes in deaf bilinguals is a strong test for language non-selectivity in general. If a sign language and a written language become non-selectively activated during visual word recognition, many more languages are likely to be processed in a non-selective manner.

1.2.3 *The role of semantic knowledge*

In the literature concerning hearing readers, a relationship has been found between word recognition and reading levels on the one hand, and semantic knowledge on the other hand (e.g., Ben-Dror, Bentin, & Frost, 1995; Howell & Manis, 1986). Given this relationship it seems logical to assume that semantic knowledge supports reading in deaf children too. However, this has not been studied intensively in deaf children.

Before the possible contribution of semantic activation to visual word recognition processes in deaf children is examined, it is necessary to examine the state of semantic knowledge in these children. Only a limited number of studies examined semantic knowledge in deaf adults, and even less in deaf children. Studies into *categorical* knowledge in deaf people, particularly children, are even more restricted, and this topic is rarely studied in relation to reading levels.

Courtin (1997), Liben (1979) and also Tweney, Hoemann, and Andrews (1975) examined semantic organization in deaf children and deaf adolescents. Courtin (1997) studied native signing deaf children. Semantic categorization differences were found between the deaf signing children and the hearing children; categorization of the deaf children was clearly affected by sign language structures, which was evidently not seen in the hearing children. Liben (1979) and Tweney et al. (1975) studied recall of information and used highly familiar stimuli in a semantic categorisation test with deaf and hearing children. Both found that the deaf children were less likely to use the categorical information in recall than hearing children. Moreover, whenever the deaf children used categorical information, recall levels were below the levels of the hearing children.

MacSweeney, Grossi and Neville (2004) studied semantic knowledge in deaf students and deaf adults. Similar to results for deaf children, their results showed that deaf signing adults process semantic information differently from hearing adults. MacSweeney et al. (2004) carried out an ERP study in deaf adults using unmasked and masked priming. Results from unmasked priming showed similar priming effects for deaf and hearing participants. However, the results from masked priming, testing more automatic processes of semantic information, were different for deaf adults when compared to hearing adults. No traditional priming effects were observed for the deaf adults.

As far as we know, Marschark, Convertino, McEvoy, and Masteller (2004) were the first to relate deaf students' semantic knowledge of categories to their reading levels. Marschark et al. (2004) found that category knowledge seemed less coherently organised in deaf participants and this knowledge was less accessible to them. The deaf participants performed more heterogeneously than the hearing participants (see also McEvoy, Marschark,

& Nelson, 1999). Moreover, the deaf participants showed more difficulties than hearing participants when drawing links from category names to exemplars. Compared to the poor readers, the participants with better reading levels showed semantic performance more similar to the hearing participants. According to Marschark et al. (2004), semantic relations, and in particular categorical relations, play an essential role in reading comprehension. Although semantic knowledge in relation to reading is important, this topic was only superficially addressed in the study by Marschark et al. (2004). Therefore, it is important to further examine the connections between categorization skills and reading in deaf participants.

1.3 *Predictors of word and text reading fluency*

In order to be able to read successfully, word decoding processes ought to be applied automatically (Kelly, 1995). If word recognition occurs with low fluency, as is the state of affairs for many deaf children (Knoors, 2001), meanings of words read earlier in a sentence might already have been forgotten (Kelly, 2003; Marschark et al., 2001). The *fluency* of the word recognition process does appear to affect the reading process of deaf children to a major extent (Kelly, 1995; 2003).

In hearing children, phonology plays a key function in the acquisition of fluent reading (Bosman & de Groot, 1996; Bosman & van Hell, 2002; Perfetti & Sandak, 2000; van Orden, 1987). In studies with deaf children, the contribution of a number of variables has been examined in relation to word and text reading. As Harris and Beech (1998) stated adequately, various factors have been proposed as contributors for reading of deaf children, and many of these factors might be important to become a good reader, e.g., phonological awareness, orthographic knowledge, vocabulary knowledge, finger spelling, speech reading, and short term memory. Harris and Beech (1998) were among the first to conduct a study in which a series of predictors towards reading was examined simultaneously. This way, the *relative contribution* of each of the predictive variables could be examined. In their 1998 study, phonological awareness, letter orientation, finger spelling, signing ability, oral ability, language comprehension, and single word recognition tests were administered to deaf children. Part of the variation in reading was predicted by phonological awareness, oral skills, and language comprehension. In another study, Kyle and Harris (2006) tested vocabulary, short term memory for pictures, phonological awareness, speech reading, reading, and spelling. The results of the deaf children suggested that productive vocabulary and speech reading skills were the strongest predictors of reading. In both studies, part of the children was educated with sign language, and another part of the children was educated in oral environments.

Even though an impressive series of variables was assessed in each of these studies, a selection of possible predictors inevitably had to be made. Moreover, the different studies did not focus upon reading *fluency*. The selection of predictors together with the limited number of studies of this type implies that the question of what skills are *most* predictive for word and text reading fluency of deaf children may only partly be answered at this moment. This is particularly true for deaf children in bilingual education settings. In the following section, a number of possible predictors of reading in deaf children are discussed successively.

According to Hermans, Knoors, Ormel, and Verhoeven (accepted for publication), the relation between sign language and reading can to a great extent be explained at the level of sign vocabulary and written vocabulary. Various other studies have reported that vocabulary is one of the most important variables for the development of reading (Paul, 1996; Mayberry, 2002), whether it be sign, speech, or written words. Furthermore, vocabulary entails receptive as well as productive proficiency. Given the deafness, receptive vocabulary of spoken words involves a large emphasis on speech reading skills, at least for children who do not have a Cochlear Implant. Mayberry (2002) provided an overview of studies into vocabulary development in deaf children. Every study mentioned by Mayberry showed that deaf children are generally delayed in vocabulary acquisition, which is related to a significantly delayed language growth. Interestingly, delays are often already apparent from an early age. Evidently, severe delays in vocabulary growth have great implications for the development of reading in deaf children.

A second important variable for reading is finger spelling. Padden and Ramsey (2002) found that teachers often explicitly link written words, finger spelling, and signs together during reading instruction. It therefore seems very likely that finger spelling plays a major role in deaf children's early reading development. Unfortunately, only a very few studies have examined the relations between finger spelling and reading (but see Harris & Beech, 1998; Treiman & Hirsh-Pasek, 1987). Although finger spelling does not seem to be used as an effective coding mechanism during reading (Treiman & Hirsh-Pasek, 1987), it could increase alphabetic knowledge, which in turn could affect phonemic awareness (Hirsh-Pasek, 1987). Hirsh-Pasek proposed that reading success increases once deaf children can segment and manipulate their finger spelled lexicons. Finger spelling might, in fact, serve as a platform for the development of phonological coding (Marschark et al., 2002).

A third important variable is phonological awareness. According to Harris and Beech (1998) not phonetic abilities but implicit phonological awareness, the ability to divide words into syllabic and sub-syllabic units, appeared to be predictive for later word recognition levels in deaf children, at least for orthographically irregular languages. Implicit phonological awareness generally develops before children learn to read (Harris & Beech, 1998). In the Harris and Beech study, 18 sets of pictures were used, 6 involving the same initial sound, 6 the same middle sound, and 6 the same final sound. Each set contained three pictures. The experimenter showed the child the first item, and named it. The child was then asked to indicate which of the remaining two pictures, which were also named by the child, had a similar name to the first one. Results showed that the deaf children performed above chance (see also Sterne & Goswami, 2000). Wolf, O'Rourke, Gidney, Lovett, Cirino, and Moris (2002) found similar predictive values for phonological awareness skill towards reading ability in hearing children. Similarly, Dyer, MacSweeney, Szcerbinski, Green, and Campbell (2003) found that phonological awareness was a factor in reading achievement in deaf as well as hearing adolescents.

Izzo (2002) and Miller (1997) investigated phonemic awareness at the alphabetic level, instead of phonological awareness at the syllable or sub-syllable level. Moreover, rather than using three pictures per set, Izzo and Miller used four illustrated items per set. Both studies included words for which target sounds were either orthographically similar (the children were not necessarily focusing on the sounds) or dissimilar to the target word (the children were necessarily focusing on the sounds). Izzo (2002) found that phonemic awareness was not significantly correlated to reading ability. Alternatively, in a study with Hebrew readers, Miller (1997) found phonemic awareness to be correlated to reading in hearing and orally educated deaf participants but not in signing deaf participants. Nevertheless, the two deaf participant groups in Miller's study did not differ in phonemic awareness. Reading ability in the signing group was, furthermore, equal to the level in the hearing group, and higher than the level in the oral deaf group. According to Izzo, the correlations between reading ability and sign language measures suggest that the better readers may be using orthographic codes, sign codes, and visual codes, rather than phonological codes. Miller (1997) found analogous results.

A fourth important variable for reading is memory. For sentence reading, memorizing the subsequent words is a prerequisite for full comprehension (Kelly, 2003). This prerequisite implies an important role for short term memory of sequential information. In many deaf children, short term memory for sequential information is limited. One possible explanation for this limited memory ability concerns auditory experience, which is known to facilitate memory for sequences (e.g., Marschark et al., 2002; Mayberry, 2002). Mayberry additionally assigns the lack of linguistic familiarity with items that have been used in the tasks as one of the explanations for limited short term memory results for deaf people. Interestingly, deaf children do not show overall limited memory skills; deaf children have shown to outperform hearing children when it concerns spatial memory tasks (Wilson, Bettger, Niculae, & Kima, 1997).

For bilingual deaf children, it is arguable that sub-lexical sign knowledge (knowledge of hand shape, movement, and location) is a fifth possible important variable contributing to (word and text) reading (see 1.4.2).

1.4 *The present thesis*

1.4.1 *Educational context*

Deaf children in the Netherlands participated in the present studies. These children received bilingual deaf education. During the last two decennia, all schools for the deaf in the Netherlands have introduced bilingual deaf education. Within the bilingual settings, the curriculum consists of a combination of Sign Language of the Netherlands (SLN) and Sign Supported Dutch (SSD). SSD is a combination of Dutch and SLN (Terpstra & Schermer, 2006). Like most sign languages, SLN has a different grammar when compared to the spoken language. In the bilingual programs in the Netherlands, a specialized deaf teacher usually provides SLN instruction to all children for several hours each week. In the classrooms, the languages of instruction are SLN and SSD. Before children enter the schools at the age of three, many already attended a specialized early intervention program from the moment of diagnosis of deafness or soon after that.

The present study concerns deaf children in schools for the deaf only. Thirty percent of deaf children in the Netherlands attend mainstream elementary education (Simea, 2007). For some of these children, the foremost reason for attending a mainstream school is related to having a Cochlear Implant, a technical devise for deaf people who have a sensorineural hearing loss, which generally increases access to sounds. A growing number of deaf children receive a Cochlear Implant, often from a very young age (Vermeulen, 2007; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007).

1.4.2 *Linguistic context*

Bilingual deaf education programs in the Netherlands were implemented as part of the development across the world in the mid-nineties of many bilingual-bicultural schools for the deaf (Knoors & Fortgens, 1995). Some of the programs were based on the assumption that skills acquired in the first language (sign language) can transfer to the second language, without the involvement of the second language in its primary form. Deaf children of deaf parents who were exposed to sign language from the start were found to have better academic achievements in comparison to deaf children of hearing parents (Strong & Prinz, 1997, 2000). This finding was one of the justifications for the implementation of bilingual-bicultural programs, in addition to the finding that many deaf children had only limited skills in Dutch and sign language (Knoors & Fortgens, 1995).

As a consequence of the often limited signing skills of hearing parents, many deaf children will be delayed in the acquisition of their signing skills (Boudrault & Mayberry, 2006; Knoors, 1993; Spencer & Harris, 2005; Marschark, Schick, & Spencer, 2005). The sign language is, however, the more accessible language for the children in the vast majority of cases (Klatter-Folmer, van Hout, Kolen, & Verhoeven, 2006; Knoors, 1993; 2007). Reading thus often takes place in a less accessible language for the deaf children, in this particular case Dutch.

1.4.3 *Overview of the dissertation*

The activation of phonology and sign features during the word recognition process was assessed in several experiments. In additional experiments, the contribution of semantic knowledge was examined and related to word and text reading. In a developmental study, the relative contribution of various predictive skills was assessed for word and text reading.

In *Chapter 2*, the results of several experiments are described, examining the activation of phonology during word recognition. In the first experiment in Chapter 2, the automatic use of phonology was studied. To examine to what extent phonology *can* be activated, the use of phonology was encouraged to the children through explicit instruction in the second experiment in Chapter 2. The paradigm used in both experiments was Word-Picture verification.

In *Chapter 3*, the activation of sign features during sign recognition and visual word recognition was examined in different experiments. In the first experiment, the activation of sign phonology and sign iconicity was examined during the process of sign recognition, using a Sign-Picture verification paradigm. Results from the Sign-Picture verification test served as the foundation for the second experiment, examining the activation of sign phonology and sign iconicity during the process of word recognition, using a Word-Picture verification paradigm.

Building on the first series of studies in Chapter 2 and Chapter 3, semantic knowledge and the importance of semantic knowledge for word and text reading were examined. The results are presented in *Chapter 4*. Semantic knowledge of categories was examined at two levels: Exemplar level (both ‘apple’ and ‘apricot’ as part of the category fruit) and sub/superordinate level (‘apple’ as part of the category fruit or vice versa, the category fruit includes ‘apple’). The quality of semantic knowledge was examined for different types of stimuli: written words, pictures, signs (deaf children only), and spoken words (hearing children only). Both levels of semantic knowledge were related to word and text reading.

In *Chapter 5*, the results of a longitudinal study are presented, which provide insight into the contributors towards word and text reading fluency. Children in primary school were assessed during three consecutive years. The influence of several variables which may influence word recognition and text reading fluency are presented. In the present study, speech rhyme (phonological awareness), finger spelling, short term memory, and sign phonological awareness were examined, in addition to the role for sign vocabulary and speech vocabulary.

Finally, in *Chapter 6*, the conclusions of the experiments and the longitudinal study are presented. Specifically, the different studies are discussed in a comprehensive overview.

References

Alegria, J. (1998). The origin and functions of phonological representations in deaf people. In C. J. Hulme, & R. Mahtesha Joshi (Eds.), *Reading and spelling: Development and disorders*. Hawah, New Jersey, Lawrence Erlbaum Associates, 263-286.

Alegria, J., Charlier, B. L., & Mattys, S. (1999). The role of lip-reading and Cued-Speech in the processing of phonological information in French-educated children. European *Journal of Cognitive Psychology, 11(4),* 451-472.

van den Bogaerde, B., & Baker, A. E. (2006). Code mixing in mother-child interaction in deaf families. In: A. E. Baker, & B. van den Bogaerde (Eds), *Language Acquisition, Special Issue of Sign Language and Linguistics*, *8,* 151-174.

Beech, J. R., & Harris, M. (1997). The prelingually deaf young reader: A case of reliance on direct lexical access? *Journal of research in reading, 20(2),* 105-121.

Ben-Dror, I., Bentin, S., & Frost, R. (1995). Semantic, phonologic, and morphologic skills in reading disabled and normal children: Evidence from perception and production of spoken Hebrew. *Reading Research Quarterly, 30,* 876-893.

Bialystok, E., Luk, G., & Kwan, E. (2005). Bilingualism, biliteracy, and learning to read: Interactions among languages and writing systems. *Scientific studies of reading, 9(1),* 43-61.

Bosman, A., & de Groot. A. (1996). Phonologic mediation is fundamental to reading: Evidence from beginning readers. *The Quarterly Journal of Experimental Psychology, 49A(3),* 715-744.

Bosman, A. M. T., & van Hell, J. G. (2002). Orthography, phonology, and semantics. In L. Verhoeven, C. Elbro & P. Reitsma (Eds.). *Studies in Written Language and Literacy, Precursors of Functional Literacy, 11,* 165-187.

Bosman, A. M. T., & van Orden, G. C. (2003). Het fonologisch coherentiemodel voor lezen en spellen, *Pedagogische Studiën*, *80,* 391-406..

Boudrault, P., & Mayberry, R. (2006). Grammatical processing in American Sign Language: Effects of age of first language acquisition and syntactic complexity. *Journal of Language and Cognitive Processes, 21(5),* 608-635.

Chamberlain, C., & Mayberry, R. I. (2000). Theorizing about the relation between American Sign Language and Reading. In C. Chamberlain, J. Morford & R. Mayberry (Eds.), *Language acquisition by eye* (pp. 221-259). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chamberlain, C., & Mayberry, R. I. (in press). ASL syntactic and narrative comprehension in good and poor deaf readers: Bilingual-Bimodal evidence for the linguistic basis of reading.

Coltheart, M., & Rastle, K. (1994). Serial processing in reading aloud: Evidence for dual-route models of reading. *Journal of Experimental Psychology: Human Perception and Performance, 20(6),* 1197-1211.

Corcoran Nielsen, D., & Luetke-Stahlman, B. (2002). Phonological awareness: One key to the reading proficiency of deaf children. *American Annals for the Deaf, 147,* 11-19

Courtin, C. (1997). Does sign language provide deaf children with an abstraction advantage? Evidence from a categorization task. *Journal of Deaf Studies and Deaf Education, 2,* 161 – 171.

Cummins, J. (1981). The role of primary language development in promoting educational success for language minority students. In *Schooling and language minority students: A theoretical framework*. Los Angeles: California State University; Evaluation, Dissemination, and Assessment Center.

Cummins, J. (2006). The Relationship between American Sign Language Proficiency and English Academic Development: A Review of the Research [1]. Paper presented at the conference '*Challenges, Opportunities, and Choices in Educating Minority Group Student.' Norway, October 27.*

Dijkstra, T., Grainger, J., & van Heuven, W. J. B. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Language, 41,* 496-518.

Dijkstra, T., van Heuven, W. J. B., & Grainger, J. (1998). Simulating cross-language competition with the bilingual interactive activation model. *Psychologica Belgica, 38(3/4),* 177-196.

Dijksta, T., & van Heuven, W. J. B. (2002). Modeling bilingual word recognition: Past, present and future. *Bilingualism: Language and Cognition, 5(3),* 219-225.

Dijkstra, T., van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5(3),* 175-197.

D' Hondt, M., & Leybaert, J. (2003). Lateralization effects during semantic and rhyme judgment tasks in deaf and hearing subjects. *Brain and Language, 87,* 227-240.

Dye, M. W. G., & Shih, S. (2006). Phonological priming in British Sign Language. *Laboratory Phonology 8.* Goldstein, L. M. L. M., Whalen, D. H., & Best, C. T., Berlin: Mouton de Gruyter.

Dyer, A., MacSweeney, M., Szczerbinski, M., Green, L., & Campbell, R. (2003). Predictors of reading delay in deaf adolescents: The relative contributions of rapid automatizated naming speed and phonological awareness and decoding. *Journal of Deaf Studies and Deaf Education, 8(3),* 215-229.

Emmorey, K. (2002). *Language, cognition, and the brain: Insights from sign language research.* Mahwah, New Jersey, London: Lawrence Erlbaum Associates, Publisher.

Emmorey, K., & Corina, D. (1990). Lexical recognition in sign language: Effects of phonetic structure and morphology. *Perceptual and Motor skills, 71,* 1227-1252.

Gaustad, M. G. (2000). Morphological analysis as a word identification strategy for deaf readers. *Journal of Deaf Studies and Deaf Education, 5(1),* 60-80.

Goldin-Meadow, S., & Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research and Practice, 16(4),* 221-228.

de Groot, A. M. B., Delmaar, P., & Lupker, S. J. (2000). The processing of interlexical homographs in translation recognition and lexical decision: Support for nonselective access to bilingual memory. *Quarterly Journal of Experimental Psychology, 53(A),* 397-428.

Hanson, V. L., & Feldman, L. B. (1989). Language specificity in lexical organization: Evidence from deaf signers' lexical organization of American Sign Language and English. *Memory & Cognition, 17(3),* 292-301.

Hanson, V. L., & Feldman, L. B. (1991). What makes signs related? *Sign Language Studies, 70,* 35-46.

Hanson, V. L., & Fowler, C. A. (1987). Phonological coding in word reading: Evidence from hearing and deaf readers. *Memory & Cognition, 15(3),* 199-207.

Harris, M., & Beech, J. R. (1998). Implicit phonological awareness and early reading development in prelingually deaf children. *Journal of Deaf Studies and Deaf Education, 3*, 205-216.

Harris, M., & Moreno, C. (2006). Speech reading and learning to read: A comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education*, *11*, 189-201.

Hermans, D., Bongaerts, T., de Bot, K., & Schreuder, R. (1998). Producing words in a foreign language: Can speakers prevent interference from their first language? *Bilingualism: Language and Cognition, 1*, 412-431.

Hermans, D., Knoors, H., & Verhoeven, L. (2007). Testbatterij voor de Nederlandse Gebarentaal [Assessment tool for Sign Language of the Netherlands].

Hermans, D., Knoors, H., Ormel, E., & Verhoeven, L. (in preparation). Spoken and sign language development for bilingual deaf children in the Netherlands: A case of Linguistic Interdependence or Linguistic Independence?

Hermans, D., Knoors, H., Ormel, E., & Verhoeven, L. (2008). A model of reading vocabulary acquisition for deaf children in bilingual education programs. *Journal of Deaf Studies and Deaf Education*, *13*, 155-174.

Hermans, D., Knoors, H., Ormel E., & Verhoeven, L. (accepted for publication). The relation between the reading and signing skills of deaf children: the role of vocabulary, Advance access published on April 8, 2008. doi.10.1093/deafed/enn009.

van Heuven, W. J. B., & Dijkstra, T. (1998). Orthographic Neighborhood Effects in Bilingual Word Recognition*. Journal of Memory and Language, 39*, 458-483.

Hildebrandt, U., & Corina, D. (2002). Phonological similarity in American Sign Language. *Language and Cognitive Processes*, *17(6),* 593-612.

Hirsh-Pasek, K. (1987). The metalinguistics of fingerspelling: An alternative way to increase reading vocabulary in congenitally deaf readers. *Reading Research Quarterly, 22*, 455-474.

Hoffmeister, R. (2000). A piece of the puzzle: ASL and reading comprehension in deaf children. In C. Chamberlain, J. Morford & R. Mayberry (Eds.*), Language acquisition by eye* (pp. 143-163). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hoover, W. A., & Gough, P. G. (1990). The simple view of reading. Reading and Writing: *An interdisciplinary Journal, 2,* 127-160.

Howell, M. J., & Manis, F. R. (1986). Developmental and reader ability differences in semantic processing efficiency. *Journal of Educational Psychology, 78(2),* 124-129.

Israelite, N., Ewoldt, C., & Hoffmeister, R. (1992). *Bilingual-bicultural education for deaf and hard-of-hearing students*. Toronto, Ontario: MGS Publications Services.

Izzo, A. (2002). Phonemic awareness and reading ability: An investigation with young readers who are deaf. *American Annals of the Deaf, 147(4),* 18-28.

Kelly, L. (1995). Processing of bottom-up and top-down information by skilled and average deaf readers and implications for whole language instruction. *Exceptional Children, 61*(*4*), 318-334.

Kelly, L. (2003). The importance of processing automaticity and temporary storage capacity to the differences in comprehension between skilled and less skilled college-age Deaf readers. *Journal of Deaf Studies and Deaf Education, 8(3),* 230-249.

Klatter-Folmer, J., van Hout, R., Kolen, E., & Verhoeven, L. (2006). Language development in deaf children‘s interactions with deaf and hearing adults: A longitudinal study. *Journal of Deaf Studies and Deaf Education, 11(2),* 238-251.

Klima, E. S., & Bellugi, U. (1979). *The signs of language.* Cambridge, MA, Harvard University Press.

Knoors, H. (1993). Over realiteiten en verwachtingen, voetangels en klemmen. Taalkundige overwegingen bij een tweetalig scholingsconcept voor dove kinderen [About realities and expectations, pitfalls and traps. Linguistic considerations for a bilingual schooling concept for deaf children]. *VEDON*, 31-39.

Knoors, H. (2001). Taalontwikkelingsstoornissen ten gevolge van doofheid [Language Development Disorders as a result of deafness]. *Stem-Spraak-Taalpathologie*, *16,* 3-31.

Knoors, H. (2007). Educational Responses to Varying Objectives of Parents of Deaf Children: A Dutch Perspective. *Journal of Deaf Studies and Deaf Education*, *12*, 243-253.

Knoors, H., & Fortgens, C. (1995). Het Rotterdamse tweetaligheidsproject: twee talen voor dove kleuters [The Rotterdam bilingualism project: two languages for deaf children in kindergarten]. *Van Horen Zeggen*, 4-11.

van der Kooij, E. (2002). *Phonological categories in Sign Language of The Netherlands: The role of phonetic implementation and iconicity.* Utrecht: LOT.

Kroll, J. F., Bobb, S. C., & Wodniecka, Z. (2006). Language selectivity is the exception, not the rule: Arguments against a fixed locus of language selection in bilingual speech. *Bilingualism: Language and Cognition*, *9*, 119-135.

Kroll, J., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*, 149-174

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education*, *11*, 273-288.

Leybaert, J. (1993). Reading in the deaf: The roles of phonological codes. *Psychological perspectives on deafness*. In M. Marschark & M. D. Clark (Eds.), Hillsdale, New Jersey, Lawrence Erlbaum Associates, Publishers, 269-308.

Leybaert, J., & Alegria., J. (1993). Is word processing involuntary in deaf children? *British Journal of Developmental Psychology, 11,* 1-29.

Leybaert, J., & Alegria, J. (1995). Spelling development in deaf and hearing children: Evidence for use of morpho-phonological regularities in French. *Reading and Writing: An interdisciplinary Journal, 7,* 89-109.

Leybaert, J., & Charlier, B. (1996). Visual speech in the head: The effect of Cued-Speech on rhyming, remembering, and spelling. *Journal of Deaf Studies and Deaf Education, 1(4),* 234-248.

Liben, L. S. (1979). Free recall by deaf and hearing children: Semantic clustering and recall in trained and untrained groups. *Journal of Experimental Child Psychology*, *27*, 105-119.

MacSweeney, M., Calvert, G. A., Campbell, R., McGuire, P. K., David, A. S., Williams, S. C. R., Woll, B., & Brammer, M. J. (2002a). Speechreading circuits in people born deaf. *Neuropsychologia*, *40*, 801-807.

MacSweeney, M., Campbell, R., & Donlan, C. (1996). Varieties of short-term memory coding in deaf teenagers. *Journal of Deaf Studies and Deaf Education, 1(4),* 249-262.

MacSweeney, M., Woll, B., Campbell, R., McGuire P. K., David, A. S., Williams, S. C. R., Suckling, J., Calvert, G. A., & Brammer, M. J. (2002b). Neural systems underlying

British Sign Language and audio-visual English processing in native users. *Brain and Language, 7,* 1583-1593.

MacSweeney, M., Grossi, G., & Neville, H. (2004). Semantic priming in deaf adults: An ERP study. *Proceedings at the Cognitive Neuroscience Society Annual Meeting*, San Francisco.

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, *6*: 1-19.

Marschark, M. (1993). Origins and Interactions in the social, cognitive, and language development of deaf children. In M. Marschark & M. D. Clarke (Eds.). *Psychological perspectives on deafness*. Hillsdale, New Jersey, Lawrence Erlbaum Associates.

Marschark, M., & Harris, M. (1996). Success and failure in learning to read: The special(?) case of deaf children. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and Intervention* (pp 279-300). Mahwah, NJ, Lawrence Erlbaum Associates.

Marschark M., & Mayer, T. (1998). Mental representation and memory in deaf adults and children. *Canadian Journal of Psychology, 39*, 145-148.

Marschark, M., Lang, H. G., & Albertini, J. A. (2002). *Educating deaf students: From research to practice*. New York: Oxford University Press.

Marschark, M., Schick, B., & Spencer, P. (2005). Understanding sign language development in deaf children. In B. Schick, M. Marschark, & P. Spencer (Eds.), *Advances in sign language development of deaf children* (pp. 3-19). New York, NY: Oxford University Press.

Marschark, M., Convertino, C., McEvoy, C., & Masteller, A. (2004). Organization and use of the mental lexicon by deaf and hearing individuals. *American Annals of the Deaf, 149(1)*, 51-61.

Mayberry, R. I. (2002). Cognitive development in deaf children: The interface of language and perception in neuropsychology. In S. J. Segalowitz, & Rapin, *Handbook of Neuropsychology*, I. Amsterdam: Elsevier. *Vol. 8, Part II:* 71-107.

Mayberry, R. I., Chamberlain, C., Waters, G., & Doehring, D. (in prep). Reading development in relation to signed language input and structure.

Mayberry, R. I., Chamberlain, C., Waters, G., & Hwang, P. (2003). *Word recognition in children who use signed language*. Paper presented at the Boston University Conference on Language Development, Boston.

Mayer, C., & Akamatsu, C. (1999). Bilingual-bicultural models of literacy education for deaf students: Considering the claims. *Journal of Deaf Studies and Deaf Education*, *4*, 1-8.

Mayer, C., & Wells, G. (1996). Can the linguistic interdependence theory support a bilingual-bicultural model of literacy education for deaf students? *Journal of Deaf Studies and Deaf Education*, *1*, 93-107.

McEvoy, C., Marschark, M., & Nelson, D. L. (1999). Comparing the mental lexicons of deaf and hearing individuals. *Journal of Educational Psychology, 91,* 1-9.

Merrills, J. D., Underwood, G., & Wood, D. J. (1994). The word recognition skills of profoundly, prelingually deaf children. *British Journal of Developmental Psychology , 12,* 365-384.

Mitchell, R. E., & Karchmer, M. (2004). Chasing the mythical 10 percent: Parental hearing status of deaf and hard of hearing students in the United States. *Sign Language Studies, 4(2),* 138-163.

Miller, P. (1997). The effect of communication mode on the development of phonemic awareness in prelingually deaf students. *Journal of Speech, Language, and Hearing Research, 40,* 1151-1163.

Miller, P. (2006). What the processing of real words and pseudohomophones can tell us about the development of orthographic knowledge in prelingually deafened individuals. *Journal of Deaf Studies and Deaf Education, 11(1),* 21-38.

Musselman, C. (2000). How do children who can't hear learn to read an alphabetic script: A review of the literature of reading and deafness. *Journal of Deaf Studies and Deaf Education, 5(1),* 9-31.

Neville, H. J., Bavelier, D., Corina, D., Rauschecker, J., Karni, A., Lalwani, A., Braun, A., Clark, V., Jezzard, P., & Turner, R. (1998). Cerebral organization for language in deaf and hearing subjects: Biological constraints and effects of experience. *Proceedings of the National Academy of Sciences of the United States of America, 95(3),* 922-929.

van Orden, G. C. (1987). A ROWE is a ROSE: Spelling, sound, and reading. *Memory and Cognition*, *15*, 181-198.

van Orden, G. C., Bosman, A. M. T., Goldinger, S. D., & Farrar IV, W. T. (1997). A recurrent-network account of reading, spelling, and dyslexia. In J. W. Donahoe & V. Packard Dorsel (Eds.), *Neural Network Models of Cognition*, *522-538*, Amsterdam, The Netherlands: Elsevier Science BV.

Padden, C., & Ramsey, C. (2000). American Sign Language and reading ability in deaf children. In C. Chamberlain, J. Morford & R. Mayberry (Eds.*), Language acquisition by eye* (165-189). Hillsdale, NJ: Lawrence Erlbaum Associates.

Parisot, A-M., Dubuisson, L., Lelievre, A., Vercaingne-Menard, A., & Villeneuve, S. (2005). Bilingualism and deafness: Correlations between deaf students mastery of Quebec Sign Language (LSQ) and their performance in reading French. *Paper presented at the fifth international symposium of bilingualism*, Barcelona.

Paul, P. V. (1996). Reading vocabulary knowledge and deafness. *Journal of Deaf Studies and Deaf Education*, *1*, 3-15.

Paul, P. (1998*). Literacy and deafness: The development of reading, writing and literate thought*. Needham Heights, MA: Allyn & Bacon.

Paul, P. (2003). Processes and components of reading. In M. Marschark, & P. E. Spencer (Eds.), *Oxford Handbook of Deaf Studies, Language, and Education.* New York, Oxford University Press.

Perfetti, C., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for deaf readers. *Journal of Deaf Studies and Deaf Education*, *5*, 32-50.

Poulisse, N., & Bongaerts, T. (1994). First language use in second language production. *Applied Linguistics*, *15*, 36-57.

Rodda, M., Cumming, C., & Fewer, D. (1993). Memory, Learning and Language: Implications for deaf education. In M. Marschark, & M. D., Clark (Eds.*), Psychological perspectives on deafness*. New Jersey: Erlbaum.

Simea (2007). Hearing impairments, specific language impairments, and multiple impairments: Student numbers. Bureau Audcom, April.

Spencer, P. E., & Harris, M. (2005). Pattern and effects of language input to deaf infants and toddlers from deaf and hearing mothers. In B. Schick, M. Marschark, & P. Spencer (Eds.). *Advances in sign language development of deaf children* (pp. 71-101). New York, NY: Oxford University Press.

Spencer, P. E., & Lederberg, A. (1997). Different modes, different models: Communication and language of young deaf children and their mothers. In L. Adamson & M. Romski (Eds.), *Communication and language acquisition. Discoveries from atypical development* (pp. 203-230). Baltimore: Paul H. Brookes.

Sterne, A., & Goswami, U. (2000). Phonological awareness of syllables, rhymes and phonemes in deaf children. *Journal of Child Psychology and Psychiatry, 41 (5)*, 609-625.

Strong, M., & Prinz, P. M. (1997). A study of the relationship between ASL and English literacy. *Journal of Deaf Studies and Deaf Education, 2*, 37-46.

Strong, M., & Prinz, P. M. (2000). Is American Sign Language related to English Literacy? In C. Chamberlain, J. Morford & R. Mayberry (Eds.), *Language acquisition by eye* (pp. 131-141). Hillsdale, NJ: Lawrence Erlbaum Associates.

Terpstra, A., & Schermer, T. (2006). Wat is NmG en waarom gebruik je het? Is er een norm voor “goed” NmG gebruik? [What is NmG and why do you use is? Is there a norm for “good” use of NmG?] *Van Horen Zeggen*, 10-17.

Transler, C., Gombert, J. E., & Leybaert, J. (2001). Phonological decoding in severely and profoundly deaf children: Similarity judgment between written pseudowords. *Applied Psycholinguistics, 22,* 61-82.

Transler, C., Leybaert, J., & Gombert, J. (1999). Do children use phonological syllables as reading units? *Journal of Deaf Studies and Deaf Education, 4*, 124-143.

Tweney, R. D., Hoemann, H. W., & Andrews, C. E. (1975). Semantic organization in deaf and hearing subjects. *Journal of Psycholinguistic Research, 4(1),* 61-73.

Treiman, R., & Hirsh-Pasek, K. (1983). Silent reading: Insights from second-generation Deaf readers. *Cognitive Psychology, 15,* 39-65.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45(1),* 2-40.

Verhoeven, L. (1994). *Ontluikende geletterdheid: Een overzicht van de vroege ontwikkeling van lezen en schrijven* [Exposing literacy: An overview of the early development of reading and writing], Swets en Zeitlinger.

Vermeulen, A. M. (2007). Reading comprehension in children with cochlear implants. PhD thesis.

Vermeulen, A. M., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with cochlear implants. *Journal of Deaf Studies and Deaf Education, 12(3)*, 283-302.

Waters, G. S., Doehring, D. G. (1990). Reading acquisition in Congenitally Deaf Children Who Communicate Orally: insights from an Analysis of Component Reading, Language, and Memory Skills. In Carr, T. H., & Levy, B. A. (Eds.), *Reading and its development*, San Diego, Academic Press**,** 323-373.

Wauters, L. N., van Bon, W., & Tellings, A. (2006). Reading comprehension of Dutch deaf children. *Reading and Writing, 19,* 49-76.

Wauters, L. N., van Bon, W. H. J., Tellings, A. E. J. M., & van Leeuwe, J. F. J. (2006). In Search of Factors in Deaf and Hearing Children's Reading Comprehension. *American Annals of the Deaf,* (3), 371–80.

Wilson, M., Bettger, J. G., Niculae, I., Klima, E. S. (1997). Modality of language shapes working memory: Evidence from digit span and spatial span in ASL signers. *Journal of Deaf Studies and Deaf Education, 2*, 150-160.

Wilson, M., & Emmorey, K. (1997). Working memory of sign language: A window into the architecture of the working memory system. *Journal of Deaf Studies and Deaf Education, 2(3),* 123-132.

Wolf, M., O'Rourke, A. G., Gidney, C., Lovett, M., Cirino, P., & Moris, R. (2002). The second deficit: An investigation of the independence of phonological and naming-speed deficits in Developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal, 15,* 43-73.

Phonological Activation during Visual Word Recognition in Deaf and Hearing Children

Chapter 2

Abstract

The role of phonological activation during visual word recognition was studied in deaf bilingual and hearing children in two Picture-Word Verification experiments. Deaf bilingual children in grade 5 mastering both Sign Language of the Netherlands and Dutch, as well as hearing children in grades 3 and 5 participated in the study. The word stimuli presented were pseudohomophones, orthographic control words, and filler words. In Experiment 1, the task was to indicate whether the word presented was spelled correctly and whether it corresponded to the picture. While the pseudohomophones sounded like the words depicted by the line drawings, they had to be rejected. That is, task performance was *hindered* by phonological recoding of the words. In Experiment 2, the task was to indicate whether the stimulus word sounded like the picture, which meant that task performance now *required* phonological recoding of the stimulus words. The results showed the hearing children to automatically activate phonology during visual word recognition irrelevant of whether they were explicitly instructed to ignore the information (Exp 1) or focus on the information (Exp 2). The deaf children showed little automatic phonological activation. Phonological information was not activated automatically during Experiment 1 and, when the deaf children were explicitly instructed to utilize phonological information in Experiment 2, they showed major difficulties doing this. The conclusion is that the bilingual deaf children used a different word processing mechanism than the hearing children.

2.1 *Introduction*

The majority of deaf children encounter major difficulties learning to read (Chamberlain & Mayberry, submitted; Mayberry, 2002; Wauters, van Bon, & Tellings, 2006). The reduced access to phonology as a result of hearing losses provides a plausible explanation for these difficulties. In fact, phonological recoding is very important for the development of visual word recognition skills (e.g., Bosman & de Groot, 1996; Bosman & van Hell, 2002; van Orden, 1987; Unsworth & Pexman, 2003). Young hearing children learning to read employ phonological recoding as early as in Grade 1, at least when they are learning to read using the "assembled phonology" reading strategy in which sub-lexical phonological representations are activated by sub-lexical orthographic representations (Bosman & de Groot, 1996). Not only young children, but also proficient readers show phonological activation during visual word recognition (van Orden, Johnson, & Hale, 1988; Perfetti & Sandak, 2000).

For deaf children, phonological recoding during the process of visual word recognition is not self-evident. Studies investigating the use of phonology during the word reading of both deaf children and deaf adults show inconsistent results (Goldin-Meadow & Mayberry, 2001; Marschark & Harris, 1996). While some deaf children appear to develop phonological skills (Harris & Beech, 1995; Transler, Gombert, & Leybaert, 2001), it is still not clear whether this phonological information is automatically activated during reading. In many cases, deaf children learn a sign language as their first language (L1) in which the phonology of a spoken language plays no role, and a written/spoken language as their second language (L2). Sign languages have no accompanying conventional writing system so deaf children who learn a sign language first do not learn to read in their L1, but instead they start reading in their L2. Given the importance of phonological activation for the development of hearing children's reading, phonological activation during the word recognition of bilingual deaf children was analyzed here. In the following sections, we will first discuss the results of previous studies of phonological activation in deaf readers and then describe the present study.

2.1.1 *Previous Studies of Phonological Activation in Deaf Readers*

Phonological activation does seem to occur in deaf readers, but only under particular circumstances. For example, Cochlear implantation, an orally based instruction system – as opposed to sign language – and a transparent orthographic system seem to increase the chance of phonological involvement in reading. Nevertheless, none of these and other factors seem sufficient to ensure phonological activation in deaf readers, as will be discussed below.

In the past, different test paradigms have been used to measure the activation of phonology during word reading. The first paradigm is lexical decision. During lexical decision, participants must indicate whether a letter string constitutes an existing word or not and both the speed and accuracy of their responding are generally measured. Support of phonological activation during lexical decision was provided in some studies (Harris & Beech, 1995; Hanson & Fowler, 1987; Transler & Reitsma, 2005), whereas no evidence was found in others (Merrills, Underwood, & Wood, 1994; Waters & Doehring, 1990). The second paradigm used to measure the activation of phonology during word reading involves similarity judgments. In this paradigm, phonological similarities between different words or pseudowords have to be judged. Support for phonological activation during similarity judgments was provided by Transler, Gombert, and Leybaert (2001), Miller (2002; 2006), and Dodd and Hermelin (1977), but not in children who were proficient signers (Miller, 2006), suggesting that correct phonological similarity judgments depends on the encouragement of making relationships between written words and phonology and/or signs in educational settings. The third test paradigm used to study phonological activation in deaf readers is the Stroop paradigm. The classic Stroop paradigm assesses the automaticity of reading (and the capacity to inhibit this process) by having a participant name the color of the ink used to print individual words such as color names that may or may not correspond to the color of the ink (e.g., red ink for the word “blue”; the participant is required to respond with “red”). Leybaert and Alegria (1993) found support for phonological activation for orally trained deaf children. A marginally significant phonology effect was found for the deaf participants when a vocal response was required but not when a manual response was required (i.e., a tendency to respond in keeping with the written color name instead of the ink color in the former case but not the latter). In contrast, the hearing control group appeared to spontaneously use phonological information for both a vocal response and a manual response. The fourth and final test paradigm used to study phonological activation among deaf readers is sentence verification. In a sentence verification task, sentences are read and judged for semantic correctness. When Hanson, Goodell, and Perfetti (1991) used English tongue twisters to study deaf adult English readers, some support of phonological activation during reading was found. In contrast, when Treiman and Hirsch-Pasek (1983) presented deaf adult participants with incorrect homophones in an English sentence verification test (e.g., the incorrect word “blew” instead of the correct word “blue”), no evidence of phonological activation during the reading of the sentences was found. In other words, the deaf adults in this study were not confused by the matching sounds of the words.

To summarize, results in each of the paradigms are mixed and the phonological system appears to be less precise for deaf children whose phonological knowledge is based on “visual input (i.e. speech reading)” than for hearing children whose phonological knowledge is based on auditory input. However, these results are still difficult to interpret due to the considerable differences in type of participants involved and the stimuli and instructions employed (see Wauters, van Bon, & Tellings, 2006; Transler, Gombert, & Leybaert, 2001).

Considerable participant variation exists across studies which precludes any clear conclusions with regard to phonological activation in deaf reading. To illustrate, children with a Cochlear Implant were included in some of the studies but not others. It is reasonable to assume that the inclusion of children with a Cochlear Implant will affect the results. Furthermore, the age at which deaf children are tested, the type of educational system to which they have been subjected, and whether they had a signing or non-signing home environment are all likely to be of influence on their use of phonology during reading and thus the results of the studies. For example, one may expect greater use of phonology when phonological skills are emphasized at the expense of signing and, conversely, relatively little use of phonology when signing is strongly emphasized at the expense of phonological training (Miller, 2002). Interestingly, some of the studies which showed phonological activation actually involved proficient signers (Hansen & Fowler, 1987; Transler & Reitsma, 2001). Others were involving orally educated students and failed to show phonological activation. In sum, as is the case with the role of test paradigm, the influence of participant characteristics is not clear.

The transparency of the relevant writing systems should also be taken into consideration. Several of the studies of the role of phonology in deaf reading have been conducted with languages that have relatively transparent writing systems such as French (Leybaert & Alegria, 1993; Transler, Gombert, & Leybaert, 2001) or Dutch (Transler &

Reitsma, 2001). The results of these studies suggest that deaf children learning a relatively transparent writing system may apply phonology during word reading.

Variation in the nature of the stimuli may have obscured the effects to be interpreted. The nature of the stimuli to-be-rejected and the stimuli to-be-accepted may be critical. For instance, the use of pseudohomophones in a lexical decision test clearly makes phonological processing counterproductive as this would only produce false-positives. In addition, the phonological processing for real words to be accepted and pseudowords to be rejected may actually be very different. Merrills et al. (1994) for example, did not find regularity effects for real words, suggesting no use of phonology, but did find phonological activation for pronounceable pseudowords when decoded by the same children.

Just as the activation of phonological information might potentially be influenced by the nature of test instructions, the level of reliance upon orthographic information can also be influenced by the nature of test instructions. In order to reject a pseudohomophone, for example, one must rely on orthographic information and ignore phonological information. Conversely, orthographic information can be made unreliable by instructing (hearing) participants to accept not only words but also pseudohomophones and reject pseudowords (Martensen, Dijkstra, & Maris, 2005). By varying the instructions for the handling of pseudohomophones (i.e., accept versus reject pseudohomophones), the automated use of phonology can be compared to the unautomated use of phonology (i.e., efforts to ignore the phonology of a pseudohomophone versus efforts to ignore the orthography of a pseudohomophone). Although a distinction between accepting and rejecting pseudohomophones was shown experimentally for hearing participants (Martensen, Dijkstra, & Maris, 2005), no such distinction has been made at this point in studies of deaf readers. Generally, deaf participants are instructed to accept the orthographic information.

On the basis of the present body of knowledge, it can be concluded that many deaf readers experience difficulties with the application of phonological information during reading tasks. Whether deaf *bilingual* children learning to read in a language with a highly transparent writing system experience similar problems cannot be determined on the basis of the foregoing results, however, and the possibility thus exists that such children may apply phonological information more or less automatically for purposes of lexical access within such languages. Whether or not deaf bilingual readers can apply phonology not only when the task *explicitly* requires phonological activation but also when the (more natural) task *implicitly* requires phonological activation is also very much the question; the former may occur even when the child does not generally use phonology for purposes of lexical access, for example. It is important to study the *potential* to activate phonology during reading in addition to the more *implicit* use of phonology during reading. This is important because the degree of phonological activation during visual word recognition is indicative of later reading levels for not only hearing children but also deaf children.

2.1.2 *Present Study*

In the present study, phonological activation was assessed in deaf children attending schools which provide support for auditory and communicative difficulties and deaf education in the Netherlands. The deaf children all received bilingual education. Phonological activation was also assessed in hearing children attending mainstream elementary schools in the Netherlands. All of the children were learning to read Dutch which has a relatively regular orthography (Transler & Reitsma, 2001).

In order to be sure that phonological activation during the process of word access was truly assessed and not merely the capacity to decide if a letter string constitutes an existing word or not, a special *Word-Picture Verification task* was employed in the present study. In order to assess the use of phonology, Dutch pseudohomophones were included (e.g., the Dutch equivalent for the English pseudohomophones ‘GOTE’ and ‘NIFE’). The rationale underlying the use of pseudohomophones was that phonological recoding of a pseudohomophone could be expected to produce activation of any word that sounds the same (i.e. ‘GOTE’ could activate ‘GOAT’) and this would indicate a role for phonological activation in visual word recognition. Two experiments were conducted: One in which pseudohomophones had to be rejected, which tests whether phonological information automatically becomes available despite attempts to ignore it, and an experiment in which pseudohomophones had to be accepted, which tests whether phonological information can be consciously activated after explicit instruction to do so. Such a distinction between ignoring and accepting of phonological information appears to be a fine test to acquire a grasp on implicit and explicit phonological activation during word reading in deaf children. First of all, the question is whether phonology is used in normal reading situations when no instructions are given with respect to the use of phonology. Secondly, the question is to what extent the children can use phonology when instructed to, irrespective of phonological activation in a more natural reading situation.

2.2 Experiment 1: Rejection of Pseudohomophones during Word Recognition

2.2.1 *Method*

Participants. There were 30 bilingual deaf children and 51 monolingual hearing children involved in the present study. The deaf children ranged in age from 10.2 to 12.8 years (mean 11.5, *SD* .74), and they attended one of three schools specialized for deaf education in the Netherlands. The majority of the deaf children were in fifth grade[1]. All of the deaf children wore conventional hearing aids, and none of them had a Cochlear Implant[2]. The schools for the deaf provide bilingual deaf education in a curriculum including a combination of the Sign Language of the Netherlands (SLN) and Sign Supported Dutch (SSD). All of the children received sign language instruction typically by a deaf teacher specialized in SLN for approximately four hours in the week from the age of four. The teachers of the deaf all used SLN or SSD as the language of instruction in the classroom. In the Netherlands, many deaf children enroll in a sign-oriented preschool program from the age of 2 or 3 years. Most of the deaf children participating in the present experiment had indeed attended such a preschool. The hearing children were between 8.5 and 12.2 years of age and either in grade 3 (mean age 9.3, *SD* .39) or grade 5 (mean age 11.4, *SD* .47) in a regular elementary school. The two grades were included in order to test whether hearing children who have a typical development show different patterns of phonological information processing across ages.

Procedure. In a word-picture verification task, 128 word-picture pairs were presented. Instructions concerning the task procedure were provided group-wise by the classroom teachers. The language of instruction was SLN. The participants were informed that a fixation point would appear on the screen for one second followed by a word on the left side of the screen and a picture on the right side of the screen. The participants had to decide whether the spelling of a word and a picture referred to the same concept or not. The participants were instructed that in those cases in which the picture and the spelling of the word referred to the same concept, a match response would have to be provided by pressing the “Enter” button marked in green on the right side of the keyboard using the right index finger. In all of the other cases, a mismatch response would have to be provided by pressing the “Caps Lock” button marked in red on the left side of the keyboard using the left index finger. The participants were further informed that the stimulus pair would disappear after responding or after a period of 10 seconds to be followed by the next stimulus pair. Questions could be asked after instruction.

The actual experimental task was carried out with groups of six children seated about 40 centimeters from a computer screen in a separate, well-lit, and spacious room in the presence of two experimenters. The task consisted of the presentation of four sets of 32 stimulus pairs preceded by eight practice pairs containing information other than that presented in the test pairs in order to familiarize the children with the experimental procedure. The word “PAUSE” appeared on the computer screen following the eight initial practice pairs.

Each set of 32 stimulus pairs was preceded by four additional set-specific practice pairs. Following presentation of these four practice pairs and the 32 stimulus pairs, the word “PAUSE” appeared on the computer screen. The next set of practice and stimulus pairs was then presented and, once the four sets of stimuli had been presented, the word “FINISHED” appeared on the screen.

Design. Half of the participants received the stimulus sets in the order one through four and half received the sets in the reverse order. The order of item presentation was determined using a Latin Square design. Within each stimulus set, the 32 stimulus pairs were presented in a uniquely random order for each child.

Stimuli. As already mentioned, 128 word-picture pairs were presented. All of the words and pictures were based on one-syllable words. The words had a high frequency of occurrence in written Dutch. The frequency measures were based on CELEX counts (Baayen, Piepenbrock, & van Rijn, 1993) and showed an average of 1.81 log frequency per million. The pictures were unambiguous and taken from the *Leesladder* (the “Reading Ladder”) (Irausquin & Mommers, 2001), which is a computer program for children with reading disabilities. The pictures were colored line drawings and depicted nouns that could be assumed to be known by six-year-old Dutch children in light of familiarity ratings of .80 or greater along a scale of 0 to 1 (Schaerlaekens, Kohnstamm, Lejaegere, & de Vries, 1999).

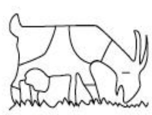
A word was presented on the left side of the computer screen and a drawing on the right side. The drawings were 5 x 5 centimeters and presented 8 centimeters to the right of the target word. Equal amounts of empty space occurred on the left and right sides of the screen.

A total of 64 items or 50% of the experimental items were matches and thus required a "yes" response. In such cases, the target word and picture represented the same concept and the target word was also spelled correctly. The other 64 items were mismatches and thus required a "no" response. In these cases, the target word and picture did not represent the same concept or the target word was spelled incorrectly.

The mismatches were further divided into two conditions. In the Pseudohomophone condition, the target letter string was a pseudohomophone of the picture name (i.e. pseudohomophone GOTE- picture name GOAT). In the Orthographically related non-word condition, the target letter string was a non-word which was orthographically related to the picture name (i.e. non-word GOAF- picture name GOAT, see Figure 1). Each of these two conditions contained 16 unique word-picture combinations, adding up to 32 items. In order to counteract a strategy effect due to the presence of picture duplication in the Pseudohomophone and Orthographic Control conditions, fillers were also presented twice (16 unique mismatch fillers and 32 unique match fillers, adding up to 96 filler items).

Figure 1

Experiment 1



Condition 1: Pseudohomophone gote

Condition 2: Orthographically related non-word goaf

The items in the Pseudohomophone and Orthographic Control conditions were matched according to the number of neighbor words using the CELEX counts (Baayen, Piepenbrock, & van Rijn, 1993). The items in the Pseudohomophone condition had an average of 10.31 neighbor words, and the items in the Orthographically related non-word condition had an average of 11.00 neighbor words.

Apparatus. In this experiment, a laptop, type Dell, Latitude 640, was used. The test was constructed using the commercially available software program E-Prime, version 1.0 (Schneider, Eschman, & Zuccolotto, 2002).

In the following, we will first present the results for the unmarked case of hearing children. Thereafter, the results for the deaf children will be presented.

2.2.2 *Results Experiment 1: Hearing Children*

Both Reaction Time (RT) and Accuracy measures were collected. Those RTs and error rates more than two standard deviations away from the participant and item means were excluded from further analysis. For the participant analyses (*F*1) and the item analyses (*F*2), repeated measures analyses of variance were conducted using the SPSS General Linear Method. Grade (grade 3 vs. 5) was treated as a between-subjects and within-item factor; Condition was treated as a within-subject and between-items factor. Marginal trends towards significance are also reported below provided the *p*-values fall within the range of .05 to .10.

Reaction Time data. The hearing children showed a significant effect of Condition ($F1(1,49) = 13.310$, $p < .01$, $\eta_p^2 = .214$; $F2(1,15) = 12.796$, $p < .01$, $\eta_p^2 = .460$). Pseudohomophones were responded to slower than orthographically related non-words (see Table 1). There was also a significant main effect of Grade ($F1(1,49) = 23.447$, $p < .001$, $\eta_p^2 = .131$; $F2(1,15) = 35.604$, $p < .001$, $\eta_p^2 = .704$). The children in grade 3 showed greater response latencies than the children in grade 5. There was no interaction between Condition and Grade. $F1(1,49) = 1.891$, $p > .1$, $\eta_p^2 = .037$; $F2(1,15) = .091$, $p > .1$, $\eta_p^2 = .006$).

Error data. The error data also revealed a significant Condition effect for the hearing children ($F1(1,49) = 57.283$, $p < .001$, $\eta_p^2 = .539$; $F2(1,15) = 80.036$, $p < .001$, $\eta_p^2 = .842$). Pseudohomophones were responded to less accurately than orthographically related non-words (see Table 1). There was also a significant main effect of Grade ($F1(1,49) = 11.053$, $p < .001$, $\eta_p^2 = .184$; $F2(1,15) = 34.286$, $p < .001$, $\eta_p^2 = .696$). The hearing children in grade 3 made more mistakes than the hearing children in grade 5. In addition, the item analyses revealed a significant interaction between Condition and Grade ($F1(1,49) = 2.577$, $p > .1$, η_p^2

= .050; $F2(1,15) = 18.491$, $p < .01$, $\eta_p^2 = .552$), with significant larger effects for the children in grade 3 than in grade 5.

Table 1

Experiment 1 Mean Verification Latencies (in Milliseconds) and Accuracy Rates (in Percentages) for Third versus Fifth Grade Hearing Children when presented with Word-Picture Pairs from Four Conditions (Standard Deviation in Parentheses)

		Hearing children	
		RT	Accuracy
Phonology (16 pairs in each of the 2 conditions)			
Condition 1: Pseudohomophones	3rd Grade	3324 (1852)	.53 (.28)
Condition 2: Orthographically related non-words		2525 (841)	.88 (.11)
Condition 1: Pseudohomophones	5th Grade	2310 (1053)	.73 (.26)
Condition 2: Orthographically related non-words		1949 (602)	.95 (.05)
Fillers			
Yes-response filler (64 pairs)	3rd Grade	2098 (645)	.93 (.06)
No-response filler (32 pairs)		2098 (512)	.92 (.05)
Yes-response filler (64 pairs)	5th Grade	1656 (370)	.93 (.07)
No-response filler (32 pairs)		1525 (388)	.92 (.06)

Conclusion. Aspects of phonology clearly affected the performance of the hearing children on a word-picture verification task. One can thus conclude that hearing children in both grades 3 and 5 spontaneously activate phonology during the process of word recognition. The item analyses for the accuracy of responding also showed the grade 3 hearing children to activate phonology to an even *greater* extent than the grade 5 hearing children.

2.2.3 *Results Experiment 1: Deaf Children*

Reaction Time data. No Condition effect was obtained for the deaf children (*F1*(1,29) = 1.072, $p > .1$, $\eta_p^2 = .036$; *F2*(1,15) = .410, $p > .1$, $\eta_p^2 = .027$). Stated differently, the performance of the deaf children did not differ significantly across the trials with pseudohomophones versus orthographically related non-words (see Table 2).

Table 2

Experiment 1 Mean Verification Latencies (in Milliseconds) and Accuracy Rates (in Percentages) for Deaf Children when presented with Word-Picture Pairs from four Conditions (Standard Deviation in Parentheses)

		Deaf children	
		RT	Accuracy
Phonology (16 pairs in each of the 2 conditions)			
Condition 1: Pseudohomophones	5th Grade	1972 (856)	.71 (.25)
Condition 2: Orthographically related non-words		2005 (1019)	.75 (.23)
Filler			
Yes-response filler (64 pairs)	5th Grade	1627 (578)	.88 (.11)
No-response filler (32 pairs)		1430 (489)	.89 (.05)

Error data. Condition showed a trend towards significance in the item analyses for the error data from the deaf children (*F1*(1,29) = 2.303, $p > .1$, $\eta_p^2 = .074$.; *F2*(1,15) = 3.158, $p < .1$, $\eta_p^2 = .174$). Pseudohomophones were responded to slightly less accurately than the orthographically related non-words (see Table 2).

Conclusion. Aspects of phonology did not significantly affect the reaction times of the deaf children on a word-picture verification task and only marginally affected the accuracy of the deaf children's responding according to the item analyses with the deaf children making slightly more mistakes in the pseudohomophone condition than in the orthographic control condition. In other words, the deaf children studied here hardly activated phonology automatically during the process of word recognition.

2.3 Experiment 2: Acceptance of Pseudohomophones during Word Recognition

2.3.1 *Method*

Participants. The same 30 bilingual deaf children and 51 hearing children who participated in Experiment 1 participated in Experiment 2.

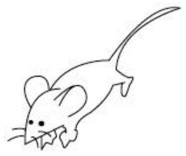
Procedure. The instructions for Experiment 2 were very different from the instructions for Experiment 1. In Experiment 1, the children had to decide whether the spelling of the target word and the picture name referred to the same concept. In Experiment 2, the children were explicitly instructed to accept target items that sounded like existing words in the spoken language which referred to the same concept as the picture name. A pseudohomophone was described to the children as a word that is spelled incorrectly but nevertheless is an existing word in the spoken language; it sounds (and looks when speech-reading) just like an existing word when pronounced. The participants had to decide whether the sound of a word and a picture referred to the same concept or not. The experimental test consisted of four sets. In each of the four sets, 4 pairs from each of the six conditions were included plus 8 fillers. For the remainder of the procedure for Experiment 2, see Experiment 1.

Design. “As in Experiment 1”

Stimuli. With explicit instructions to attend to aspects of phonology, 128 word-picture pairs were presented for verification. All of the items differed from the items in Experiment 1. Once again, however, 64 stimulus pairs constituted matches and 64 constituted mismatches (see Figure 2). Experiment 2 included six conditions. The six conditions reflected one of three factors—Phonology, Semantics, or Phonology via Semantics—and were as follows: Conditions 1 and 2 each consisted of 16 unique word-picture pairs that referred to the same concept and thus required a “yes” response; Conditions 3 through 6 each consisted of 16 unique word-picture pairs that referred to a different concept and thus required a “no” response. The remaining pairs were 16 unique filler pairs presented twice or, in other words, 32 filler pairs that referred to the same concept an thus required a “yes” response.

Figure 2

Experiment 2

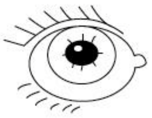


Phonology:

Condition 1: Pseudohomophone mowse

Condition 2: Orthographically related word mouse

Semantics:



Condition 3: Strong Semantic relation nose

Condition 4: Weak Semantic relation chair

Phonology via Semantics:

Condition 5: Pseudohomophone nife

Condition 6: Orthographically related non-word kife

Condition 1 involved pseudohomophones, matched items (factor phonology); Condition 2, orthographically related words, matched items (factor phonology); Condition 3, strong semantic relation, mismatch items (factor semantics); Condition 4, weak semantic relation, mismatched items (factor semantics); Condition 5, pseudohomophones in a strong semantic relation, mismatched items (factor phonology via semantics); and Condition 6, orthographically related non-words in a strong semantic relation, mismatched items (factor phonology via semantics). In Condition 3 and 4, the same words and pictures were used, but in different combinations. In Condition 1, three of the pseudohomophones were mistakenly presented on the laptops as correctly spelled words. These three items and also the three pairs with orthographically related words in Condition 2 were for that reason removed from further analyses, adding up to the deletion of 6 pairs from further analyses.

The words used in the six different conditions in Experiment 2 were selected using the same criteria as in Experiment 1. The words in the experimental conditions and the control conditions were matched with regard to the number of neighbor words and the number of letters based on the CELEX counts (Baayen, Piepenbrock, & van Rijn, 1993). For the Phonology factor, the items in Condition 1 had an average of 12.46 neighbor words and 3.92 letters; the items in condition 2 had an average of 12.0 neighbor words and 3.85 letters. The log frequency was 1.73 per million words. For the Semantics factor, the items in Condition 3 had an average of 18.19 neighbor words and 3.88 letters; the items in Condition 4 also had an average of 18.19 neighbor words and 3.88 letters given that the same words were used in different word-picture combinations. The log frequency was 1.77. For the Phonology via Semantics factor, the items in Condition 5 had an average of 7.94 neighbor words and 4.5 letters; the items in Condition 6 had an average of 6.88 neighbor words and 4.5 letters. The use of nonwords in both conditions resulted in no value for log frequency.

Apparatus. As in Experiment 1.

2.3.2 *Results Experiment 2: Hearing Children*

The same outlier procedure and statistical analyses were conducted as in Experiment 1. For the participant analyses (*F*1) and the item analyses (*F*2), repeated measures analyses of variance were conducted using the SPSS General Linear Method. Phonology, Semantics, and Phonology via semantics were all treated as within-subject and between-items factors. Grade (grade 3 vs. 5) was treated as a between-subjects and within-item factor (Table 3).

Reaction Time data. A significant main effect of Phonology was observed for the hearing children ($F1(1,50) = 30.634$, $p < .001$, $\eta_p^2 = .380$; $F2(1,12) = 52.728$, $p < .001$, $\eta_p^2 =$

.815). Pseudohomophones were responded to slower than orthographically related words. There was also a significant main effect of Grade (*F1*(1,50) = 7.047, $p < .05$, $\eta_p^2 = .124$; *F2*(1,12) = 26.104, $p < .001$, $\eta_p^2 = .658$). The children in grade 3 showed significantly larger response latencies than the children in grade 5. There was no interaction effect between Phonology and Grade. *F1*(1,50) = 1.939, $p > .1$, $\eta_p^2 = .037$; *F2*(1,12) = 3.093, $p > .1$, $\eta_p^2 = .205$).

There was no main effect of Semantics for the hearing children (*F1*(1,50) = 1.401, $p > .1$, $\eta_p^2 = .027$; *F2*(1,15) = 2.332, $p > .1$, $\eta_p^2 = .135$). A significant main effect of Grade was obtained (*F1*(1,50) = 10.219, $p < .01$, $\eta_p^2 = .170$; *F2*(1,15) = 47.044, $p < .001$, $\eta_p^2 = .758$). The children in grade 3 showed greater response latencies than the children in grade 5. There was no interaction between Semantics and Grade (*F1*(1,50) = .015, $p > .1$, $\eta_p^2 = .000$; *F2*(1,15) = .094, $p > .1$, $\eta_p^2 = .006$).

A significant main effect of Phonology via semantics was also detected for the hearing children (*F1*(1,50) = 8.682, $p < .01$, $\eta_p^2 = .148$; *F2*(1,15) = 5.990, $p < .05$, $\eta_p^2 = .285$). Only now pseudohomophones in semantically related pairs were responded to more quickly than orthographically related non-words in otherwise semantically related pairs. A significant main effect of Grade was also found (*F1*(1,50) = 4.790, $p < .05$, $\eta_p^2 = .087$; *F2*(1,15) = 35.155, $p < .001$, $\eta_p^2 = .701$). The children in grade 3 showed larger response latencies than the children in grade 5. There was no interaction between Phonology via semantics and Grade. *F1*(1,50) = .043, $p > .1$, $\eta_p^2 = .001$; *F2*(1,15) = .011, $p > .1$, $\eta_p^2 = .005$).

Error data. Phonology did not significantly affect the error data from the hearing children (*F1*(1,50) = .993, $p > .1$, $\eta_p^2 = .019$; *F2*(1,12) = 1.177, $p > .1$, $\eta_p^2 = .089$). Pseudohomophones were not responded to less accurately than orthographically related words (see Table 3). There was also no significant main effect of Grade (*F1*(1,50) = .039, $p > .1$, $\eta_p^2 = .001$; *F2*(1,12) = .138, $p > .1$, $\eta_p^2 = .011$). However, the interaction between Phonology and Grade showed a trend towards significance in the item analyses (*F1*(1,50) = 1.351, $p > .1$, $\eta_p^2 = .026$; *F2*(1,12) = 3.698, $p < .1$, $\eta_p^2 = .236$).

A main effect of Semantics was detected in the participant analyses of the error data from the hearing children (*F1*(1,50) = 15.603, $p < .001$, $\eta_p^2 = .238$; *F2*(1,15) = 1.415, $p > .1$, $\eta_p^2 = .086$). Responses on pairs with a strong semantic relation were less accurate than responses on pairs with a weak semantic relation. No main effect of Grade was attained

($F1(1,50) = 2.366$, $p > .1$, $\eta_p^2 = .045$; $F2(1,15) = 6.881$, $p < .05$, $\eta_p^2 = .314$). And no interaction between Semantics and Grade was detected ($F1(1,50) = .010$, $p > .1$, $\eta_p^2 = .000$; $F2(1,15) = .011$, $p > .1$, $\eta_p^2 = .001$).

Table 3

Experiment 2 Mean Verification Latencies (in Milliseconds) and Error Rates (in Percentages) for Third and Fifth Grade Hearing Children when presented with Word-Picture Pairs from Seven Conditions (Standard Deviation in Parentheses)

		Hearing Children	
		RT	Accuracy
Phonology (16 pairs in each of the 2 conditions)			
Condition 1: Pseudohomophones	3rd Grade	2309 (688)	.89 (.14)
Condition 2: Orthographically related words		1922 (571)	.89 (.11)
Condition 1: Pseudohomophones	5th Grade	1884 (409)	.88 (.16)
Condition 2: Orthographically related words		1653 (287)	.91 (.07)
Semantics (16 pairs in each of the 2 conditions)			
Condition 3: Strong Semantic Relation	3rd Grade	2350 (691)	.85 (.11)
Condition 4: Weak Semantic Relation		2262 (773)	.90 (.13)
Condition 3: Strong Semantic Relation	5th Grade	1869 (416)	.89 (.07)
Condition 4: Weak Semantic Relation		1798 (850)	.94 (.06)
Phonology via semantics (16 pairs in each of the 2 conditions)			
Condition 5: Pseudohomophones via semantics	3rd Grade	2455 (730)	.86 (.13)
Condition 6: Orthographically related non-words via semantics		2686 (959)	.94 (.10)
Condition 5: Pseudohomophones via semantics	5th Grade	2086 (431)	.88 (.07)
Condition 6: Orthographically related non-words via semantics		2286 (498)	.95 (.05)
Fillers (32 pairs)			
Yes-response filler	3rd Grade	1791 (656)	.94 (.10)
Yes-response filler	5th Grade	1379 (300)	.95 (.04)

A significant main effect of Phonology via Semantics was found for the error data from the hearing children ($F1(1,50) = 30.801$, $p < .001$, $\eta_p^2 = .381$; $F2(1,15) = 7.575$, $p < .05$, $\eta_p^2 = .336$). Pseudohomophones in semantically related pairs were responded to less accurately than orthographically related non-words in semantically related pairs. No significant main effect of Grade was observed ($F1(1,50) = .592$, $p > .1$, $\eta_p^2 = .012$; $F2(1,15) = 1.150$, $p > .1$, $\eta_p^2 = .002$). There was no interaction between Phonology via semantics and Grade ($F1(1,50) = .032$, $p > .1$, $\eta_p^2 = .001$; $F2$ $(1,15) = .032$, $p > .1$, $\eta_p^2 = .002$).

Conclusion. For the hearing children, phonology appeared to be easily applied with explicit instructions to use phonological information for purposes of picture-word verification. That is, the error data in conditions 1 and 2 show the hearing children to fully access the necessary phonological information, but the reaction times show it to be difficult to fully ignore the orthographic information presented. When pseudohomophones were included in semantically related pairs, phonological activation was found to influence both speed and accuracy of the word recognition process. Children in grade 3 and 5 were less accurate when pseudohomophones were included in semantically related pairs in comparison to orthographically related non-words, also included in semantically related pairs. In other words, both type of pairs (condition 5 and 6) entailed a semantic relation which resulted in semantic interference in these children (as can be seen in the comparison of condition 3 and 4), but those pairs including pseudohomophones (condition 5) caused additional interference to those pairs including orthographically related non-words (condition 6). This difference shows phonological activation to be causing response competition. In this particularly demanding situation, the pseudohomophones (but not the orthographically related non-words) falsely suggest a “yes-response” because they sound like existing words, which should subsequently be changed into a “no- response” because word and picture do not refer to the same concept. The response times for “phonology via semantics” were remarkable because they showed a facilitation effect for phonology instead of the expected pseudohomophone inhibition effect. Their responses were faster for the pseudohomophones when included in semantically related item pairs, but nevertheless more mistakes were made by the children. This suggests a speed-accuracy trade off, or responding (incorrectly) before a good-quality judgment was made on the similarity of concepts for the word and picture.

2.3.3 *Results Experiment 2: Deaf Children*

The same outlier procedure and statistical analyses were conducted as in Experiment 1. Phonology, Semantics, and Phonology via semantics were all treated as a within subject- and between item factors. All deaf children were in the same Grade (grade 5).

Reaction Time data. A significant main effect of phonology was found for the reaction time data from the deaf children ($F1(1,27) = 10.095$, $p < .01$, $\eta_p^2 = .272$; $F2(1,12) = 12.123$, $p < .01$, $\eta_p^2 = .503$). The deaf children responded considerably slower to the pseudohomophones that to the orthographically related words.

For Semantics, there was no effect for the deaf children ($F1(1,28) = .874$, $p > .1$, $\eta_p^2 = .030$; $F2(1,15) = .101$, $p > .1$, $\eta_p^2 = .007$). Stimulus pairs with strong semantic relations were responded to just as fast as stimulus items with weak semantic relations (see Table 4).

For Phonology via Semantics, no effect was obtained for the deaf children ($F1(1,28) = .049$, $p > .1$, $\eta_p^2 = .002$; $F2(1,15) = .012$, $p > .1$, $\eta_p^2 = .001$). Pseudohomophones in semantically related pairs were responded to just as fast as orthographically related non-words in semantically related stimulus pairs (see table 4).

Error data. A main effect of phonology in the error data from the deaf children was detected as well ($F1(1,28) = 35.438$, $p < .001$, $\eta_p^2 = .559$; $F2(1,12) = 34.486$, $p < .001$, $\eta_p^2 = .753$). Pseudohomophones were responded to considerably less accurately than orthographically related words (see Table 4).

A marginally significant main effect of Semantics was detected in only the participant analyses of the error data from the deaf children, ($F1(1,28) = 3.809$, $p < .1$, $\eta_p^2 = .120$; $F2(1,15) = 1.786$, $p > .1$, $\eta_p^2 = .106$). Stimulus pairs with strong semantic relations were responded to less accurately than stimulus items with weak semantic relations (see Table 4).

Finally, no effect of Phonology via Semantics was found for the deaf children ($F1(1,28) = .000$; $F2(1,15) = .000$).

Conclusion. In contrast to Experiment 1, a difference in Experiment 2 between results in condition 1 versus condition 2 implied that phonology was not readily available. In Experiment 2, orthography needs to be ignored, and decisions need to be based on phonology. The deaf children had difficulty to rely on phonology in Experiment 2, and appeared to heavily rely upon orthographic information even when a judgment was to be made on the basis of phonology. For the factor Phonology, the deaf children studied here showed a much larger acceptance of correctly spelled words (e.g. “MOUSE”) which matched the picture concepts and therefore sounded the same as the pseudohomophones which, evidently, also matched the picture when sounded out. The deaf children also showed a marginal error effect of Semantics, but there was no evidence of phonological activation via semantics. The limited accuracy of the deaf children’s responding to the pseudohomophones even when instructed to pay attention to the sound of the target items in Experiment 2 shows that they cannot readily access phonological information, even when instructed to do so.

Table 4

Experiment 2 Mean Verification Latencies (in Milliseconds) and Error Rates (in Percentages) for Deaf Children when presented with Word-Picture Pairs from Seven Conditions (Standard Deviation in Parentheses)

		Deaf children	
		RT	Accuracy
Phonology (16 pairs in each of the 2 conditions)			
Condition 1: Pseudohomophones	5th Grade	2404 (997)	.52 (.24)
Condition 2: Orthographically related words		1824 (482)	.76 (.11)
Semantics (16 pairs in each of the 2 conditions)			
Condition 3: Strong Semantic Relation	5th Grade	2097 (678)	.80 (.13)
Condition 4: Weak Semantic Relation		2184 (852)	.85 (.16)
Phonology via semantics (16 pairs in each of the 2 conditions)			
Condition 5: Pseudohomophones via semantics	5th Grade	2169 (718)	.86 (.13)
Condition 6: Orthographically related non-words via semantics		2155 (728)	.86 (.13)
Fillers (32 pairs)			
Yes-response filler	5th Grade	1516 (420)	.86 (.10)

2.4 General Discussion

From the present study, it can be concluded that bilingual deaf children who learn the transparent writing system of Dutch show very little phonological activation during automatic visual word processes when instructed to focus on the orthography of the words and respond as fast as possible (Experiment 1). Hearing children, in contrast, could not ignore phonological information during automatic visual word recognition processes, which was shown by strong pseudohomophone effects. Accuracy and reaction times for the hearing children showed less accurate and also slower responses upon the presentation of pseudohomophones (e.g., GOTE together with a picture of a GOAT) in a "no" response (i.e., mismatch) in comparison to control items (e.g., GOAF together with a picture of a GOAT) in a "no" response (i.e., mismatch).

When explicit instructions were provided to only pay attention to phonological information and thus ignore orthographic information and respond as fast as possible (Experiment 2), the deaf children still relied mainly on orthographic information. For the deaf children, thus, it was difficult to activate phonology at the sub-lexical phoneme level. The hearing children, in contrast, successfully ignored orthographic information in order to process the words phonologically at the sub-lexical level, although not entirely which was seen in the slower response times for pseudohomophones than for control words. Taken together, the results of Experiments 1 and 2 showed that phonology is easily activated by hearing children but not by deaf children.

In Experiment 2, two comparisons were used to test for phonological activation and instructions for participants were to only pay attention to phonological information. One of the comparisons required a "yes" (i.e., match) response and one of the comparisons required a "no" (i.e., mismatch) response. In the first comparison in experiment 2 involving a *match* (pseudohomophone GOTE- picture GOAT versus word GOAT- picture GOAT; condition 1 and condition 2), pseudohomophone effects were an indication of insufficient phonological activation to decide that the sound of the word and the picture name represented the same concept. Both the reaction times and error data showed pseudohomophone inhibition effects for the deaf children, showing that the deaf children could not activate phonological information sufficiently when instructed to. The deaf children could not easily decide whether a pseudohomophone sounded like the concept in the picture. Conversely, the error data for the hearing children did not show pseudohomophone effects, showing that they could activate phonological information when instructed to.

In the second comparison involving a pseudohomophone *mismatch* (pseudohomophone GOTE- picture SHEEP versus non-word GOAF- picture SHEEP; condition 5 and condition 6), pseudohomophone effects were an indication that decisions were based on phonological information. The reaction times and error data of the deaf children showed no inhibition effects for semantically related pairs which included mismatched pseudohomophones (pseudohomophone GOTE- picture SHEEP) when compared to semantically related pairs which included mismatched control non-words (non-word GOAF- picture SHEEP). The deaf children processed only orthographic information despite explicit instructions to ignore the orthography of the items and rely upon phonology solely. For the deaf children, a pseudohomophone like GOTE was a non-word as much as GOAF was a non-word. There was no confusion for the deaf children as a result of the inclusion of pseudohomophones. The reaction times of the hearing children, however, showed facilitation effects in reaction times and inhibition effects in accuracy for the mismatched pseudohomophones (i.e., GOTE) in otherwise semantically related stimulus pairs (i.e., SHEEP) when compared to mismatched control non-words (i.e., GOAF) in semantically related stimulus pairs (i.e., SHEEP). The decisions for the semantically related pairs containing pseudohomophones appeared to be made too quickly and on the basis of phonological information by the hearing children, and this meant the correct acceptance of a pseudohomophone as sounding like an existing word but the incorrect acceptance of a mismatched but semantically related pair as identical. For the hearing children, when judging two semantically related concepts for similarity, the inclusion of a pseudohomophone (condition 5) resulted in more confusion when compared to the inclusion of a non-word (condition 6), showing that phonological activation occurred when processing the pseudohomophones by the hearing children but not by the deaf children. The semantic manipulation made the present task highly complex for the children, and the deaf children were not able to access phonology in any of the pseudohomophone comparisons.

The deaf bilingual children in the present study appear to process words in a different way than their hearing controls. The deaf children in our study seemed to use orthographic information but not phonological information. The results for the hearing children in the present study are in line with those for hearing adults who have been found by Martensen, Dijkstra, and Maris (2005) showing difficulties in ignoring the phonological and orthographic information presented in lexical decision tasks. The participating adults in the study by Martensen, Dijkstra, and Maris were instructed to either accept pseudohomophones or reject them. The acceptance and rejection data in their study as well as in our study showed the use of phonological as well as orthographic information in word recognition. Phonology could not be ignored when instructed to rely upon orthography (Experiment 1) and, conversely, orthography could not be entirely ignored when explicitly instructed to rely upon phonology (Experiment 2).

To summarize, the results thus show phonological information to be accessed very easily by hearing children but not by deaf children. Taking into consideration that phonological recoding is very important for the development of visual word recognition, it seems logical to assume that deaf children are in a disadvantaged position. In alphabetic languages, sub-lexical phonological encoding is an important aspect in the acquisition of reading. Phonological encoding gives children a tool to recognize words in the written language they are familiar with in the spoken language. Not being able to use this effective tool might imply a disadvantage when learning written words.

The following explanations could possibly account for the lack of phonological effects in the results of the deaf children: The first possible explanation concerns the use of pseudohomophones in a Picture-Word Verification task. The pseudohomophones in our Picture-Word Verification tasks require a fine-grained phonological analysis at the sub-lexical level in order to show up in the reaction time data and accuracy data. It is possible that the deaf children are not able to process pseudohomophones up to this sub-lexical level and therefore do not show phonological effects. Marschark and Spencer (2003) note that deaf people rely on visual speech reading to understand auditory speech information. In support of our sub-lexical phonological analysis explanation, Marschark and Spencer showed that 50 percent of English words are ambiguous with other words for deaf people who rely on speech reading. For that reason, it seems likely that phonology is represented less precisely or differently for deaf children when compared to hearing children. Hearing children can process pseudohomophones up to the required fine-grained sub-lexical level and therefore do show phonological effects.

The second explanation concerns the identification of the exact meaning of spoken words in Experiment 2. The children had to identify whether the pseudohomophones sounded like the words presented in the pictures in order to evaluate the match between the words and pictures. For this Word-Picture Verification technique, good quality semantic knowledge of spoken words is required to perform successfully. For the deaf children, semantic knowledge of spoken words might not yet be sufficiently specific (Hermans, Knoors, Ormel, & Verhoeven, 2008).

The third explanation relates to the reading level of deaf children. It is well-known that many deaf children suffer from reading delays. For hearing children, the proficiency to decode words phonologically precedes the process of learning to read. On the other hand, deaf children may start to activate phonology as they grow older, when their reading levels increase (Harris & Beech, 1998). The children in the present study are in elementary school, and therefore still rather at the start of the process of learning to read, which might explain the lack of phonological activation effects.

Fourth, the relationship between the spoken language and the written language is cultivated in schools for the deaf, but also the relationship between the sign language and the written language. Since a sign language is more accessible than a spoken language for most deaf children, they are more likely to use the relations between sign language and the written language during reading during the initial years of reading, as opposed to the relations between a spoken language and the written language (Hermans, Knoors, Ormel, & Verhoeven, accepted for publication). The use of the relation between phonology and written words might explain the lack of phonological activation in deaf children in the present study. The previous explanations imply that a combination of prerequisites is needed to activate phonology during the process of visual word recognition by deaf children.

Implications of the results

The present findings have several implications for established views on word recognition of deaf children. The first implication concerns the transparency of the written language system being mastered by the children. The results indicate that these deaf children miss out on the beneficial use of sub-lexical relations. It is widely recognized that the transparency of a writing system can play a role in the phonological processing of hearing people. In transparent writing systems, sub-lexical phonological encoding generally plays an important role during the acquisition of reading. Sub-lexical phonological encoding can help hearing children to recognize words which are yet unknown in the written language, but already mastered in the spoken language. Despite exposure of the deaf children to a relatively transparent writing system that should—according to theories based on hearing individuals—facilitate the use of phonology during reading, they showed little use of phonology and this irrespective of the amount of reliance on phonology promoted in the task. This implies that sub-lexical relations between phonology and orthography are not exploited. Deaf children may treat highly transparent writing systems as if they are less-transparent systems. For these children, building up a written vocabulary will have to take place in a different way. There are several methods and techniques to increase access to phonological information for deaf people. These methods include speech reading (Harris & Moreno, 2006) and Cued Speech (Alegria, Charlier, & Mattys, 1999; Dodd & Hermelin, 1977; Leybaert & Charlier, 1996; Transler et al., 2001). Cochlear Implantation is a technique which aims at the increase of access to the spoken language (Vermeulen, 2007; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). The children in the present study did not have Cochlear Implants, nor did they use Cued Speech. Sometimes, people who are intensively exposed to Cued Speech or who have Cochlear Implants can activate phonology during word recognition. The implication of the results in the present study is that there is no extensive phonological activation during word recognition without the use of these methods or techniques. Nevertheless, several studies have shown that deaf readers who were exposed to phonological support systems frequently or even continuously do not show the same brain specialization as hearing readers (D'Hondt and Leybaert, 2003). That is, the results of several brain imaging studies suggest that the lexical and phonology systems of deaf children remain different from those of hearing children (MacSweeney, et al., 2002a; 2002b).

The present results may also imply that deaf young children cannot activate phonology *yet* during word recognition. After all, some studies have reported on phonological activation in deaf adults. Children who are exposed to the relationships between phonology and written words may develop phonological activation as they grow older. In a different study, bilingual deaf children were found to activate aspects of sign language during second language visual word recognition, which suggests a more embodied approach to word recognition on the part of such deaf children (Ormel, Hermans, Knoors, & Verhoeven, submitted). It is thus also possible that bilingual deaf children develop a language system that is fundamentally different from the systems of hearing children.

In future research, the exact nature of bilingual deaf people's phonological knowledge should be further investigated. The non-phonological lexical processing strategies of highly proficient deaf readers might also be examined in future research to identify how not only the phonology of the spoken language but also factors such as sign language proficiency can alternatively or interactively increase reading proficiency levels (see, for example, Miller, 2002, on the processing of Hebrew words). That is, the contributions of factors other than the phonology of the spoken language to reading proficiency require greater investigation.

For those children familiar with sign language, the extent to which sign language activation plays a role *during* word reading should also be examined. It is possible, for example, that the activation levels for the different aspects of sign language and the different aspects of the phonology of the spoken language may shift as a result of increased reading levels and thus change over time. Reliance on sign language may decrease even if sign information continues to play a role in the processing of words. The interplay between sign language information, phonology of the spoken language, and written words deserves a large amount of attention in (word) reading in deaf children and adults.

Note 1: In the Netherlands, schools for the deaf may utilize different age limits for grade placement.

Note 2: It should be kept in mind that the focus of the present study was on bilingual deaf children who did not have Cochlear Implants. Nowadays, many deaf children receive a Cochlear Implant to provide access or increase their access to phonological information. For deaf children who received a Cochlear Implant at a young age, phonological activation may play a much larger role in their reading than for deaf bilingual children without a Cochlear Implant as in the present study (see Vermeulen, 2007, for a study of children with Cochlear Implants in mainstream education). The activation of phonology by deaf children with a Cochlear Implant in mainstream education versus bilingual education may also be examined in future research in order to assess the influence of different types of input (Sign language versus speech) on phonological activation.

References

Aaron, P. G., Keetay, V., Boyd, M., Palmatier, S., & Wacks, J. (1998). Spelling without phonology: A study of deaf and hearing children. *Reading and Writing: An Interdisciplinary Journal, 10*, 1-22.

Alegria, J. (1998). The origin and functions of phonological representations in deaf people. In Hulme, C. J., & Mahtesha Joshi, R. (Eds.), *Reading and spelling: Development and disorders*. Hawah, New Jersey, Lawrence Erlbaum Associates, 263-286.

Alegria, J., Charlier, B. L., & Mattys, S. (1999). The role of lip-reading and Cued-Speech in the processing of phonological information in French-educated children. European *Journal of Cognitive Psychology, 11(4),* 451-472.

Alegria, J., Leybaert, J., Charlier, B., & Hage, C. (1992). On the origin of phonological representations in the deaf: hearing lips and hands. In Alegria, J., Holemder, D., De Morais, J., & Radeau, M. (Eds.). *Analytic approaches to human cognition*, Dordrecht, Holland, Elsevier.

Allman, T. M. (2002). Patterns of spelling in young deaf and hard of hearing students. *American Annals of the Deaf, 14 (1),* 46-64.

Baayen, R., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX Lexical Database. Technical report*, Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Beech, J. R., & Harris, M. (1997). The prelingually deaf young reader: A case of reliance on direct lexical access?. *Journal of research in reading, 20(2),* 105-121.

Berent, I. & Perfetti, C. A. (1995). A rose is a REEZ: The two cycles model of phonology assembly in reading English. *Psychological Review, 102(1),* 146-184.

Bosman, A., & de Groot. A. (1996). Phonologic mediation is fundamental to reading: Evidence from beginning readers. *The Quarterly Journal of Experimental Psychology, 49A(3),* 715-744.

Bosman, A. M. T., & van Hell, J. G. (2002). Orthography, phonology, and semantics. In Verhoeven, L., Elbro, C., & Reitsma, P. (Eds.). *Studies in Written Language and Literacy, Precursors of Functional Literacy, 11,* 165-187.

Burden, V., & Campbell, R. (1994). The development of word-coding skills in the born deaf. An experimental study of deaf school leavers. *British Journal of Developmental Psychology, 12(3),* 331-349.

Campbell, R. (1997). Read the lips: Speculations on the nature and role of lipreading in cognitive development of Deaf children. In Marshark, M., Siple, P., Lillo-Martin, D., Campbell, R., & Everhart, V.S. (Eds.). *Relations of language and thought. The view from sign language and Deaf children*, New York, Oxford, Oxford University Press.

Chamberlain, C., & Mayberry, R. I. (2000). Theorizing about the relation between American Sign Language and reading. In Chamberlain, C., Morford, J. P., & Mayberry, R. I (Eds.). *Language acquisition by eye.*

Chamberlain, C., & Mayberry, R. I. (submitted). ASL syntactic and narrative comprehension in good and poor readers: Bilingual-Bimodal evidence for the linguistic basis of reading.

Dijkstra, T., & van Heuven, W. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5,* 175-197.

D' Hondt, M., & Leybaert, J. (2003). Lateralization effects during semantic and rhyme judgement tasks in deaf and hearing subjects, *Brain and Language, 87*, 227-240.

Dodd & Hermelin (1977). Phonological coding by the prelingually deaf. *Perception and Psychophysics, 21,* 413-417.

Dyer, A., MacSweeney, M., Szczerbinski, M., Green, L. & Campbell, R. (2003). Predictors of reading delay in deaf adolescents: The relative contributions of rapid automatised naming speed and phonological awareness and decoding. *Journal of Deaf Studies and Deaf Education, 8(3),* 215-229.

Fishler, I. (1985). Word recognition, use of context, and reading skill among deaf college students. *Reading Research Quarterly,* 203-215.

Gaustad, M. G. (2000). Morphological analysis as a word identification strategy for deaf readers. *Journal of Deaf Studies and Deaf Education, 5(1),* 60-80.

Goldin-Meadow, S., & Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research and Practice*, *16(4),* 221-228.

Hanson, V. L. (1986). Access to spoken language and the acquisition of orthographic structure: Evidence from deaf readers. *The quarterly Journal of Experimental Psychology, 38A*, 193-212.

Hanson, V. L. (1989). Phonology and reading: Evidence from profoundly deaf readers. *Phonology and reading disability. Solving the reading puzzle.* In Shankweiler, D. L., The University of Michigan Press.

Hanson, V. L., Goodell, E. W., & Perfetti, C. A. (1991). Tongue-twister effects in the silent reading of hearing and deaf college students. *Journal of Memory and Language, 30,* 319-330.

Hanson, V. L., & Feldman, L. B. (1989). Language specificity in lexical organization: Evidence from deaf signers' lexical organization of American Sign Language and English. *Memory & Cognition, 17(3),* 292-301.

Hanson, V. L., Shankweiler, D., & Fischer, F. W. (1983). Determinants of spelling ability in deaf and hearing adults: Access to linguistic structure. *Cognition, 14,* 323-344.

Hanson, V. L., & Fowler, C. A. (1987). Phonological coding in word reading: Evidence from hearing and deaf readers. *Memory & Cognition, 15(3),* 199-207.

Harris, M., & Beech, J. (1995). Reading development in prelingually deaf children. *In Nelson, K.E. & Réger, Z. (Eds.), Children's language, 8,* 181-202. *Hillsdale, NJ, Lawrence Erlbaum Associates, Inc.*

Harris, M., & Beech, J. R. (1998). Implicit phonological awareness and early reading development in prelingually deaf children. *Journal of Deaf Studies and Deaf Education, 3(3),* 205-216.

Harris, M., & Moreno, C. (2006). Speech reading and learning to read: a comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education, 11(2), 189*-200.

Hermans, D., Knoors, H., Ormel E., & Verhoeven, L. (2008). A model of reading vocabulary acquisition for deaf children in bilingual education programs. *Journal of Deaf Studies and Deaf Education*, *13,* 155-174.

Hermans, D., Knoors, H., Ormel E., & Verhoeven, L. (accepted for publication). The relation between the reading and signing skills of deaf children: the role of vocabulary. *Journal of Deaf Studies and Deaf Education,* Advance access published on April 8, 2008. doi.10.1093/deafed/enn009.

Ho, C. S., & Bryant, P. (1997). Phonological skills are important in learning to read Chinese. *Developmental Psychology, 33(6),* 946-951.

Irausquin, R., & Mommers, C. (2001). *Leesladder. Een programma voor kinderen met leesmoeilijkheden.* [Reading ladder. A program for children with reading difficulties]. Zwijsen.

Kelly, L. P. (1995). Processing of bottom-up and top-down information by skilled and average deaf readers and implications for whole language instruction. *Exceptional Children, 61(4),* 318-334.

Kelly, L. P. (2003). The importance of processing automaticity and temporary storage capacity to the differences in comprehension between skilled and less skilled college-age Deaf readers. *Journal of Deaf Studies and Deaf Education, 8(3),* 230-249.

Leybaert, J. (1993). Reading in the deaf: The roles of phonological codes. *Psychological perspectives on deafness*. Marschark, M., & Clark, M.D.(Eds.), Hillsdale, New Jersey, Lawrence Erlbaum Associates, Publishers, 269-308.

Leybaert, J. (1998). Effects of phonetically augmented lipspeech on the development of phonological representations in deaf children. In Marschark, M., & Clark, M.D. (Eds.). *Psychological Perspectives on Deafness,* 2, Mahwah, New Jersey, Lawrence Erlbaum Associates, Publishers.

Leybaert, J. (2000). Phonological acquired through the eyes and spelling in deaf children. *Journal of Experimental Child Psychology, 73,* 291-319.

Leybaert, J., & Alegria, J. (1990). Cued Speech and the acquisition of reading by deaf children. *Cued Speech Journal, 4,* 24-38.

Leybaert, J., & Alegria., J. (1993). Is word processing involuntary in deaf children? *British Journal of Developmental Psychology, 11,* 1-29.

Leybaert, J., & Alegria, J. (1995). Spelling development in deaf and hearing children: Evidence for use of morpho-phonological regularities in French. *Reading and Writing: An interdisciplinary Journal, 7,* 89-109.

Leybaert, J., & Charlier, B. (1996). Visual speech in the head: The effect of Cued-Speech on rhyming, remembering, and spelling. *Journal of Deaf Studies and Deaf Education, 1(4),* 234-248.

Leybaert, L., & Lechat, J. (2001). Variability in deaf children's spelling: the effect of language experience. *Journal of Educational Psychology, 93(3),* 554-562.

Locke, J. L. (1978). "Phonemic effects in the silent reading of hearing and deaf children." *Cognition, 6,* 175-187.

MacSweeny, M., Campbell, R., & Donlan, C. (1996). Varieties of short-term memory coding in deaf teenagers. *Journal of Deaf Studies and Deaf Education, 1(4),* 249-262.

MacSweeney, M., Calvert, G. A., Campbell, R., McGuire, P. K., David, A. S., Williams, S. C. R., Woll, B., & Brammer, M. J. (2002a). Speechreading circuits in people born deaf. *Neuropsychologia*, *40,* 801-807.

MacSweeny, M., Woll, B., Campbell, R., McGuire P. K., David, A. S., Williams, S. C. R., Suckling, J., Calvert, G. A., & Brammer, M. J. (2002b). Neural systems underlying British Sign Language and audio-visual English processing in native users. *Brain and Language, 7,* 1583-1593.

Mayberry, R. I. (2002). Cognitive development in deaf children: the interface of language and perception in neuropsychology. In S. J. Segalowitz, & Rapin, I. (eds.). *Handbook of Neuropschology*. Amsterdam: Elsevier. *Vol. 8, Part II:* 71-107.

Marschark, M., & Shroyer, E. H. (1993). Hearing status and language fluency as predictors of automatic word and sign recognition. *American Annals of the Deaf, 138(4),* 370-375.

Marschark, M., & Harris, M. (1996). Success and failure in learning to read: The special (?) case of deaf children. In Cornoldi C., & Oakhill, J. (Eds.). *Reading comprehension difficulties: Process and intervention*, Lawrence Erlbaum Associates, Hillsdale, NJ, 279–300.

Marschark, M., Lang, H. G., & Albertini, J. A. (2002). *Educating deaf students. From research to practice.* New York, Oxford University Press.

Martensen, H., Dijkstra, T., & Maris, E. (2005). A werd is not quite a word: On the role of sublexical phonological information in visual lexical decision. *Language and cognitive processes, 20(4),* 513-552.

McEvoy, C., Marschark, M., & Nelson, D. L. (1999). Comparing the mental lexicons of deaf and hearing individuals. *Journal of educational psychology, 91,* 312 – 320.

Merrills, J. D., Underwood, G. & Wood, D. J. (1994). The word recognition skills of profoundly, prelingually deaf children. *British Journal of Developmental Psychology , 12,* 365-384.

Miller, P. (1997). The effect of communication mode on the development of phonemic awareness in prelingually deaf students. *Journal of Speech, Language, and Hearing Research, 40*, 1151-1163.

Miller, P. (2002). Communication mode and the processing of printed words: Evidence from readers with prelingually acquired deafness. *Journal of Deaf Studies and Deaf Education, 7(2),* 312-329.

Miller, P. (2006). What the processing of real words and pseudohomophones can tell us about the development of orthographic knowledge in prelingually deafened individuals. *Journal of Deaf Studies and Deaf Education, 11 (1),* 21-38.

Müller, K., & Brady, S. (2001). Correlates of early reading performance in a transparent orthography. *Reading and Writing: An Interdisciplinary Journal, 14*, 757-799.

Neville, H. J., Bavelier, D., Corina, D., Rauschecker, J., Karni, A., Lalwani, A., Braun, A., Clark, V., Jezzard, P., & Turner, R. (1998). Cerebral organisation for language in deaf and heaing subjects: Biological constraints and effects of experience. *Proceedings of the National Academy of Sciences of the United States of America, 95(3),* 922-929.

Nielsen, D. C., & Luetke-Stahlman., B. (2002). Phonological awareness: One key to the reading proficiency of deaf children. *American Annals of the Deaf, 147(3),* 11-19.

Olsen, A., & Nickerson, J. F. (2001). Syllabic organization and deafness: Orthographic structure or letter frequency in reading? *The quarterly Journal of Experimental Psychology, 54A(2),* 421-438.

van Orden, G. C. (1987). A ROWE is a ROSE: Spelling, sound, and reading. *Memory and Cognition, 15*, 181-198.

van Orden, G. C., Johnson, J. C., & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 371-385.

Ormel, E., Knoors, H., & Verhoeven, L. (in preparation). Predictors of Reading Proficiency in Deaf Children Learning to Read: A Longitudinal Study.

Ormel, E., Hermans, D., Knoors, H., & Verhoeven, L. (submitted). Cross-language effects in visual word recognition: the case of bilingual deaf children.

Padden, C. A. (1993). Lessons to be learned from the young deaf orthographer. *Linguistics and Education 5,* 71-86.

Padden, C. Hanson, V. (2000). Search for the missing link: The development of skilled reading in deaf children. *The signs of language revisited. An anthology to honor Ursula Bellugi and Edward Klima*. K. Emmorey, & Lane, H. Mahwah: New Jersey; London, Lawrence Erlbaum Publishers.

Padden, C., & Ramsey, C. (1998). Reading ability in signing deaf children. *Topic of Language Disorders*, *18(4),* 30-46.

Paul, P. V. (2003). Processes and components of reading. *Oxford handbook of Deaf studies, Language, and Education.* M. Marschark, & Spencer, P.E. Oxford, University Press**:** 97-109.

Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for Deaf readers. *Journal of Deaf Studies and Deaf Education, 5(1),* 32-50.

Samar, V. C., Parasnis, I., & Berent, G. P. (2002). Deaf poor readers' pattern reversal visual evoked potentials suggest mognocellular system deficits: Implications for diagnostic neuroimaging of dyslexia in deaf individuals. *Brain and Language, 80,* 21-44.

Schaerlaekens, A., Kohnstamm, G. A., & Lejaegere, M. (1999). *Streeflijst woordenschat voor zesjarigen: Derde herziene versie gebaseerd op nieuw onderzoek in Nederland en België*. [Target list vocabulary for 6-year-old children]. Lisse: Swets & Zeitlinger.

Schaper, M. W., & Reitsma, P. (1993). The use of speech-based recoding in reading by prelingually deaf children. *American Annals of The Deaf, 138(1),* 46-54.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime. Psychology software tools, *Learning Research and Development Centre,* University of Pittsburgh, Pittsburgh.

Spencer, L. H., & Hanley, J. R. (2003). Effects of orthographic transparency on reading and phoneme awareness in children learning to read in Wales. *British Journal of Psychology, 94,* 1-28.

SPSS for Windows, Rel. 11.0.0. 2002, Chicago: SPSS Inc.

Sterne, A., & Goswami., U. (2000). Phonological awareness of Syllables, Rhymes, and Phonemes in Deaf Children. *Journal of Child Psychiatry, 41(5),* 609-625.

Stone, G. O. & van Orden, G. C. (1993). Strategic control of processing in word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *19*(4), 744–774.

Strong, M., & Prinz, P. (1998). Is American sign language skill related to English literacy? *Language Acquisition by Eye.* In Chamberlain, C., Morford, J.P., & Mayberry, R.I., Mahwah, New Jersey, Lawrence Erlbaum Associates.

Sutcliffe, A., Dowker, A., & Campbell, R. (1999). Deaf children's spelling: Does it show sensitivity to phonology? *Journal of Deaf Studies and Deaf Education, 4(2),* 111-123.

Tan, L. H., Spinks, J. A., Eden, G. F., Perfetti, C. A., & Siok, W. T. (2005). Reading depends on writing, in Chinese, *Proceedings of the National Academy of Sciences of the United States of America, 102 (24),* 8780- 8785.

Tractenberg, R. E. (2002). Exploring hypotheses about phonological awareness, memory, and reading achievement. *Journal of Learning Disabilities, 35(5),* 407-424.

Transler, C., Gombert, J. E. & Leybaert, J. (2001). Phonological decoding in severely and profoundly deaf children: Similarity judgment between written pseudowords. *Applied Psycholinguistics, 22,* 61-82.

Transler, C., Leybaert, J. & Gombert, J. E. (1999). Do Deaf children use phonological syllables as reading units? *Journal of Deaf Studies and Deaf Education, 4(2),* 124-143.

Transler, C. & Reitsma, P. (2005). Phonological coding in reading of deaf children. Pseudohomophone effects in deaf children. *British Journal of Developmental Psychology, 23*, 525-542.

Treiman, R., & Hirsch-Pasek, K. (1983). Silent reading: Insights from second-generation deaf readers. *Cognitive Psychology, 15,* 39-65.

Unsworth, S. J., & Pexman, P.M. (2003). The impact of reader skill on phonological processing in visual word recognition. *The quarterly Journal of Experimental Psychology, 56A(1),* 63-81.

Vermeulen, A. M. (2007). Reading comprehension in children with cochlear implants. PhD thesis, Radboud University Nijmegen.

Vermeulen, A. M., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with cochlear implants. *Journal of Deaf Studies and Deaf Education, 12(3),* 283-302.

Wang, M., Koda, K., & Perfetti, C. A. (2003). Alphabetic and nonalphabetic L1 effects in English word identification: a comparison of Korean and Chinese English L2 learners. *Cognition*, *87,* 129-149.

Wang, M., Perfetti, C. A., & Liu, Y. (2005). Chinese-English biliteracy acquisition: cross-language and writing system transfer. *Cognition*, *97,* 67-88.

Waters, G. S., Doehring, D. G. (1990). Reading acquisition in Congenitally Deaf Children Who Communicate Orally: insights from an Analysis of Component Reading, Language, and Memory Skills. In Carr, T. H., & Levy, B. A. (Eds.). *Reading and its development.*, San Diego, Academic Press**:** 323-373.

Wauters, L. N., van Bon, W. & Tellings, A. (2006). Reading comprehension of Dutch deaf children. *Reading and Writing, 19,* 49-76.

van Wijnendaele, I., & Brysbaert, M. (2002). Visual word recognition in bilinguals: Phonological priming from the second to the first language. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 616-627.

Cross-Language Effects in Visual Word Recognition: The Case of Bilingual Deaf Children

Chapter 3

Abstract

To investigate the activation of sign features during visual word recognition in bilingual deaf children, the role of sign phonology and sign iconicity was examined using two experimental paradigms: sign-picture verification and word-picture verification. Participants had to make decisions about sign-picture and word-picture pairs manipulated according to phonological sign features (i.e. hand shape, movement, and location) and iconic sign features (i.e., transparent depiction of meaning or not). Sign phonology and sign iconicity were strongly activated for the deaf children during both of the verification tasks. Phonologically related sign pairs resulted in relatively longer response latencies and more errors while iconic sign pairs resulted in relatively shorter response latencies and fewer errors. No such effects were found in the word-picture verification task with hearing children. The results provide evidence for non-selective language activation in deaf children.

3.1 *Introduction*

A greatly debated topic in bilingual research is whether the two languages in the mental lexicons of bilinguals operate as separate systems (Gerard & Scarborough, 1989) or in a non-selective manner (de Groot, Delmaar, & Lupker, 2000; Dijkstra, Grainger, & van Heuven, 1999; Dijkstra, van Heuven, & Grainger, 1998; Kroll & Stewart, 1994; Kroll, Bobb, & Wodniecka, 2006). The evidence seems to point in the direction of the latter (Marian & Spivey, 2003; van Hell & Dijkstra, 2002). That is, the recognition of words in one of the languages known by bilinguals appears to be automatically affected by lexical knowledge of the other language known by participants (Dijkstra, van Jaarsveld, & ten Brinke, 1998; Gollan, Forster & Frost, 1997). In general, the languages studied with respect to cross-language interaction have been languages with accompanying writing systems and varying degrees of orthographic and phonological overlap between the two languages. One question that thus remains to be answered is the extent to which the *overlap* between the languages known by the bilingual is critical for non-selective language activation (i.e., general language activation). The topic of the present study is therefore the degree of cross-language interaction for deaf bilingual children who are thus familiar with two languages that show very little overlap: Sign Language of the Netherlands versus Dutch.

In contrast to spoken languages, sign languages do not have an accompanying written system (Evans, 2004; Padden & Ramsey, 1998), which means that there is *no orthographic overlap* between a sign language and a spoken language. There is also *minimal phonological overlap* between signed and spoken languages because sign language relies upon visual and spatial information rather than sound. People who know a sign language and deaf people who read, in particular, therefore provide an excellent venue for the study of non-selective language activation.

The focus of the present study is on visual word recognition, and the main question is whether deaf children activate sign language features during Dutch word recognition. In other words, does the visual word recognition of deaf bilingual children occur in a language non-selective manner?

3.1.1 *Non-Selective Language Access in Bilinguals*

Most studies of visual word recognition in bilinguals have examined bilingual adults with mastery of two languages with similar (alphabetic) scripts: English and Dutch (de Groot, Delmaar, & Lupker, 2000; van Heuven, Dijkstra, & Grainger, 1998), French and Dutch (van Wijnendaele & Brysbaert, 2002), or English and French (Bijeljac-Babic, Biardeau & Grainger, 1997). Van Heuven et al., for instance, presented participants with a number of tasks (e.g., progressive demasking and lexical decision) in which the number of orthographic neighbor words in the target language and the non-target language were manipulated. The study showed the processing of the target words in one language to automatically activate the orthographic neighbor words in not only the same language but also in the other language. The conclusion which can be drawn from this and comparable studies is that word processing operates in a language non-selective manner. Evidence for language non-selectivity has even been found for trilinguals who have mastered Dutch, English, and German (Lemhöfer, Dijkstra & Michel, 2004) or Dutch, English, and French (van Hell & Dijkstra, 2002). Interestingly, van Hell and Dijkstra further showed a weaker language (i.e., the second or third language) to influence the processing of the first language and vice versa (i.e., the first language to influence the processing of the weaker languages).

Some studies were employed in the visual word recognition of adults who have mastered languages with highly varying scripts such as Korean, Chinese, and English (Wang, Koda, & Perfetti, 2003), Arabic, English, and French (Kandill & Jiang, 2004), Hebrew and English (Gollan, Forster, & Frost, 1997), Chinese, English, French, and Dutch (Keatley, Spinks, & de Gelder, 1994). When Wang et al. (2003) studied the L2 English word recognition of bilinguals whose first language (L1) was either alphabetic Korean or non-alphabetic Chinese, those whose L1 was non-alphabetic Chinese showed a different manner of processing L2 English than those whose L1 was alphabetic Korean (see also Akamatsu, 1999). Kandill and Jiang (2004) studied bilingual word recognition using word lists that included words from two familiar languages (mixed word lists) and words from one familiar language (non-mixed word lists). The latencies during word recognition of Arabic dominant Arabic-English bilinguals was then compared to the latencies during word recognition of English dominant English-French bilinguals. For mixed word lists, response times were found to be slower for different scripts (as in the case of Arabic and English) than for similar scripts (as in the case of French and English), which shows language script of the two familiar languages to clearly play a role in bilingual word recognition. Consequently, the degree of bilingual language activation may be different for two highly varying scripts when compared to two similar scripts. Gollan et al. (1997) studied word recognition in either Hebrew-English or English-Hebrew bilinguals and found, irrespective of the first language of the participants, L1 words to be activated while processing L2 words but L2 words to *not* be activated while processing L1 words. Similarly, Keatley, Spinks, and de Gelder (1994) found L1 priming effects for L2 word recognition but not vice versa for Chinese-English and French-Dutch bilinguals. In sum, the results of these studies show script overlap to affect the degree of language interaction during word recognition. That is, non-selective language activation appears to occur for languages with differing scripts but to a lesser extent than for languages with similar scripts.

The possibility of non-selective language activation has also recently been examined for bilingual children. Bialystok, Luk, and Kwan (2005) compared three groups of young bilingual children learning languages with various degrees of script overlap, namely: Chinese-English, Hebrew-English, or Spanish-English. Children learning Hebrew or Spanish in addition to English showed an influence of the respective language on their English performance while those children learning Chinese in addition to English (with no script overlap) showed no such influence. The degree of script overlap between the two languages seemed to contribute largely to the influence of L1 literacy on L2 literacy during the early stages of reading. When Wang, Perfetti, and Liu (2005) examined the role of phonology and orthography in L1 and L2 on word reading in the other language (L1 or L2) for already fluent Chinese dominant Chinese-English bilingual children, however, word reading performance was sensitive to the children's phonological skills, but not their orthography skills. In other words, the evidence regarding cross-language effects in children who learned two highly varying scripts is not as yet clear.

3.1.2 *Non-Selective Language Access in Deaf People*

Despite a large degree of distinctiveness between the languages known by bilinguals, it increasingly appears to be the case that languages can interact non-selectively during perception tasks at all times and even when only one language has been consciously activated for processing (van Hell, 2002). Consistent with the view that lexical items from both languages can be activated while processing words in only one language, Emmorey, Borinstein, and Thompson (2005) have shown sign language to influence speech production in hearing adult bilinguals who are thus familiar with both a sign language and a spoken language. The hearing bilinguals in the Emmorey et al. study had deaf parents and native mastery of both English and American Sign Language (ASL). ASL intrusion occurred by code-blending and was found to occur during a conversation with a monolingual English speaker and therefore not in a situation requiring sign language. The concept code-blending already shows us that something special can be seen in bi-modal bilingualism (familiarity with a sign language and a spoken language), which cannot be seen in uni-modal bilingualism (i.e. familiarity with two spoken languages) for which concepts as code-mixing and code-switching are used. The special aspect in bi-modal bilingualism concerns the possibility of *producing* sign and spoken information simultaneously (see also Baker & van den Bogaerde, in press, and van den Bogaerde & Baker, 2006), which is not possible for two spoken words. It is not understood yet how this possibility to process signs and spoken words simultaneously during production can affect *perception* processes. Moreover, studies of production do not necessarily reveal a great deal about non-selective processes during perception.

A study of sign language interference during the perception of language was conducted by Treiman and Hirsh-Pasek (1983) who studied the activation of sign language during the reading of English by deaf adults. More specifically, Treiman and Hirsh-Pasek examined the roles of signs, phonology of the spoken language, and finger spelling activation in a sentence reading task and found some activation of sign but no activation of phonology or finger spelling. In more recent study by Mayberry, Chamberlain, Waters, and Hwang (2003), the influence of sign knowledge during the word reading of deaf children was similarly examined. Beginning deaf readers accurately recognized more words when the relation between the sign and the word was consistent (the words had one-to-one sign translation equivalents) as opposed to inconsistent (the words did not have sign translation equivalents), with the latter case usually eliciting finger spelling of the words. In other words, signs seemed to be used for those words that had sign translation equivalents.

The above findings provide evidence for the influence of sign information during the processing of both speech and written English. Emmorey et al. provided evidence from the speech of hearing adults; Treiman and Hirsch-Pasek provided evidence from the sentence reading of deaf adults; and Mayberry et al. provided evidence from the word reading of deaf children. In contrast, Hanson and Feldman (1989, 1991) found no evidence of non-selective language activation among bilingual deaf adults when sign morphology activation (1989) was examined for the reading of an English word prime followed by the reading of an English target word by skilled deaf readers. A number of the prime-target pairs had overlapping sign base morphologies (morphologically related noun-verb pairs, partly sharing hand shape, place of articulation, movement, and orientation, i.e. sit-chair), which meant that the overlapping pairs could be expected to be processed more slowly and less accurately than the other pairs when sign morphology plays a role in the reading of English words. However, Hanson and Feldman did not find any evidence of such interference.

Unlike hearing children and obviously due to their weak phonological knowledge of the spoken language, most deaf children do not effectively use phonological recoding mechanisms to automatically access the meanings of familiar printed words (Beech & Harris, 1997; Waters & Doehring, 1990). While the findings of several studies suggest that at least some deaf adult readers can exploit phonological knowledge during reading (Hanson & Fowler, 1987; Leybaert, 1993; Transler, Gombert, & Leybaert, 2001), the results of many other studies show most deaf children and adults to not activate phonological information during reading (Merrills, Underwood, & Wood, 1994; Miller, 2006; Treiman & Hirsch-Pasek, 1983; Waters & Doehring, 1990). In other words, the activation of phonology during the reading of words by most deaf readers lags far behind that of hearing readers (e.g., Beech & Harris, 1997; Marschark, Lang, & Albertini, 2002). Stated differently: The phonology of the spoken language is not easy to access for deaf children and adults, which means that deaf readers do not benefit as much from the connection between phonology and orthography during reading as hearing people do. Very little is known about the alternative activation patterns used by deaf children during reading (Izzo, 2002) or, more specifically, the activation of sign information during the word reading of deaf children.

3.1.3 *Present Study*

Only a few studies have investigated the possibility of non-selective language activation among deaf children although deaf bilingual children present a unique opportunity to study language processing. More specifically, the question can be raised whether non-selective language access occurs for only spoken languages with associated writing systems or also for the combination of a signed language with a spoken/written language and thus two languages with minimal overlap. Given that sign languages do not have an accompanying script, it is intriguing to ask if signs — on the one hand — and spoken or written words — on the other hand — may still affect each other during the processing of one or the other of these languages.

The goal of the present study was to investigate the activation of the sign translation equivalent in Sign Language of the Netherlands (SLN) when deaf children are asked to read Dutch words. In the Netherlands, deaf children usually grow up in a joint sign language/sign supported Dutch/spoken language environment with mostly hearing parents. In the vast majority of cases, the sign language is the more natural and accessible language for the children (Klatter-Folmer, van Hout, Kolen, & Verhoeven, 2006; Knoors, in press).

At least two sign language features might affect the word recognition of deaf children: sign phonology, which is also called sign formational parameter information, and sign iconicity. The individual signs in all sign languages are composed of phonemes, which thus constitute the sign phonology (Corina & Sandler, 1993; Corina & Knapp, 2006; Dye & Shi, 2006; Emmorey, McCullough, & Brentari, 2003; Hildebrandt & Corina, 2002; Klima & Bellugi, 1979; Thompson, Emmorey, & Gollan, 2005). The most relevant sign phonemes include hand shape, movement of hands and arms, location of hands relative to the body, and hand-palm orientation (Emmorey & Corina, 1990). Sign iconicity refers to the mapping between the meaning of a sign and its form; the level of transparency or translucency. In spoken languages, onomatopoeia is a classic example of iconicity (Pietrandrea, 2002). In sign languages, the associations between the form of (parts of) the sign and the meaning of the sign are frequently more transparent than in spoken languages (Emmorey, 2002; van der Kooij, 2002). For instance, in many sign languages, the meanings of the signs for ‘house’ or ‘ball’ are provided by the form of the signs (‘a roof’ or ‘a round object’).

In order to determine if SLN is non-selectively activated during lexical access to Dutch written words, a series of experiments was undertaken. The aim of Experiment 1 was to assess whether our sign manipulations in Experiment 2, the essential word test, did show the expected inhibition and facilitation effects in a *sign* test. Given that the investigation of sign phonology is a relatively new area of research, also for SLN, Experiment 1 appears crucial to us. In Experiment 1, the roles of sign iconicity and sign phonology in the processing of SLN by deaf elementary school-aged children were documented in a sign-picture verification task. For sign phonology, extended overlap between underlying SLN signs was expected to create an *interference effect* for sign-picture verification; Responses to word-picture pairs for which the two sign translation equivalents share underlying sign phonology are expected to be slower and less accurate than responses to pairs for which the two sign translations equivalents do not share underlying sign phonology. For sign iconicity, the close association between the form of a sign and its meaning was expected to produce a *facilitation effect* in the sign-picture verification task; Responses to items with strongly iconic sign translation equivalents are expected to be faster and more accurate than responses to items with weakly iconic sign translation equivalents. Semantic relatedness was examined in Experiment 1 in order to verify the paradigm and consequently the roles of iconicity and phonology. Semantic relations were expected to create an interference effect, in line with the results of similar studies (Damien & Bowers, 2003).

Up until now, studies of the roles of sign iconicity and sign phonology have been conducted among deaf adults and not in relation to visual word recognition. In Experiment 2, we therefore investigated whether aspects of underlying sign iconicity and underlying sign phonology also play a role in the visual word recognition of deaf children using a word-picture verification task. Also for word-picture verification, sign phonology was expected to create an *interference effect* and sign iconicity was expected to produce a *facilitation effect*. Semantic relatedness was examined to verify the roles for phonology and iconicity. Only written Dutch stimulus materials and task demands accompanied the word-picture verification task and no reference was made to SLN. Knowledge of sign language was not required to respond adequately to the word stimuli, and the involvement of spoken Dutch was not assessed.

In order to verify that the effects in the word-picture verification task with the deaf children could be attributed to the underlying phonological and iconicity aspects of SLN, the same word-picture verification task was undertaken with hearing children who have no knowledge of sign language.

The specific research questions were as follows.

1. Is there a sign phonology and sign iconicity effect during sign-picture verification (Experiment 1)?
2. Is visual word recognition for deaf children language selective or non-selective (Experiments 1 vs. 2)?

3.2 Experiment 1: Sign-Picture Verification in Deaf Children

3.2.1 *Method*

Participants. The participants in the present study were 40 bilingual deaf children ranging in age from 97 months to 146 months (mean = 126; SD = 20). The participants were in two age groups. The younger participants were between 97 and 123 months (*N* = 20, mean = 115; *SD* = 7.6, around Grades 3 and 4[3]) and the older participants were between 124 and 146 months (*N* = 20, mean = 132; *SD* = 7.1, around Grades 5 and 6[3]). The children attended one of three schools for deaf education in the Netherlands. All of the schools provided bilingual deaf education with a curriculum that consisted of a combination of SLN and Sign Supported Dutch (SSD). In SSD, Dutch word order is used with the support of signs. The children had been taught Sign Language of the Netherlands from the age of four years at school. Prior to the age of four, many of the children had already attended preschool for deaf children and thus interacted with caregivers who used sign language. Formal exposure to written Dutch started at the age of four years.

Stimuli. In the sign-picture verification task, 192 sign-picture pairs were presented: 50% of the sign-picture pairs were matches and thus required a “yes” response while 50% of the pairs were mismatches and thus required a “no” response. The sign videos were part of the standard SLN lexicon. The videos were created by the Dutch Centre for Sign Language and presented on the left side of a computer screen. The pictures originated from *Leesladder* [Reading Ladder] (Irausquin & Mommers, 2001), which is a computer program for children with reading disabilities. The pictures were colored 6 by 6 centimeter line drawings representing nouns and presented on the right side of the computer screen. The experimental stimuli were created with the aid of two pilot studies[1]. That is, the stimulus items were distributed across six conditions reflecting the strengths of three factors: Sign Iconicity

(Condition 1: Strong Sign Iconicity; Condition 2: Weak Sign Iconicity, see FIGURE 1), Sign Phonology (Condition 3: Strong Phonological Relation between two signs; Condition 4: Weak Phonological Relation between two signs, see FIGURE 2), and Semantics (Condition 5: Strong Semantic Relation; Condition 6: Weak Semantic Relation).

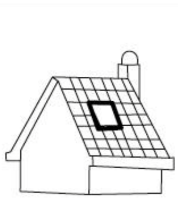
In the second pilot study, we demonstrated that hearing children without any knowledge of sign language recognized the meaning of the strong iconic signs (Condition 1) significantly better than the meaning of the weak iconic signs (Condition 2), showing that the meanings of the signs were recognizable as a result of the form of the sign. Each of the 6 conditions contained 24 unique sign-picture combinations.

Figure 1

Level of Iconicity. In Experiment 1, the participants were shown a videotaped sign (e.g., the sign for house) and a picture (e.g., of a house). In Experiments 2, the participants were shown a written word (e.g., the letter string "house") and a picture (e.g., of a house). In experiment 2, the signs were not shown to the participants.

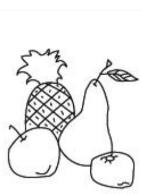
Condition 1: Strong Iconicity

house



Condition 2: Weak Iconicity

fruit



In Condition 1 and 2, the pictures, and therefore the unique pairs were repeated once, adding up to 48 items in Condition 1 and 48 items in Condition 2 (96 pairs referring to the same concept; e.g. sign for horse and a picture of a horse). The rationale behind the repetition of unique items in condition 1 and 2 was based on the design for conditions 3 to 6, which also involved repetition of pictures. Conditions 3 through 6 each involved 24 pairs referring to different concepts (e.g., the sign for dog and a picture of a chair). Condition 4 and Condition 6 were both constructed by recombining the signs and pictures from the related conditions (i.e., Conditions 3 and 5, respectively) in such a manner that unrelated pairs were formed.[2] The experimental test consisted of four sets of stimuli initially preceded by a separate practice set, which included 10 items. The practice set contained items that were different from the experimental sets. Each of the four experimental sets consisted of 12 pairs from Condition 1 (match), 12 pairs from Condition 2 (match), and 6 pairs from Condition 3 (mismatch), Condition 4 (mismatch), Condition 5 (mismatch), and Condition 6 (mismatch), respectively; 48 unique pairs per set. At the start of each stimulus set, four new practice items were shown.

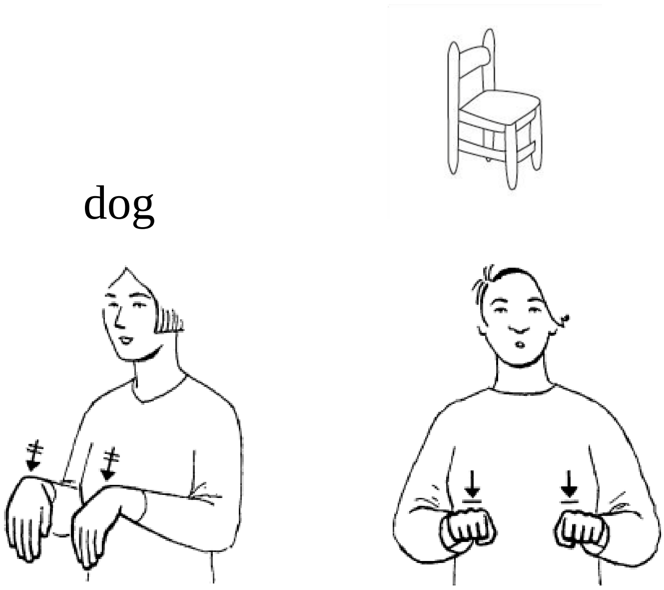
Word orthography frequency measures were based on CELEX counts (Baayen, Piepenbrock, & van Rijn, 1993). Sign frequency measures are not yet available for SLN. Recombining the signs and pictures in Condition 3 and 5 into unrelated pairs in condition 4 and 6, respectively, resulted in identical word and picture properties with identical word orthography frequencies, and number of letters between Condition 3 and Condition 4 (Phonological Relation) and also between Condition 5 and Condition 6 (Semantic relation), based on the word translations of the signs and the words corresponding to the pictures.

It was not intended to compare Phonology directly to Semantics or Iconicity, which implied that word properties could be different between the three different factors; Phonology, Semantics, and Iconicity. The purpose of the present study was to examine effects of Phonology and to examine effects of Iconicity for bilingual deaf children. Semantics was included in order to certify the use of a Sign-Picture paradigm with deaf children in case of null effects of Iconicity and Phonology.

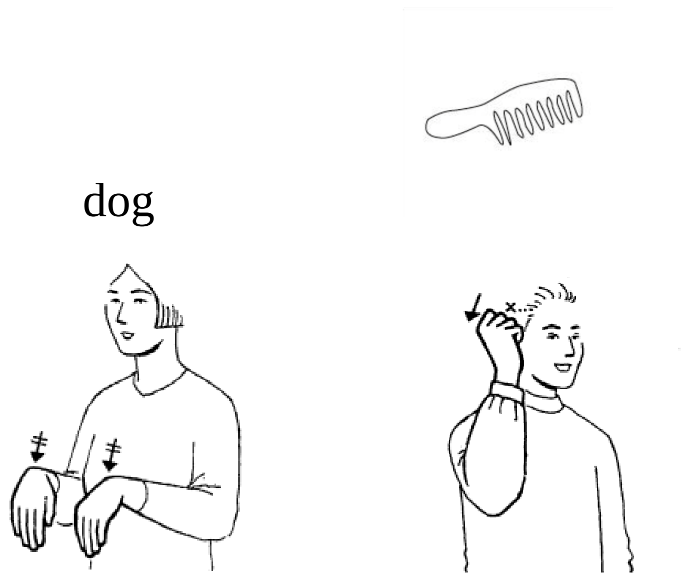
Figure 2

Sign Phonological Relatedness. In Experiment 1, participants were shown a videotaped sign (e.g., the sign for a dog) and a picture (e.g., of a chair). In Experiment 2, the participants were presented a word (e.g., the letter string “dog”) and a picture (e.g., of a chair). In experiment 2, the signs were not shown to the participants.

Condition 3: Strong Phonological Relation between Signs



Condition 4: Weak Phonological Relation between Signs



In Condition 3 and Condition 4, the word translations for the signs and the words corresponding to the pictures had a combined average of 1.52 log frequency per million, using Celex measures, and an average frequency of 18.979 per 15.000, as observed in the children's corpora by Schrooten and Vermeer (1994). The mean length was 5.46 letters. In Condition 5 and 6, there was an average of 1.53 log frequency per million, using Celex measures, and an average frequency of 38.839 per 15.000 as observed for children by Schrooten and Vermeer (1994). The mean length was 4.31 letters. Identical properties between conditions were evidently not seen between Condition 1 and Condition 2 where the signs and pictures were not kept identical. The word translations for the signs and the words corresponding to the pictures in Condition 1 had an average of 1.59 log frequency per million, using Celex measures, an average frequency of 22.208 per 15.000, as observed by Schrooten and Vermeer and the mean length was 4.66 letters. In Condition 2 the word translations for the signs and the words corresponding to the pictures had an average of 1.52 log frequency per million (Celex), an average frequency of 22.791 per 15.000 as observed in the children's corpora (Schrooten and Vermeer, 1994), and the mean length was 5.21 letters.

Design. The order of presentation was constructed using a Latin Square design. And within each stimulus set, the 48 pairs were presented in a random order per child.

Apparatus. In this experiment, a laptop, type Dell, Latitude 640, was used. The test was constructed using the commercially available software program E-Prime, version 1.0 (Schneider, Eschman, & Zuccolotto, 2002).

Procedure. The instructions for the task were provided in SLN on a class basis provided by the teachers of the children. After group instruction, questions could be asked about the procedure. The experiment was then conducted with groups of six children in a separate, well-lightened room with two experimenters present. The distance between the children and the screen was approximately 40 centimeters. During instruction, the participants were informed that a fixation point would appear on the screen for one second, followed by a SLN sign on the left side of the screen and a picture on the right side of the screen, which appeared simultaneously with the sign onset. When both the sign and picture referred to the same concept, a match response was required and the respondent had to press the "Enter" button that had a green mark on it. When the sign and picture did not refer to the same concept, a mismatch response was required and the respondent had to press the "Caps Lock" button that had a red mark on it. The stimuli disappeared after the participant responded or after a period of 10 seconds and the next item followed. After the instructions were provided and understood by the participants, the practice set with 10 items was presented. After these 10 items, the Dutch word for “break” appeared on the screen, indicating the start of a self-paced break; the participants could continue by pressing one of the response buttons. After every 52 items (4 practice items plus 48 stimulus items), a self-paced break occurred again. Upon completion of the four sets of stimuli, the Dutch word for “End” appeared.

3.2.2 *Results*

Both Response Time (RT) and Accuracy of responding were measured per item (see Table 1). The RTs were measured from the onset of the stimuli and, for the RT analyses, erroneous responses and RTs that were more than two standard deviations from the participant’s mean and the item mean were excluded from further analysis. For the younger participants, 1.29% of the data was excluded. For the older participants 1.46% of the data was excluded from further analysis. Participant and item analyses were performed on the data. The F-values for the participant analyses will be referred to as *F*1; the *F*-values for the item analyses will be referred to as *F*2. A One-way ANOVA was conducted for the item analyses on the Sign Iconicity data (i.e. on Conditions 1 and 2). Repeated measures ANOVAs were conducted for the participant analyses on the Sign Iconicity data (i.e. Conditions 1 and 2). Repeated measures ANOVAs were also conducted for the participant as well as the item analyses on Sign Phonological Relatedness (i.e. Conditions 3 and 4) and on Semantic Relatedness (i.e. Conditions 5 and 6).

Response Time data. In this analysis, Sign Iconicity was treated as a within subjects and between items factor. Sign Phonology was treated as a within subjects and within items factor, and Semantics was similarly treated as a within subjects and within items factor. Grade was treated as a between subjects factor and within items factor.

A significant facilitation effect was found for Sign Iconicity (see Table 1). No interaction was found between grade and Sign Iconicity ($F1(1,38) = .592$, $p > .1$, $\eta_p^2 = .015$; $F2(1,46) = 1.018$, $p > .1$, $\eta_p^2 = .022$). Strongly iconic pairs were responded to faster than weakly iconic pairs ($F1(1,38) = 24.181$, $p < .001$, $\eta_p^2 = .389$; $F2(1,46) = 4.480$, $p < .05$, $\eta_p^2 =$

.089). A main effect for grade was also detected ($F1(1,38) = 6.620$, $p < .05$, $\eta_p^2 = .148$; $F2(1,46) = 199.3356$, $p < .001$, $\eta_p^2 = .813$). The older children responded significantly faster than the younger children. A significant inhibitory effect was found for Sign Phonological Relatedness. No interaction was found between grade and Sign Phonological Relatedness ($F1(1,38) = 2.953$, $p < .1$, $\eta_p^2 = .072$; $F2(1,23) = .539$, $p > .05$, $\eta_p^2 = .023$). Pairs of items with strong phonological relations between the relevant signs (condition 3) were responded to more slowly than pairs of items with weak phonological relations between the relevant signs (condition 4) ($F1(1,38) = 60.647$, $p < .001$, $\eta_p^2 = .615$; $F2(1,23) = 16.405$, $p < .001$, $\eta_p^2 = .416$) and a main effect for grade was also detected ($F1(1,38) = 7.712$, $p < .01$, $\eta_p^2 = .169$; $F2(1,23) = 107.093$, $p < .001$, $\eta_p^2 = 823$), with the older participants responding faster than the younger participants. An inhibitory effect was also found for Semantic Relatedness. There was no interaction between grade and Semantics ($F1(1,38) = .00$, $p > .1$, $\eta_p^2 = .000$; $F2(1,23) = .551$, $p > .1$, $\eta_p^2 = .023$). Semantically related pairs (condition 5) were responded to slower than semantically unrelated pairs (condition 6) ($F1(1,38) = 8.187$, $p < .01$, $\eta_p^2 = .177$; $F2(1,23) = 2.364$, $p > .1$, $\eta_p^2 = .093$). Again, a main effect was found for grade ($F1(1,38) = 6.710$, $p < .01$, $\eta_p^2 = .150$; $F2(1,23) = 57.932$, $p < .001$, $\eta_p^2 = .716$), with the older children responding faster than the younger children.

Error data. Sign Iconicity, Phonological Relatedness, and Semantic Relatedness also produced significant main effects on the error data, but not interactions with grade. The effect of Sign Iconicity showed fewer errors to be made with strongly iconic pairs than with weakly iconic pairs ($F1(1,38) = 46.675$, $p < .001$, $\eta_p^2 = .551$; $F2(1,46) = 11.213$, $p < .01$, $\eta_p^2 = .196$.); No interaction was found between grade and Sign Iconicity ($F1(1,38) = .943$, $p > .1$, $\eta_p^2 = .024$; $F2(1,46) = 1.399$, $p > .1$, $\eta_p^2 = .030$), and no main effect was found for grade ($F1(1,38) = .094$, $p > .1$, $\eta_p^2 = .002$; $F2(1,46) = ..281$, $p > .1$, $\eta_p^2 = .006$). The effect of Phonological Relatedness showed more errors to be made for pairs with strong phonological relations ($F1(1,38) = 200.170$, $p < .001$, $\eta_p^2 = .840$; $F2(1,23) = 18.489$, $p < .001$, $\eta_p^2 = .446$); no interaction was found between grade and Sign Phonology ($F1(1,38) = 1.625$, $p > .1$, $\eta_p^2 = .041$; $F2(1,23) = 2.138$, $p > .1$, $\eta_p^2 = .085$). A significant effect was found for grade, but only in the item analyses ($F1(1,38) = 1.263$, $p > .1$, $\eta_p^2 = .031$; $F2(1,23) = 5.583$, $p < .05$, $\eta_p^2 = .195$). And the effect of Semantic Relatedness similarly showed more errors to be made for pairs with strong semantic relations ($F1(1,38) = 45.339$, $p < .001$, $\eta_p^2 = .544$; $F2(1,23) =$

2.206, $p < .1$, $\eta_p^2 = .088$), but an interaction was found between grade and Semantics ($F1(1,38) = 6.219$, $p < .05$, $\eta_p^2 = .141$; $F2(1,23) = 4.197$, $p < .1$, $\eta_p^2 = .154$). The younger participants showed a larger effect for condition than the older participants did (younger participants: $F(1(19) = 78.583$, $p < .001$, $\eta_p^2 = .805$; $F2(1,23) = 3.566$, $p < .1$, $\eta_p^2 = .134$; older participants: ($F1(1,19) = 6.163$, $p < .05$, $\eta_p^2 = .245$; $F2(1,23) = .891$, $p > .1$, $\eta_p^2 = .037$). No main effect was found for grade ($F1(1,38) = .012$, $p > .1$, $\eta_p^2 = .000$; $F2(1,23) = .048$, $p > .1$, $\eta_p^2 = .002$).

Table 1

Mean Response Times (in Milliseconds) and Accuracy Rates (in Percentages) for Experiment 1 on the Sign-Picture Verification of Deaf Children (with Standard Deviations presented in Parentheses).

		RT	Error rates
Sign Iconicity			
Condition 1: Strong	3rd/4th Grade	1871 (455)	.92 (.05)
Condition 2: Weak		1959 (367)	.83 (.09)
Condition 1: Strong	5th/6th Grade	1542 (378)	.93 (0.6)
Condition 2: Weak		1680 (384)	.81 (.11)
Sign Phonological Relatedness			
Condition 3: Strong	3rd/4th Grade	2437 (419)	.72 (.12)
Condition 4: Weak		2178 (409)	.94 (.05)
Condition 1: Strong	5th/6th Grade	2054 (376)	.68 (.14)
Condition 2: Weak		1887 (375)	.93 (.08)
Semantic Relatedness			
Condition 5: Strong	3rd/4th Grade	2147 (456)	.88 (.06)
Condition 6: Weak		2093 (476)	.96 (.03)
Condition 1: Strong	5th/6th Grade	1830 (329)	.90 (.08)
Condition 2: Weak		1769 (341)	.94 (.07)

Conclusion

The three experimental factors all produced significant effects. The expected inhibition for sign phonology showed that the presentation of a sign results in the activation of other signs with overlapping sign phonology. The expected sign iconicity effect showed that the presentation of a strongly iconic sign resulted in facilitated processing when compared to the processing of a weakly iconic sign. The expected semantic inhibition effect showed that the paradigm is effective. To conclude, the same manipulations can be used to examine non-selective language access in Experiment 2.

3.3 Experiment 2: Word-picture Verification

Although the children of our main interest are the deaf children, an overall analysis including deaf and hearing children would ideally be preferred. The Levene 's test of Equality of Error showed that significantly different Standard Deviations were found for the results of the deaf and hearing children. Interactions between hearing status (i.e. deaf vs. hearing) and Sign Iconicity, Sign Phonology, and Semantics, respectively, were analyzed only to provide an indication of differences between the deaf and hearing children. Significant interactions were found[4]. The results for the hearing participants are discussed in Part a, after which the results for the deaf participants are discussed in Part b.

3.3.1 Part a: Word-Picture Verification in Hearing Children

Hearing children were examined in order to check the manipulations. In line with our assumptions, hearing children who are not familiar with a sign language should not show any sign effects in the Word-Picture Verification Test. If sign effects were to be found with hearing children, it would show that the present materials are not adequately measuring the use of sign phonology and sign iconicity. In that case, results could, for example, be affected by the pictures.

3.3.2 *Method*

Participants. A total of 72 hearing children participated in the present control study. The children were in grade 3 (with a mean age of 105 months, *SD* = 5.1 months) and grade 5 (with a mean age of 132 months, *SD* = 4.3 months). The hearing children attended one of two elementary schools in The Netherlands, and none of the hearing children were familiar with SLN.

Stimuli. For the present word-picture verification task, the signs from Experiment 1 were replaced by words (i.e., their translations) (see Figures 1 and 2).

Apparatus and procedure. Nearly the same apparatus was used and procedures were followed as in Experiments 1; the only difference was the use of words instead of signs. The respondent was instructed to give a match response when both the word and picture referred to the same concept, and the respondent had to press the “Enter” button that had a green mark on it. When the word and picture did not refer to the same concept, a mismatch response was required and the respondent had to press the “Caps Lock” button that had a red mark on it.

3.3.3 *Results*

The responses to the 96 word-picture pairs were analyzed, and the results are summarized in Table 2. For each participant, the mean RT and error scores were computed for the three factors. For the RT measures, erroneous responses and RTs that were more than two standard deviations from the participant and item mean were excluded from further analysis. For the younger hearing participants, 1.72% of the data was excluded. For the older participants, 1.92% of the data was excluded from further analysis.

Sign Iconicity was treated as a within subjects and between items factor; Phonological Relatedness of sign translation equivalents was treated as a within subjects and within items factor; and Semantic Relatedness was treated as a within subjects and within items factor. Grade was treated as a between subject factor and within items factor.

Response Time data. For Sign Iconicity, no main effect was obtained (i.e. pairs with strongly versus weakly iconic sign translation equivalents did not influence the response times) ($F1(1,96) = 2.074$, $p > .1$, $\eta_p^2 = .021$; $F2\ (1,46) = .182$, $p > .1$, $\eta_p^2 = .004$). A main effect of grade was detected ($F1(1,96) = 25.370$, $p < .001$, $\eta_p^2 = .209$; $F2(1,46) = 612.927$, $p <$

.01, $\eta_p^2 = .930$) with the fifth graders responding faster than the third graders (see Table 3). There was no interaction between grade and condition ($F1(1,96) = .457$, $p > .1$, $\eta_p^2 = .005$; $F2(1,46) = .401$, $p > .1$, $\eta_p^2 = .009$). For Phonological Relatedness of the sign translation equivalents, there was similarly no main effect of condition (i.e., pairs with strongly similar sign translation equivalents versus dissimilar sign translations did not affect the response times, $F1(1,96) = .064$, $p > .1$, $\eta_p^2 = .001$; $F2(1,23) = .134$, $p > .1$, $\eta_p^2 = .006$). A significant main effect of grade was again found with the fifth grade children responding faster than the third grade children ($F1(1,96) = 22.986$, $p < .001$, $\eta_p^2 = .193$; $F2\ (1,23) = 147.119$, $p < .001$, $\eta_p^2 = .865$). An interaction between grade and condition did not occur ($F1(1,96) = .540$, $p > .1$, $\eta_p^2 = .006$; $F2(1,23) = 1.036$, $p > .1$, $\eta_p^2 = .043$). Finally, a main effect of Semantic Relatedness was not found for response time ($F1(1,96) = .172$, $p > .1$, $\eta_p^2 = .002$; $F2(1,23) = .149$, $p > .1$, $\eta_p^2 = .006$) while a main effect of grade was with the fifth graders responding faster to both semantically related and semantically unrelated pairs than the third graders ($F1(1,96) = 21.868$, $p < .001$, $\eta_p^2 = .186$; $F2(1,23)= 307.849$, $p < .001$, $\eta_p^2 = .930$). An interaction between grade and condition was again not found ($F1(1,96) = 1.479$, $p > .1$, $\eta_p^2 = .015$; $F2(1,23) = 1.523$, $p > .1$, $\eta_p^2 = .062$).

Error data. A main effect of Sign Iconicity was not found in the error analyses ($F1(1,96) = 1.695$, $p > .1$ $\eta_p^2 = .017$; $F2(1,46) = .564$, $p > .1$, $\eta_p^2 = .012$). There was also no main effect of Phonological Relatedness of the sign translation equivalents ($F1(1,96) = .038$, $p > .1$, $\eta_p^2 = .000$; $F2(1,23) = 0.012$, $p > .1$, $\eta_p^2 = .001$). For Sign Iconicity, the error analyses showed no main effect of grade ($F1(1,96) = .214$, $p > .1$, $\eta_p^2 = .002$; $F2(1,46) = .849$, $p > .1$, $\eta_p^2= .018$). There was also no interaction effect between grade and condition ($F1(1,96) = .004$, $p > .1$, $\eta_p^2 = .000$; $F2(1,46) = .004$, $p > .1$, $\eta_p^2 = .000$). The error analyses for Phonological Relatedness of the signs translation equivalents showed marginal effects for grade but only in the item analyses ($F1(1,96) = 2.034$, $p > .1$, $\eta_p^2 = .021$; $F2(1,23)= 3.062$, $p < .1$, $\eta_p^2 = .117$). An interaction between grade and condition did not occur ($F1(1,96) = .038$, $p > .1$, $\eta_p^2 = .000$; $F2(1,23) = .020$, $p > .1$, $\eta_p^2 = .001$). With respect to Semantic Relatedness, a significant main effect of grade was not found, which means that the two grades showed similar error levels ($F1(1,96) = .290$, $p > .1$, $\eta_p^2 = .003$; $F2(1,23) = .658$, $p > .1$, $\eta_p^2 = .028$). A main effect of condition occurred ($F1(1,96) = 20.819$, $p < .01$, $\eta_p^2 = .178$; $F2(1,23) = 6.693$, $p < .01$, $\eta_p^2 = .225$). More errors were made on pairs with a strong semantic relation than on pairs with a weak semantic relation. A significant interaction between grade and condition did not occur ($F1(1,96) = .552$, $p > .1$, $\eta_p^2 = .006$; $F2(1,23) = .523$, $p > .1$, $\eta_p^2 = .022$), which means that the two grades showed similar error patterns.

Table 2

Mean Response Times (in Milliseconds) and Accuracy Rates (in Percentages) for Experiment 2 on the Word-Picture Verification of Hearing Children in Third or Fifth Grade (with Standard Deviations presented in Parentheses).

		RT	Error rates
Sign Iconicity			
Condition 1: Strong	3rd Grade	1660 (478)	.93 (.06)
Condition 2: Weak		1670 (424)	.93 (.07)
Condition 1: Strong	5th Grade	1269 (299)	.93 (.04)
Condition 2: Weak		1298 (278)	.94 (.04)
Sign Phonological Relatedness			
Condition 3: Strong	3rd Grade	2224 (708)	.91 (.07)
Condition 4: Weak		2244 (702)	.91 (.07)
Condition 3: Strong	5th Grade	1666 (421)	.93 (.06)
Condition 4: Weak		1655 (514)	.93 (.06)
Semantic Relatedness			
Condition 5: Strong	3rd Grade	1983 (487)	.90 (.07)
Condition 6: Weak		2001 (596)	.93 (.07)
Condition 5: Strong	5th Grade	1578 (355)	.90 (.07)
Condition 6: Weak		1543 (395)	.94 (.06)

Conclusion

The hearing children who were not familiar with sign language did not show the sign effects that the deaf children did. No main effects or significant interactions with grade were found for Sign Iconicity or Phonological Relatedness. As expected, Semantic Relatedness produced a main effect in the error data, which shows that the hearing children activate semantically related words when reading single words. Significant grade effects showed the older children to be faster and, in some cases, more accurate than the younger children irrespective of condition.

3.3.4 Part b: Word-picture Verification in Deaf Children

3.3.5 Method

Participants. The participants in this study were 40 deaf children ranging in age from 109 months to 157 months. Six of these children also participated in Experiment 1. The participants were in two age groups. The younger participants were in the middle grades, between 109 and 131 months (around grades 3 and 4[3], *N* = 20, mean = 122 months; *SD* = 6.5 months) and the older participants were in the upper grades, between 132 and 157 months (around grades 5 and 6, *N* = 20, mean = 144 months; *SD* = 7.3 months). Similar to Experiment 1, the children attended one of three schools for deaf education in the Netherlands (see Participants Experiment 1).

Stimuli. For the present word-picture verification task, the sign items used in Experiment 1 were replaced by written words (see Figures 1 and 2). The words were presented on the left side of the computer screen using an Arial size 36 font; the pictures were presented on the right side of the computer screen.

Apparatus and procedure. The same apparatus was used and procedures were followed as in Experiments 2, part a. Evidently, the deaf participants were instructed similarly to the hearing children; to provide a match response when a word and picture referred to the same concept, without explicit reference to sign translations.

3.3.6 *Results*

The responses for a total of 96 word-picture pairs were analyzed (see Table 3). For each participant, the mean RTs and error scores were computed for Sign Iconicity, Sign Phonological Relatedness, and Semantic Relatedness. For the RT measures, erroneous responses and RTs that were more than two standard deviations from the participant and item means, respectively, were excluded from further analysis. For the younger participants, 0.4% of the data was excluded. For the older participants, 0.76% of the data was excluded from further analyses.

Similar to Experiment 1, Sign Iconicity was treated as a within subjects and between items factor; Sign Phonological Relatedness was treated as a within subjects and within items factor; and Semantic relatedness was treated as a within subjects and within items factor. Grade was treated as between subjects and within items factor. Hearing status was a between subjects and within items factor.

Response Time data.

The results for the deaf children showed that no interaction was found between grade and Sign Iconicity ($F1(1,38) = .018$, $p > .1$, $\eta_p^2 = .000$; $F2(1,46) = .667$, $p > .1$, $\eta_p^2 = .014$), but a significant facilitation effect was found for Sign Iconicity for the deaf participants ($F1(1,38) = 24.970$, $p < .001$, $\eta_p^2 = .397$; $F2(1,46) = 10.841$, $p < .01$, $\eta_p^2 = .191$). Strongly iconic sign pairs (word-picture pairs with strongly iconic sign translation equivalents) were responded to faster than weak iconic items (word-picture pairs with weakly iconic sign translation equivalents, see Table 2). No effect was found for grade ($F1(1,38) = .042$, $p > .1$, $\eta_p^2 = .001$; $F2(1,46) = 1.145$, $p > .1$, $\eta_p^2 = 024$). For Phonological Relatedness, the effect was inhibitory ($F1(1,38) = 6.972$, $p < .05$, $\eta_p^2 = .155$; $F2(1,23) = 1.257$, $p > .1$, $\eta_p^2 = .05$) with no interaction between grade and Sign Phonology ($F1(1,38) = .512$, $p > .1$, $\eta_p^2 = .013$; $F2(1,23) = .500$, $p > .1$, $\eta_p^2 = .021$). Word-picture pairs with strong underlying sign phonology relations were responded to more slowly than those word-picture pairs with weak underlying sign phonology relations. Again, no effect was found for grade ($F1(1,38) = .242$, $p > .1$, $\eta_p^2 = .006$; $F2(1,23) = .715$, $p > .1$, $\eta_p^2 = .030$). The effect of Semantic Relatedness was also inhibitory in the participant analysis ($F1(1,38) = 12.025$, $p < .001$, $\eta_p^2 = .240$; $F2(1,23) = .303$, $p > .1$, $\eta_p^2 = .013$), and no interaction was found between grade and Semantics ($F1(1,38) = 1.241$, $p > .1$, $\eta_p^2 = .032$; $F2(1,23) = .010$, $p > .1$, $\eta_p^2 = .000$). Semantically related word-picture pairs were responded to slower on average than semantically unrelated word-picture pairs in a similar way for younger and older deaf participants, and a marginal main effect for grade was found in the item analysis ($F1(1,38) = .528$, $p > .1$, $\eta_p^2 = .014$; $F2(1,23) = 3.523$, $p < .1$, $\eta_p^2 = .133$). The older children responded faster than the younger children.

Error data.

For the deaf children, Sign Iconicity, Phonological Relatedness, and Semantic Relatedness also produced significant main effects in the analyses of the error rates for Experiment 2. The effect of Sign Iconicity shows fewer errors to be made for those word-picture pairs with strong underlying sign iconicity ($F1(1,38) = 6.349$, $p < .05$, $\eta_p^2 = .143$; $F2(1,46) = 18.461$, $p < .001$, $\eta_p^2 = .286$), given that no interaction was found between grade and Sign Iconicity ($F1(1,38) = .300$, $p > .1$, $\eta_p^2 = .008$; $F2(1,46) = .657$, $p > .1$, $\eta_p^2 = .014$). There was no main effect for grade ($F1(1,38) = .002$, $p > .1$, $\eta_p^2 = 000$; $F2(1,46) = .844$, $p > .1$, $\eta_p^2 = .018$). The significant effect of Phonological Relatedness shows more errors to be made for word-picture pairs with strong phonological relations between their sign translation equivalents than for word-picture pairs with only weak phonological relations between their sign translation equivalents. No interaction was found between grade and Sign Phonology in the participant analyses ($F1(1,38) = .752$, $p > .1$, $\eta_p^2 = .019$), but a significant interaction was found in the item analyses ($F2(1,23) = 4.862$, $p < .05$, $\eta_p^2 = .175$). The effect for Phonological Relatedness was found across grades in the participant analyses ($F1(1,38) = 6.349$, $p < .05$, $\eta_p^2 = .143$) and only for older deaf participants in the item analyses ($F2(1,23) = 6.343$, $p < .05$, $\eta_p^2 = .216$), but not for younger deaf children ($F2(1,23) = .161$, $p > .1$, $\eta_p^2 = .007$). No main effect was found for grade ($F1(1,38) = .002$, $p > .1$, $\eta_p^2 = .000$). Similarly, the significant effect of Semantic Relatedness shows more errors to be made for semantically related pairs than for semantically unrelated pairs ($F1(1,38) = 9.442$, $p < .01$, $\eta_p^2 = .199$; $F2(1,23) = 3.776$, $p < .1$, $\eta_p^2 = .141$), given that no interaction was found again between grade and Semantics ($F1(1,38) = .117$, $p > .1$, $\eta_p^2 = .003$; $F2(1,23) = .229$, $p > .1$, $\eta_p^2 = .010$). In the item analysis, a marginal main effect was detected for grade ($F1(1,38) = .899$, $p > .1$, $\eta_p^2 = .\ 023$; $F2(1,23) = 3.225$, $p < .1$, $\eta_p^2 = .123$), in advance of the older deaf children.

Table 3

Mean Response Times (in Milliseconds) and Accuracy Rates (in Percentages) for Experiment 2 on the Word-Picture Verification of Deaf Children in Third/Fourth or Fifth/Sixth Grade (with Standard Deviations presented in Parentheses).

		RT	Error rates
Sign Iconicity			
Condition 1: Strong	$3^{rd}/4^{th}$ Grade	1465 (465)	.93 (.06)
Condition 2: Weak		1596 (455)	.91 (.08)
Condition 1: Strong	$5^{th}/6^{th}$ Grade	1459 (334)	.94 (.06)
Condition 2: Weak		1582 (371)	.91 (.08)
Sign Phonological Relatedness			
Condition 3: Strong	$3^{rd}/4^{th}$ Grade	2123 (700)	.87 (.11)
Condition 4: Weak		2006 (629)	.89 (.14)
Condition 3: Strong	$5^{th}/6^{th}$ Grade	2058 (619)	.89 (.07)
Condition 4: Weak		1981 (584)	.94 (.08)
Semantic Relatedness			
Condition 5: Strong	$3^{rd}/4^{th}$ Grade	1988 (648)	.88 (.15)
Condition 6: Weak		1876 (593)	.93 (.09)
Condition 5: Strong	$5^{th}/6^{th}$ Grade	1887 (520)	.91 (.08)
Condition 6: Weak		1722 (420)	.95 (.07)

Conclusion

The findings for this word-picture verification task resemble those for the sign-picture task. Not surprisingly, the effects were somewhat smaller but nevertheless significant or marginal for Sign Phonology and Sign Iconicity in the word-picture task. We can thus conclude that aspects of both underlying sign phonology and underlying sign iconicity are activated during visual word recognition. Effects for grade, however, were seen in Experiment

1, but not in Experiment 2. In other words, for the processing of signs, differences are seen across grades, in favor of the children in the upper grades. This advance for the deaf children in the upper grades has not been detected for the processing of words. The semantic effects were in line with generally observed semantic effects, namely that semantically related items are activated when reading single words.

3.4 General Discussion

Language Non-selectivity for Bilingual Deaf Children

In this research, evidence was found for non-selective language processing on the part of deaf children. To start with, the results of the first experiment showed deaf children to clearly not only activate the presented sign, but also multiple sign phonology related signs. When the sign phonology of two signs partly overlapped, inhibition occurred on the task; that is, phonologically related signs were apparently activated during the verification task, which resulted in slower and less accurate responding. The phonological activation of signs demonstrated in this experiment is also in agreement with the findings of recent research on the sign processing of deaf adults (Dye & Shi, 2006). When the sign to be processed was highly iconic (i.e., the meaning of the sign resembled the form to a considerable extent), facilitation was found to occur; that is, strongly iconic signs produced faster and more accurate responding. In the bilingual experiment with deaf children (i.e., Experiment 2, part b), support was found for the hypothesis of non-selective language processing. During the word-picture verification task, the non-target (i.e., sign) language also underwent activation and the results of this experiment therefore show language non-selective sign feature activation during word recognition. We can thus conclude that the activation of aspects of sign phonology and iconicity holds not only for sign recognition but also for visual word recognition.

The word-picture verification results reported here for bilingual deaf children are in line with the results of an increasing number of studies on bilingual hearing people (van Wijnendaele & Brysbaert, 2002; Wang, Koda, & Perfetti, 2003). Non-selective language access has been demonstrated not only for bilinguals processing languages with similar scripts but also for bilinguals processing languages with highly different scripts. The results of the present study show that the assumption of non-selective language activation can be further extended to include situations in which one of the languages has no script whatsoever or, in this case, sign language. The results also show non-selective language access to occur for languages involving different modalities.

For the sake of thoroughness it was demonstrated that sign feature effects do not occur for hearing children during a word-picture verification task. In other words, the activation of sign features during the process of word-picture verification by the deaf children can only be explained by the children's sign knowledge.

Hanson and Feldman (1989, 1991), however, did not find such non-selective language access for deaf adults while reading English words. These apparently conflicting results suggest that non-selective language access on the part of signing bilinguals may actually depend on the type of task used and on participant variables. Different groups of signing bilinguals should therefore be studied using different tasks in order to replicate the results of past studies and enable generalization of the relevant findings from the past to the present.

Although the signs belong to SLN and the written Dutch words are part of the Dutch language, we do not intend to claim that the written Dutch words are mapped onto the spoken Dutch words. This question is still open to inquiry. Given the results of the present study, however, it can be claimed that sign phonology and iconicity influence access to the meanings of written words and thus provide evidence for non-selective language access.

A second question that remains open to inquiry is the question to what extent bilingual language input of the deaf children affects their bilingual lexicon. Van den Bogaerde and Baker (2006), for example, have shown some hearing mothers of deaf children to provide code-blends of signs and spoken words to their children, mostly observed for nouns. The deaf children (who were up to 3 years old) did not produce any code-blended or code-mixed utterances. At the same time, Mayberry (2002) has shown that deaf children of hearing parents experience far more limited language experience than deaf children of deaf parents. Deaf parents generally provide their deaf children with a full sign language. To what extent different types of pre-school language input in language contact situations can affect bilingual word processing in deaf children requires further investigation.

Possible Causes of Sign Phonology Relatedness Effects

In this study, underlying sign phonology overlap clearly inhibited the performance of deaf children on a word-picture verification task. Only one explanation can account for this inhibition effect, which is sub-lexical sign mediation during the process of written word recognition. In Figure 3, we present a schematic depiction of processes expectedly involved in visual word recognition in deaf children, in line with our results.

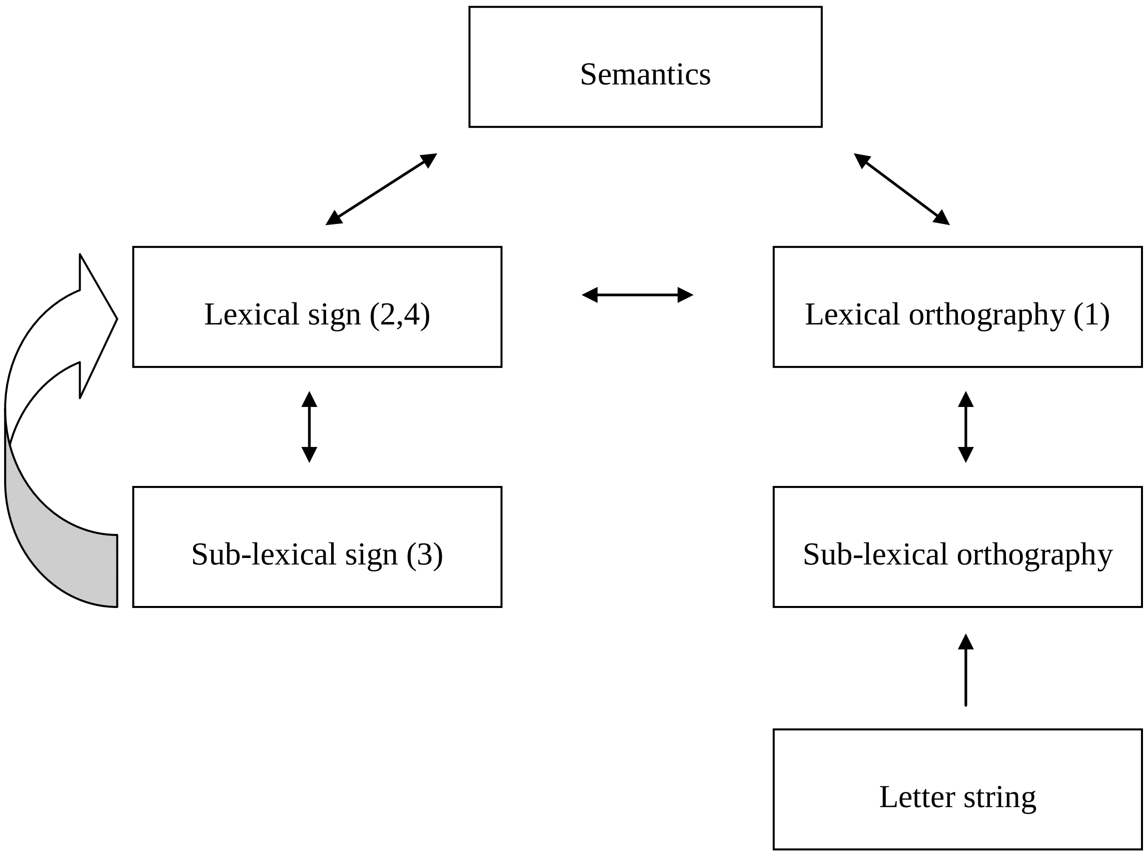


Figure 3. Sign activation during visual word recognition in deaf children

As depicted in Figure 3, we would like to argue the following: Once lexical orthography is activated (1), the sign translation equivalent of the target word becomes activated (2). Sign phonology (sub-lexical sign) also becomes activated: i.e., movement of the sign; hand shape; location of the sign; and orientation of the hands (3). The correct combination of sub-lexical sign features is activated, but also combinations whereby only a part of these four features is activated. For example, the sign for DOG activated the correct combinations of sub-lexical sign features part of the sign DOG, but also combinations whereby three out of the four sub-lexical sign features are activated, apart from a different hand shape. In this example of DOG, the incomplete activation of the sub-lexical sign combination corresponds for instance to the sign for CHAIR amongst other signs (see Figure 2). This example illustrates that overlapping combinations of sub-lexical sign features are activated, together with the accompanying lexical signs (4). Orthography and sign both activate associated semantics.

The inhibition effect occurs as a result of competing lexical items with overlapping combinations of sub-lexical sign features. In the word-picture verification for DOG and CHAIR, DOG also activated the sign for CHAIR. Therefore both word and picture activated the sign for CHAIR, which lead to competition for a 'yes-response', even though the concepts between DOG and CHAIR are largely dissimilar (and thus required a 'no-response'). In a recent study of hearing adults, Thierry and Wu (2004) found similar non-selective activation for the reading of unrelated English words by Chinese-English bilinguals. According to Thierry and Wu, certain Chinese character overlaps can cause confusion and hence inhibition when bilingual Chinese-English hearing students are asked to read unrelated English words with underlying related Chinese character translation equivalents. Similarly, we found that sign phonological overlap of the translation equivalents for Dutch words created confusion during the verification of Dutch words and pictures. The sign inhibition effect parallels the activation of related lexical items in two alternative languages, which has been demonstrated in orthographic neighborhood studies, although related items in our study were within sign language (sign neighbors) instead of related in the two alternative languages (see van Heuven, Dijksta, & Grainger, 1998, for an explanation of orthographic Dutch-English neighborhood effects). The sub-lexically related signs in the present study can similarly be regarded as neighboring signs, which can undergo activation during the reading of Dutch words. Stated differently, inhibition effects due to underlying sign relatedness can be seen as the sign variant of phonological inhibition effects during word recognition (see Gaskell & Marslen-Wilson, 1999, 2002, for an explanation of bimodal priming).

Corina and Knapp (2006) examined sign phonological relatedness in a production study, using a sign-picture priming paradigm which required naming of a picture. Evidently, production effects may reveal different processes than perception effects. Nevertheless, the production data reveal interesting patterns which may partly also apply to sign and bilingual word perception processes in the present study. Results by Corina and Knapp showed that effects of sign phonological relatedness depended on the number of phonological parameters (one, two or three, based on movement, hand shape and place of articulation/ location) that were overlapping between the two signs. Three parameters shared slowed down naming, whereas one or two parameters shared facilitated phonological parameters. One of their explanations is the induction of a lexical sign neighbor effect, in a similar way as is seen in the present study.

Also, when movement and location properties were shared, a more prominent naming effect was found by Corina and Knapp (2006) when compared to when movement and hand shape or location and hand shape were shared. This is in line with a series of other studies (first observed by Klima & Bellugi, 1979). In the present study, different combinations of sign phonology parameters were included. A number of recent studies have made a clear distinction between different types of overlap. Although such a distinction partly may seem like a good approach, it should also be noted that that a yes or no distinction between overlap and no overlap is a rather robust approach. For example, two signs can have an identical movement or a highly distinctive movement. However, two signs can also have very similar but distinctive movements. One important question at present is how to deal with such sign pairs. Another issue relates to the differential importance for the occurrence of different hand shapes, different locations, and different movements. For example, signs at typical locations may play a different role when compared to signs in neutral signing space. These issues have not been resolved as yet, and may have influenced past sign phonology studies. In the present study, different types of overlap were included (nine pairs shared hand shape, movement, and location, either completely or to a major extend; five pairs shared location and movement; five pairs shared location and hand shape, four pairs shared hand shape and movement, and one pair shared location only). The pairs were chosen from an initial list of 120 sign pairs, based on judgments made by fluent signers, and therefore not based on certain types of shared properties beforehand. However, when the results for the different types of overlap were examined, no differences were found on the basis of these robust types of overlap.

The Role of Sign Iconicity

The present results suggest that sign iconicity plays a facilitation role in the sign and word recognition of deaf elementary school-aged children. Two different explanations may account for the iconicity effect. First, the sign acquisition process may play an important role. Highly iconic signs provide a more direct link to their underlying meaning than less iconic signs and may therefore be acquired more readily. In a similar vein, words with an iconic sign translation may be easier to remember than words with a non-iconic sign translation. In other words, the direct link between an iconic sign and its meaning may facilitate the learning of the sign's word translation as well. It is also possible that the iconicity effect occurs independent of an acquisition advantage for iconic signs. At the moment of processing signs or words, the iconic features of the objects represented by the signs may simply facilitate recognition (Markman & Justice, 2004). In fact, the results of several studies suggest that sign iconicity may not play a large role in sign acquisition (Morford, 1996; Orlansky & Bonvillian, 1984). During the production of a sign verb by deaf adults, moreover, sign iconicity does not appear to differentially activate the neural system underlying the production of lexical items (Emmorey et al, 2004). Deaf adult patients with brain lesions also show no effects of iconicity (Atkinson et al., 2005). However, other studies strongly emphasize the importance of iconicity during the initial stages of sign language learning (Luftig, 1983; Markman & Justice, 2004), during meaning judgments of signs (Vigliocco, Vinson, Woolfe, Dye, & Woll, 2005) and also during grammatical processes at a later age (Wilcox, 2004). For both the acquisition and processing of sign language, ambiguous results have been found for the role of iconicity. Also for iconicity, different types can be distinguished, for example iconicity based on functions or iconicity based on forms of (parts of) objects (Vigliocco et al., 2005). It seems evident that additional research is needed to disambiguate these results.

Implications for Current Models of Bilingual Word Recognition

The current findings extend earlier research on languages that share a script or have two different scripts. The present results show two very different languages to interact non-selectively during visual word recognition; in fact, one of the languages had no accompanying script in the present study and still affected visual word recognition. In the present highly unique case, moreover, one of the languages was a spatial language with particular grammatical rules. In previous research, it has been shown that the higher the degrees of orthographic and phonological overlap between two language systems, the greater the likelihood of interaction between the two language systems. Given that sign language does not have an accompanying script, script overlap with Dutch was obviously lacking. However, when Gollan, Forster, & Frost (1997) studied spoken languages with different scripts (i.e., Hebrew and English), script resemblance was not required to obtain cross-language priming during visual word recognition by bilinguals. In contrast to research in which similar — alphabetic — scripts have been studied, however, priming occurred for only dominant language and not the other language. In line with this finding, Thierry and Wu (2004) have provided electrophysiological evidence for the activation of Chinese when processing printed English words but only for those participants for whom Chinese was the L1 and not for native English speakers. The absence of a priming effect for the non-dominant language when the scripts of two languages show little overlap, but not when the scripts are similar, shows language script differences to an important role in the interaction between languages. Given that sign language is the more natural and accessible language for many deaf children (Klatter-Folmer et al., 2006), it is presumably the L1 and thus the dominant language for deaf bilinguals. Dutch can then be regarded as the non-dominant L2 language but, as yet, there is no means to determine which of the two languages is most dominant for deaf Dutch children. The present findings clearly show sign language to play a role during the processing of printed words at times and, if sign language is regarded as the dominant language, the results are in agreement with the results of both research on languages with overlapping scripts and language with non-overlapping scripts in that activation of the more dominant language while processing the less dominant language appears to be the case.

Several models have been developed to characterize word processing in bilingual situations. One of the most distinguished bilingual word identification models is the BIA+ model (Dijksta & van Heuven, 2002). While the BIA+ model was originally introduced to describe visual word identification in languages with an accompanying script, the model can possibly be extended to the present findings, in line with Figure 3. More specifically, extension of the Identification System[5] part of the BIA+ model into a Deaf Bilingual Interactive Activation model appears to be possible (see Dijkstra & van Heuven, 2002, for detailed explanation of the BIA+ model).

Given the specific differences between the two languages studied here, namely Dutch and Sign Language of the Netherlands, the language nodes L1 and L2 as presented in the original BIA+ model possibly ought to be supplemented by lexical and sub-lexical sign in addition to the lexical and sub-lexical orthographic and phonological components. As stated before, sub-lexical sign information can be hand shape, movement, location, and orientation.

Further studies are nevertheless necessary to ascertain various lexical and sub-lexical connections between signs and words that play a role during word identification.

Directions for future research

In general, the word recognition skills of deaf children have been shown to have little automaticity (Knoors, 2001; Marschark, Lang, & Albertini, 2002). One possible explanation for the non-selective language activation found in the present study may therefore lie in the fact that the deaf children's word reading skills — and, for that matter, their signing skills — were still developing. Are the same activation patterns found for deaf bilinguals with better word recognition skills (e.g., deaf adults or deaf college students) or is it possible that the concepts underlying written words are accessed without intervening sign activation under such circumstances?

To further evaluate the role of language distance in the occurrence of selective versus non-selective language processing, it would be very valuable to be able to screen bilingual deaf children and bilingual deaf adults with respect to language dominance. A distinction could then be made between deaf or hearing bilinguals for whom sign language is the dominant language, and deaf or hearing bilinguals for whom sign language is the non-dominant language. The roles of the dominant and non-dominant languages in word processing could then be assessed and whether interference appears to take place during sign recognition and during word recognition could be determined. Different age groups or a longitudinal research design could also be used to monitor the development of signing and word reading skills. And in such a manner, the question of whether the step between lexical orthography and sub-lexical sign always involves lexical sign mediation can perhaps be answered. MacWinney (2005) has argued that the amount of transfer between two languages may diminish (but not disappear completely, see Dijkstra, 2005) as the languages are acquired and develop into nearly full-blown languages. The newly learned L2 forms will gain stronger connections to underlying concepts and related concepts, diminishing the need for L1 mediation (Kroll & Stewart, 1994). The widespread preference for sign language on the part of children similarly suggests that closer connections may exist between signs and concepts than between words and concepts at this stage. When the deaf children grow older, however, the conceptual connections may change and a stronger link between words and concepts may certainly emerge. Our knowledge of how deaf children learn to read is currently very limited (Mayberry, 2002), and it is therefore critical that the present study be extended to monitor the development of both the signing and reading skills of deaf children on a regular and simultaneous basis.

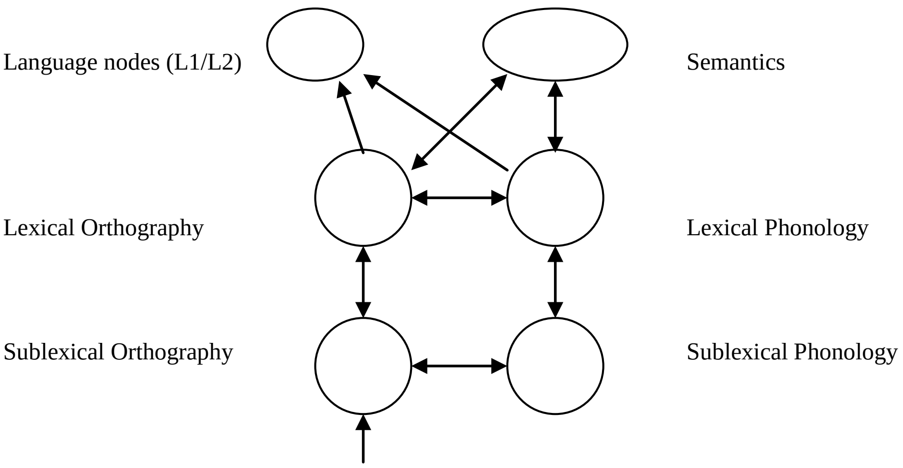
Note 1: Two pilot studies were conducted to justify the selected stimulus materials for Experiments 1 and 2. In the first pilot study, various videotaped signs were judged along a 0-7 scale for sign phonology by three deaf and four hearing adults who were highly proficient signers. In the second pilot study, various other signs were judged by 20 hearing children for their level of iconicity: a total of 24 strongly iconic signs and 24 weakly iconic signs were presented on a computer. One second following sign offset, four words appeared simultaneously on the computer screen and the task of the participant was to identify which of the four words belonged to the presented SLN sign. The hearing children were able to correctly identify the iconic signs, confirming the assumption that the meanings of these signs were detectable by the forms.

Note 2: In other words, Condition 6 consisted of the same set of signs and pictures as Condition 5 but combined in a semantically unrelated manner. In Condition 5, for example, the Dutch sign for sofa was combined with a picture of a bar stool; similarly, the Dutch sign for carrot was combined with a picture of a bean. In Condition 6, semantically unrelated pairs were created via the combination of the sign for sofa with a picture of a carrot, for example, or the combination of the sign for bar stool with a picture of a bean.

Note 3: In the schools for the deaf in the Netherlands, age ranges within one group can sometimes be larger than in one group in mainstream elementary education. One of the younger participants in Experiment 1 was already participating in the upper grades.

Note 4: The results of the overall GLM repeated-measures analysis of the response times including deaf and hearing children show a significant interaction between hearing status (i.e. deaf vs. hearing) and Sign Iconicity ($F1(1,136) = 11.616$, $p < .01$, $\eta_p^2 = .079$; $F2(1,46) = 24.339$. $p < .001$, $\eta_p^2 = .346$), and also between hearing status and Sign Phonology ($F1(1,136) = 4.713$, $p < .05$, $\eta_p^2 = .033$; $F2(1,23) = .673$, $p > .1$, $\eta_p^2 = .000$) and hearing status and Semantics ($F1(1,136) = 6.055$, $p<.05$, $\eta_p^2 = .043$; $F2(1,23) = .134$, $p > .1$, $\eta_p^2 = .006$).
The results of the overall analysis of the error data including deaf and hearing children again show a significant interaction between hearing status (i.e. deaf vs. hearing) and Sign Iconicity ($F1(1,1360 = 10.327$, $p <.01$, $\eta_p^2 = .071$; $F2(1,23) = 17.292$, $p < .001$, $\eta_p^2 = .273$) and also between hearing status and Sign Phonology ($F1(1,136) = 5.283$, $p < .05$, $\eta_p^2 = .037$; $F2(1,23) = 1.289$, $p > .1$, $\eta_p^2 = .053$), but not between hearing status and Semantics ($F1(1,136) = .513$, $p > .1$, $\eta_p^2 = .004$; $F2(1,23) = .336$, $p > .1$, $\eta_p^2 = .014$).

Note 5: The Identification System in the BIA+ model for bilingual word recognition (Dijkstra & van Heuven, 2002)



References

Abu-Rabia, S. (2001). Testing the interdependence hypothesis among native adult bilingual Russian-English students. *Journal of Psycholinguistic Research, 30(4)*, 437-455.

Akamatsu, N. (1999). The effects of first language orthographic features on word recognition processes in English as a second language. *Reading and Writing: An interdisciplinary journal*, *1*, 381-403.

Atkinson, J., Marshall, J., Woll, B., & Thacker, A. (2005). Testing comprehension abilities in users of British Sign Language. *Brain and Language*, *94*, 233-248.

Baayen, R., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX Lexical Database. Technical report*, Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Baker, A. E., & van den Bogaerde, B. (in press). Code mixing in signs and words in input to and output from children. In: Plaza-Pust, C., & Moralez Lopéz, E. (Eds), *Sign bilingualism: Language Development, Interaction, and Maintenance in Sign Language Contact Situations*, Amsterdam: Benjamins.

Beech, J. R., & Harris, M. (1997). The prelingually deaf young reader: A case of reliance on direct lexical access? *Journal of research in reading, 20(2)*, 105-121.

Bialystok, E., Luk, G., & Kwan, E. (2005). Bilingualism, biliteracy, and learning to read: Interactions among languages and writing systems. *Scientific studies of reading, 9(1),* 43-61.

Bijeljac-Babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory and Cognition*, *25*, 447-457.

van den Bogaerde, B., & Baker, A. E. (2006). Code mixing in mother-child interaction in deaf families. In: Baker, A. E., & van den Bogaerde, B. (Eds), *Language Acquisition, Special Issue of Sign Language and Linguistics, 8*, 151-174.

Corina, D., & Knapp, H. P. (2006). Lexical retrieval in American Sign Language Production. In: *Laboratory Phonology 8.* Goldstein, L. M. L. M., Whalen, D. H., & Best, C. T.(eds), Berlin: Mouton de Gruyter.

Corina, D. P., & Sandler, W. (1993). On the nature of phonological structure in sign language, *Phonology, 10*, 165-207.

Damien, M. F., & Bowers, J. S. (2003). Locus of semantic interference in a word picture interference task. *Psychonomic Bulletin and Review, 10(1),* 111-117.

Dijkstra, T. (2005). Bilingual visual word recognition and lexical access. *Handbook of Bilingualism: Psycholinguistic approaches.* Kroll, J. & de Groot, A. Oxford, University Press, 179-201.

Dijkstra, T., Grainger, J., & van Heuven, W. J. B. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Language*, *41*, 496-518.

Dijkstra, T., van Heuven, W. J. B., & Grainger, J. (1998). Simulating cross-language competition with the bilingual interactive activation model. *Psychologica Belgica, 38(3/4),* 177-196.

Dijksta, T., & van Heuven, W. J. B. (2002). Modeling bilingual word recognition: Past, present and future. *Bilingualism: Language and Cognition, 5(3),* 219-225.

Dijkstra, T., van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5(3),* 175-197.

Dijkstra, T., van Jaarsveld, H., & ten Brinke, S. (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism: Language and Cognition*, *1*, 51-66.

Dye, M. W. G., & Shih, S. (2006). Phonological priming in British Sign Language. *Laboratory Phonology 8*. Goldstein, L. M. L. M., Whalen, D. H., & Best, C. T., Berlin: Mouton de Gruyter.

Emmorey, K. (2002). *Language, cognition, and the brain: Insights from sign language research.* Mahwah, New Jersey, London: Lawrence Erlbaum Associates, Publisher.

Emmorey, K., Borinstein, H. B, & Thompson, R. (2005). *Bimodal bilingualism: Code-blending between spoken English and American Sign Language.* 4th International Symposium of Bilingualism, Arizona State University, Tempe, Arizona, Somerville, MA, Cascadill.

Emmorey, K., & Corina, D. (1990). Lexical recognition in sign language: Effects of phonetic structure and morphology. *Perceptual and Motor skills, 71,* 1227-1252.

Emmorey, K., McCullough, S., & Brentari, D. (2003). Categorical perception in American Sign Language. *Language and Cognitive Processes*, *18(1),* 21-45.

Emmorey, K., Grabowski, T., McCullough, S., Damasio, H., Ponto, L., Hichwa, R., & Bellugi, U. (2004). Motor-iconicity of sign language does not alter the neural systems underlying tool and action naming. *Brain and Language, 89,* 27-37.

Evans, C. (2004). Literacy development in deaf students: Case studies in bilingual teaching and learning. *American Annals of the Deaf*, *149(1),* 17-27.

Gaskell, M. G., & Marslen-Wilson, W. D. (1999). Ambiguity, competition, and blending in spoken word recognition. *Cognitive Science*, *23(4)*, 439-462.

Gaskell, M. G., & Marslen-Wilson, W. D. (2002). Representation and competition in the perception of spoken words. *Cognitive Psychology*, *45*, 220-266.

Gerard, L. D., & Scarborough, D. L. (1989). Language-specific lexical access of homographs by bilingual. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15,* 305-313.

Goldin-Meadow, S. and Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research and Practice*, *16(4),* 221-228.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates in Hebrew-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23(5),* 1122-1139.

Goswami, U. (2002). In the beginning was the rhyme? A reflection on Hulme, Hatcher, Nation, Brown, Adams, and Stuart. *Journal of Experimental Child Psychology*, *82*, 47-57.

de Groot, A. M. B., Delmaar, P., & Lupker, S. J. (2000). The processing of interlexical homographs in translation recognition and lexical decision: Support for nonselective access to bilingual memory. *Quarterly Journal of Experimental Psychology*, *53(A),* 397-428.

Hanson, V. L., & Feldman, L. B. (1989). Language specificity in lexical organization: Evidence from deaf signers' lexical organization of American Sign Language and English. *Memory and Cognition*, *17(3),* 292-301.

Hanson, V. L., & Feldman, L. B. (1991). What makes signs related? *Sign Language Studies, 70,* 35-46.

Hanson, V. L., & Fowler, C .A. (1987). Phonological coding in word reading: Evidence from hearing and deaf readers. *Memory & Cognition*, *15(3),* 199-207.

van Hell, J. G., & Dijkstra, T. (2002). Foreign language knowledge can influence native language performance in exclusively native context. *Psychonomic Bulletin & Review, 9(4),* 780-789.

van Hell, J. G. (2002). Bilingual word recognition beyond orthography: On meaning, linguistic context and individual differences. *Bilingualism: Language and Cognition, 3,* 209-212.

Hermans, D., Knoors, H., Ormel, E., & Verhoeven, L. (in preparation). Spoken and sign language development for bilingual deaf children in the Netherlands: A case of Linguistic Interdependence or Linguistic Independence?

van Heuven, W. J. B., Dijksta, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, *39*, 458-483.

Hildebrandt, U., & Corina, D. (2002). Phonological similarity in American Sign Language. *Language and Cognitive Processes*, *17(6),* 593-612.

Irausquin, R., & Mommers, C. (2001). *Leesladder*. *Een programma voor kinderen met leesmoeilijkheden.* [Reading ladder. A program for children with reading difficulties]: Zwijsen.

Izzo, A. (2002). Phonemic awareness and reading ability: An investigation with young readers who are deaf. *American Annals of the Deaf*, *147(4),* 18-28.

Kandil, M. A., & Jiang, N. (2004). The role of scripts in bilingual lexical organization: Evidence from switching cost. *Georgia State Working Papers in Applied Linguistics*, *1*, 1-14.

Keatley, C. W., Spinks, J. A., & de Gelder, B. (1994). Asymmetrical cross-language priming effects. *Memory & Cognition*, *22(1),* 70-84.

Klatter-Folmer, J., van Hout, R., Kolen, E., & Verhoeven, L. (2006). Language development in deaf children 's interactions with deaf and hearing adults: A longitudinal study. *Journal of Deaf Studies and Deaf Education*, *11(2),* 238-251.

Klima, E. S., & Bellugi, U. (1979). *The signs of language.* Cambridge, MA, Harvard University Press.

Knoors, H. (2001). Taalontwikkelingsstoornissen ten gevolge van doofheid [Language Development Disorders as a result of deafness]. *Stem-Spraak-Taalpathologie*, *16*, 3-31.

Knoors, H. (in press). Educational responses to varying objectives of deaf parents of deaf children: a Dutch perspective. *To appear in: Journal of Deaf Studies and Deaf Education*.

Koda, K. (1999). Development of L2 intraword orthographic sensitivity and decoding skills. *The modern language journal*, *83(1),* 51-64.

van der Kooij, E. (2002). *Phonological categories in Sign Language of The Netherlands: The role of phonetic implementation and iconicity.* Utrecht: LOT.

Kroll, J., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*, 149-174.

Kroll, J. F., Bobb, S. C., & Wodniecka, Z. (2006). Language selectivity is the exception, not the rule: Arguments against a fixed locus of language selection in bilingual speech. *Bilingualism: Language and Cognition*, *9*, 119-135.

Lemhöfer, K., Dijkstra, T., & Michel, M. (2004). Three languages, one ECHO: cognate effects in trilingual word recognition. *Language and Cognitive Processes*, *19(5),* 585-611.

Leybaert, J. (1993). Reading in the deaf: The roles of phonological codes. In M. Marschark, & M. D. Clark, *Psychological perspectives on deafness.* Hillsdale, New Jersey, Lawrence Erlbaum Associates, Publishers, 1, 269-308.

Luftig, R. L. (1983). Variables influencing the learnability of individual signs and sign lexicons: A review of the literature. *Journal of Psycholinguistic Research, 12(4),* 361-376.

MacWinney, B. (2005). A unified model of language acquisition. *Handbook of Bilingualism: Psycholinguistic Approaches.* J. Kroll, & de Groot, A. Oxford: University Press, 49-67.

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition, 6(2),* 97-115.

Markman, P. T., & Justice, E. M. (2004). Sign language iconicity and its influence on the ability to describe the function of objects. *Journal of Communication Disorders, 37(6)*, 535-546 .

Marschark, M, Lang., H. G., & Albertini, J. A. (2002). *Educating deaf students. From research to practice.* New York: Oxford University Press.

Mayberry, R. I. (2002). Cognitive development in deaf children: the interface of language and perception in neuropsychology. In S. J. Segalowitz, & Rapin, I., *Handbook of Neuropsychology,* Amsterdam: Elsevier. *Vol. 8, Part II:* 71-107.

Mayberry, R. I., Chamberlain, C., Waters, G., & Hwang, P. (2003, November). *Word recognition in children who use signed language.* Paper presented at the Boston University Conference on Language Development, Boston.

McBride-Chang, C., Bialystok, E., Chong, K. K. Y., & Lo, Y. (2004). Levels of phonological awareness in three cultures. *Journal of Experimental Child Psychology*, *89*, 93-111.

Merrills, J. D., Underwood, G. & Wood, D. J. (1994). The word recognition skills of profoundly, prelingually deaf children. *British Journal of Developmental Psychology, 12,* 365-384.

Miller, P. (2002). Communication mode and the processing of printed words: Evidence from readers with prelingually acquired deafness. *Journal of Deaf Studies and Deaf Education, 7(2),* 312-329.

Miller, P. (2006). What the processing of real words and pseudohomophones can tell us about the development of orthographic knowledge in prelingually deafened individuals. *Journal of Deaf Studies and Deaf Education, 11(1),* 21-38.

Morford, J. (1996). Insights to language from the study of gesture: A review of research on the gestural communication of non-signing deaf people. *Language and Communication, 16(2),* 165-178.

Muljani, D., Koda, K., & Moates, D. R. (1998). The development of word recognition in a second language. *Applied Psycholinguistics, 19(1),* 99-113.

Orlansky, M. D., & Bonvillian, J. D. (1984). The role of iconicity in early sign language acquisition. *Journal of Speech and Hearing Disorders, 49*, 287-292.

Padden, C., & Ramsey, C. (1998). Reading ability in signing deaf children. *Topics in Language Disorders*, *18(4)*, 30-46.

Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for Deaf readers. *Journal of Deaf Studies and Deaf Education*, *5(1)*, 32-50.

Pietrandrea, P. (2002). Iconicity and arbitrariness in Italian Sign Language. *Sign Language Studies*, *2(3)*, 296-321.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime. Psychology software tools, *Learning Research and Development Centre*, University of Pittsburgh, Pittsburgh.

Schrooten, W., & Vermeer, A. (1994). Woorden in het basisonderwijs. 15.000 woorden aangeboden aan leerlingen, TUP (Studies in Meertaligheid 6).

SPSS for Windows, Rel. 11.0.0. 2002, Chicago: SPSS Inc.

Thierry, G., & Wu, Y. J. (2004). Electrophysiological evidence for language interference in late bilingual. *NeuroReport*, *15(10)*, 1555-1558.

Thompson, R., Emmorey, K., & Gollan, T. (2005). "Tip of the fingers" experiences by deaf signers. *Psychological Science*, *16(11)*, 856-860.

Transler, C., Gombert, J. E., & Leybaert, J. (2001). Phonological decoding in severely and profoundly deaf children: Similarity judgment between written pseudowords. *Applied Psycholinguistics*, *22*, 61-82.

Treiman, R., & Hirsh-Pasek, K. (1983). Silent reading: Insights from second-generation Deaf readers. *Cognitive Psychology*, *15*, 39-65.

Vigliocco, G., Vinson, D. P., Woolfe, T., Dye, M. W. G., & Woll, B. (2005). Language and imagery: effects of language modality. *Proceedings of the Royal Society B*, *272*, 1859-1863.

Wang, M., Koda, K., & Perfetti, C. A. (2003). Alphabetic and nonalphabetic L1 effects in English word identification: a comparison of Korean and Chinese English L2 learners. *Cognition*, *87*, 129-149.

Wang, M., Perfetti, C. A., & Liu, Y. (2005). Chinese-English biliteracy acquisition: cross-language and writing system transfer. *Cognition*, *97*, 67-88.

Waters, G. S. D., & Doehring. G. (1990). Reading acquisition in Congenitally Deaf Children Who Communicate Orally: insights from an Analysis of Component

Reading, Language, and Memory Skills. *Reading and its development.* T. H. Carr, & Levy, B. A. San Diego, Academic Press**,** 323-373.

van Wijnendaele, I., & Brysbaert, M. (2002). Visual word recognition in bilinguals: Phonological priming form the second to the first language. *Journal of Experimental Psychology: Human Perception and Performance*, *28(3)*, 619-627.

Wilcox, S. (2004). Cognitive iconicity: Conceptual spaces, meaning, and gesture in signed languages. *Cognitive Linguistics*, *15(2)*, 119-147.

The Role of Semantics in the Reading Development of Deaf Children

Chapter 4

Abstract

Learning to read is a major obstacle for children who are deaf. The otherwise significant role of phonology is limited as a result of hearing loss. However, semantic knowledge can facilitate word recognition and reading comprehension. In the present study, the quality of the semantic knowledge of both deaf and hearing children was therefore examined for different types of stimuli: Written words, pictures, signs (deaf children only), and spoken words (hearing children only). The importance of semantic knowledge for the word recognition and reading comprehension of children in the middle and higher elementary school grades was also examined. More specifically, the exemplar and superordinate levels of semantic categorization were examined in terms of reaction times and accuracy. The results showed the hearing children to outperform the deaf children on each type of stimulus and particularly for written word stimuli. The results also revealed positive correlations between semantic performance and word recognition and reading comprehension, respectively.

4.1 *Introduction*

According to the most recent models of word perception, word recognition can be assumed to involve the interaction between phonology, orthography, and semantics (Bosman & van Hell, 2002; Hino, Pexman, & Lupker, 2002; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989; van Orden & Goldinger, 1994). Semantics is attributed a larger role than in most of the earlier models of word perception. The role of phonology in visual word recognition and reading comprehension of hearing children and adults is currently considered obvious (Berent & Perfetti, 1995; Bosman & de Groot, 1996; Share & van Orden, 1987, 1988; van Orden, Johnston, & Hale, 1988; Unsworth & Pexman, 2003). In general, moreover, people learn to read with little or no effort and in a short period of time. For most deaf people, however, word recognition and reading comprehension are complex and difficult skills (Marschark, Lang, & Albertini, 2002; Wauters, van Bon, & Tellings, 2006).

Studies of the role of phonology in the reading of deaf children and adults have produced mixed results. In some studies, phonological activation has not been found to occur in the word recognition of deaf children (e.g., Miller, 2006; Ormel, Hermans, Knoors, Hendriks, & Verhoeven, in preparation; Waters & Doehring, 1990). In other studies, activation of phonological knowledge has been found to occur for deaf college students (Hanson & Fowler, 1987) and for deaf children using Cued Speech (Transler, Leybaert, & Gombert, 1999; Transler, Gomberth, & Leybaert, 2001). Despite these conflicting findings, it is nevertheless agreed that the use of phonology by deaf children and adults is fairly limited (Leybaert & Charlier, 1996; Merrills, Underwood, & Wood, 1994; Miller, 2006; Waters & Doehring, 1990). In cases of limited phonology, it is suspected that semantic knowledge may provide critical reading support (e.g. Kyle & Harris, 2006).

One way to assess the role of semantic knowledge is to assess the proficiency of semantic categorization (Jerger & Damian, 2005). This can be done in terms of both superordinate/subordinate relations (e.g., the bee as part of the superordinate category of insects) and at the level of the exemplar (e.g., both the bee and the mosquito are part of the category of insects). In fact, semantic categorization has been widely used to gain insight into the organization of the semantic memory system and the relevant categorical relations have been found to become increasingly elaborate during the first few years of elementary school (e.g., Aitchinson, 1994; Blewitt & Toppino, 1991; Borghi & Caramelli 2003; Lucariello, Kyratzis, & Nelson, 1992; Nguyen & Murphy, 2003). Not only knowledge of categorical relations but particularly the speed of access for this categorical information appear to affect the extraction of semantic information from memory and also, thus, the extraction of semantic information while reading (i.e., word decoding) (Howell & Manis, 1986). That is, effective retrieval of semantic information and particularly the categorical associations between words is needed for fluent reading (e.g., Hagtvet, 2003; Howell & Manis, 1986).

Several researchers have further documented the associations between semantic categorization and word decoding (Gijsel, Ormel, Hermans, Verhoeven, & Bosman, submitted; Howell & Manis, 1986; Vellutino, Scanlon, & Spearing, 1995). In the study by Howell and Manis, for example, poor word decoders performed slower than good word decoders on a semantic categorization task in both a condition using pictures and a condition using words. Gijsel et al. confirmed these findings for pictures and words and also found evidence of an association between semantic knowledge and *spoken* word recognition. In other research, Vellutino et al. (1995) showed the semantic skills of good word decoders to be better than the semantic skills of poor word decoders but only in the upper grades of elementary school; the semantic skills of good versus poor word decoders, however, did not differ from each other in the lower grades of elementary school. In other studies, in contrast, significant associations between semantic categorization and word decoding have simply not been found in ten and eleven-year-old children (Assink, van Bergen, van Teeseling, & Knuijt ,2004; Silva-Pereyra et al., 2003). Assink et al. performed a semantic priming study, examining semantic association strength and semantic association type and Silva-Pereyra et al. performed an event-related potentials (ERP) study examining word categorization (animal versus non-animal) and picture categorization (animal versus non-animal), and they found results which indicated no semantic processing underachievement for poor readers. Assink et al. found no relationship between semantics and reading ability and Silva-Pereyra et al. found no differences in the N400 component between poor readers and control children. However, the methodologies used in these studies (priming and ERPs) are different from the semantic categorization tasks in other studies. The apparent lack of an association between semantic knowledge and word decoding may be a result of the use of priming and ERPs.

In addition to associations between semantic knowledge and word decoding/recognition, the associations between semantic knowledge and reading comprehension have also been studied. Ben-Dror, Bentin, and Frost (1995), for example, found children with poor reading comprehension to perform worse on a number of semantic categorization tasks than children with normal reading comprehension, which suggests an association between underlying categorical knowledge and reading comprehension (see also Vellutino, Fletcher, Snowling, & Scanlon, 2004; Vellutino, Scanlon, & Spearing, 1995). When Nation and Snowling (1998) found evidence of an association between semantic categorization skill and reading comprehension, they further suggested that poor reading comprehension may be due to the non-automatic access of underlying semantic information. In other research, Adams, Bowyer-Crane, and Snowling (2004) found 10% of the poor readers in their study, as based on reading comprehension, to have perfect phonological decoding skills but clear semantic difficulties, which is in line with the assumption that not just the phonological skills in many cases but also the semantic skills of otherwise normally developing children are strongly related to their level of reading proficiency.

4.1.1 *Deaf Bilingual Children*

Due in part to the limited phonological information available to them, deaf children experience major difficulties learning to read (Hermans, Knoors, Ormel, & Verhoeven, 2008; Perfetti & Sandak, 2001). Similarly, the development of semantic knowledge is delayed for most deaf children due to a lack of full access to a language—including sign language—during the first few years of their lives (Chamberlain & Mayberry, in press; Mayberry, 2002; Planting, 2005). This is particularly true for deaf children growing up in hearing families because the acquisition of a sign language appears to be a difficult task for the hearing parents and hearing teachers of deaf children (Marschark et al., 2002; Fortgens, 2003). Nevertheless, sign language is the more natural and accessible language for the vast majority of deaf children (Klatter-Folmer, van Hout, Kolen, & Verhoeven, 2006; Knoors, in press); sign language appears to be the preferred language for most deaf people; and semantic knowledge may play a more important role in the word recognition skills and reading comprehension of deaf children when compared to hearing children.

During the initial stages of learning to read, the meaning of a written word is often associated with the visual sign equivalent by deaf-bilingual children (Ormel, Hermans, Knoors, & Verhoeven, submitted). During a visual word recognition test, Ormel et al. indeed found evidence for the activation of sign information. That is, deaf-bilingual children appear to process written words in a bilingual fashion and, in fact, their sign language knowledge may need to be developed *first* to facilitate the development of categorical relationships. In a number of studies, knowledge of signs has been found to affect the manner in which written words are recognized by deaf readers (Mayberry, Chamberlain, Waters, & Hwang, 2003; Treiman & Hirsh-Pasek, 1983). In several other studies, a positive association between knowledge of sign language and reading proficiency has also been demonstrated (Hoffmeister, 2000; Chamberlain & Mayberry, in press; Padden & Ramsey, 2000; Strong & Prinz, 2000). Given that isolated words constitute the building blocks for reading comprehension (Dijkstra & van Heuven, 2002) and that word recognition is highly predictive of reading comprehension (Hoover & Gough, 1990), it can be argued that children's ability to recognize individual words with the aid of phonological and semantic knowledge may be critical. It is also possible that the role of semantic knowledge in the process of learning to read may be more critical for deaf children than for hearing children due to the limited access to phonological information for the deaf children.

The semantic knowledge of deaf readers and the speed of accessing this knowledge together with how these relate to the word recognition and reading comprehension skills of deaf readers have been rarely studied (MacSweeney, Gossi, & Neville, 2004). The semantic knowledge of young deaf-bilingual children who are just learning to read has simply not been studied. Information regarding deaf children's semantic knowledge to date involves only the frequent mention of poor vocabulary skills (Marschark et al., 2002). Nevertheless, when Courtin (1997) examined the semantic categorization skills of second generation deaf children who were fluent signers at the age of six, their performance on a semantic categorization task was found to be similar to that of hearing children but clearly affected by sign language structures. Unfortunately, the associations of the children's semantic categorization skills to their reading skills were not examined. Similarly, in studies of deaf adults, the categorical organization of semantic information and automatic processing of this information have been shown to differ from that of hearing adults (MacSweeney, Grossi, & Neville, 2004;

Marschark, Convertino, McEvoy, & Masteller, 2004) but, once again, this information was not examined in relation to reading skill.

4.1.2 *Present Study*

In the present study, we first assessed the semantic skills of both deaf and hearing children. We then assessed the associations between the semantic and reading skills of the deaf children. The deaf children were being taught in bilingual education settings, which include the Sign Language of the Netherlands in addition to (Sign Supported) Dutch. Sign Language of the Netherlands is a full-blown sign language with its own grammatical rules, whereas Sign Supported Dutch is a combination between Dutch and Sign Language of the Netherlands; the Dutch words are generally accompanied by signs. The semantic knowledge and speed of access to the semantic knowledge of the deaf children were investigated at different grade levels in order to gain insight into this possible source for reading difficulties, in addition to the already assumed limited phonological knowledge (Miller, 2006; Waters & Doehring, 1990). In addition, the deaf children's semantic knowledge and speed of access to semantic knowledge were examined in relation to the speed of word recognition and their reading comprehension.

One of the reasons for why many deaf readers and hearing people with poor reading skills show weaker semantic knowledge than other readers may lie in the use of written words to assess semantic knowledge (see Marschark et al., 2004). Pictures may be easier to process than words for young readers or readers with otherwise limited reading skills (Vellutino, Scanlon, DeSetto, & Pruzek, 1981; Vellutino et al., 1990). Similarly, the severe decoding difficulties of many deaf children when confronted with written words—but not signs—may severely impede assessment of their semantic knowledge, at least when the child has received sufficient language input starting from a very young age. Pictures can be assumed to be even less problematic, and we therefore used both signs and pictures, in addition to written words, to assess the semantic skills of the deaf children and pictures to assess the semantic skills of the hearing children and thereby avoid any reliance on their visual word recognition skills. To further assess the organization of the children's underlying semantic knowledge and the speed of access to this knowledge, the semantic information was assessed using two levels of categorization and thus in two different experiments. In Experiment 1, the children's semantic knowledge was assessed at the level of the exemplar. In Experiment 2, the children's semantic knowledge was assessed at the level of the subcategory (i.e., superordinate and subordinate relations).

4.2 Experiment 1: Exemplar categorization

In Experiment 1, the children's semantic knowledge was assessed at the level of the exemplar (e.g., both the bee and the mosquito are insects). The stimuli were presented in three conditions: a) pictures, b) spoken words/visual signs, or c) written words. The performances of the deaf and hearing children were then compared within the different conditions. In other words, whether or not the deaf children in the present study showed the same categorical exemplar knowledge and speed of access to this knowledge as the hearing children was examined. The knowledge of the deaf children was then compared across the different conditions and different grade levels. Thereafter, whether or not the deaf-bilingual children's categorical knowledge and speed of access to this knowledge relate to their word recognition and reading comprehension skills was examined. We expected the hearing children to outperform the deaf children in the written words condition but not, or to a lesser extent, in the spoken/sign or picture conditions. Given the reading difficulties experienced by most deaf children, the deaf-bilingual children were expected to encounter the largest difficulties in the written word condition relative to the sign and picture conditions. And finally, both the deaf children's categorical exemplar knowledge and speed of access to this knowledge were expected to show associations to their word recognition and reading comprehension skills.

4.2.1 *Method*

Participants

Deaf and hearing elementary school students from grades three through six participated in the present study. The deaf children constituted the experimental group with 39 boys and 20 girls from three different schools for deaf education in the Netherlands (n = 59). The mean age for the deaf children ranged from 103 months (SD = 8 months) in grade three to 149 months (SD = 6 months) in grade six. Of the 59 deaf children, 24 were in grades three and four (i.e., the lower grades hereafter) and 35 were in grades five and six (i.e., the upper grades hereafter). The schools all provided bilingual deaf education and support for children with auditory and communicative difficulties, and the curriculum involved alternation between Sign Language of The Netherlands (SLN) and (Sign Supported) Dutch (SSD).

The hearing children constituted the control group with 42 boys and 46 girls from two regular elementary schools in the Netherlands (n = 88). The mean age for the hearing children ranged from 102 months (*SD* = 6.5 months) in grade three to 152 months (*SD* = 6.5 months) in grade six. Of the 88 hearing children, 41 were in the lower grades and 47 were in the upper grades of elementary school.

The children's reading levels were assessed using a national standardized reading comprehension test (i.e., the so-called *CITO* test). Reading Age Equivalent scores (RAE) were then derived from these scores.

Materials

The materials presented in the three exemplar categorization conditions involved either pictures, signs/spoken words, or written. In all three of the conditions, four pictures were presented for the respondent to select that picture which best matches the stimulus. The words in the exemplar experiment were matched for log frequencies per million words, number of letters, and number of neighbor words using the CELEX counts (Baayen, Piepenbrock, & van Rijn, 1993). The majority of the stimuli were one syllable CVC, CCVC, CVCC, or CCCVC words. The pictures were taken from the Dutch *Leesladder* (i.e. "Reading Ladder"), which is a computer program for children with reading disabilities (Irausquin & Mommers, 2001). The pictures in the exemplar experiment were colored line-drawings and represented nouns that could be assumed to be familiar to most six-year-old Dutch children (Schaerlaekens, Kohnstamm, Lejaegere, & de Vries, 1999; familiarity rating≥ .80 along a scale of 0 to 1). In addition, only high-imageability words were selected for use (van Loon-Vervoorn, 1985; imageability rating > 5.5 along a seven-point scale). Detailed descriptions of the three conditions in Experiment 1 are presented below.

Pictures. This condition consists of 20 experimental trials, preceded by three practice trials. A target picture is presented (e.g., a picture of an orange) and then four pictures consisting of the target response and three distracters are presented simultaneously. The target response represents a concept from the same taxonomic category (e.g., a picture of a cherry). The categories included were: Insects, predators, mammals, rodents, reptiles, sense organs, vegetables, fruit, furniture, transport, clothes, jewels, parts of the body, tools, toys, and buildings. The different trials involved exemplars from different semantic categories, with the exception of the categories of vegetables, fruits, parts of the body, and buildings; each of these categories were used on two occasions. One of the distracter pictures was a semantic distracter and included for half of the stimuli: A concept (e.g., egg) that belongs to a higher superordinate category (e.g., food) and not, thus, the category represented by the target stimulus (e.g., orange). A second distracter picture is a phonological distracter such as "beer" for the target stimulus "ear" (used on 11 of the 20 trials) or a perceptual distracter such as "ball" for the target stimulus "orange" (used on 9 of the 20 trials). The criterion for phonological similarity was sharing the end-rime with the stimulus. Perceptual similarity was created in terms of similar contours or colors. A third distracter picture was an unrelated picture such as "chair" for the target stimulus "orange" and used with all of the stimuli. For those stimuli with no semantic distracter, two unrelated pictures were included among the response options. The criterion for the unrelated picture was absence of a semantic (i.e., taxonomic or associative) relation, perceptual relation, or phonological similarity. Both accuracy and reaction time were measured. The items in the picture condition had an average of 4.6 letters, 14.5 neighbor words (i.e., words differing 1 letter from the target word), and a log frequency of 1.29.

Signs/spoken words. This condition consisted of 20 experimental trials, preceded by three practice trials. The stimuli were drawn from the same categories used in the picture condition. The sign stimuli were presented on a computer screen; the spoken stimuli were presented orally. The response options were again four pictures presented simultaneously. The exact stimuli and response options differed from the picture condition. The majority of the sign and spoken word stimuli consisted of one-syllable words. Six stimuli involved two syllables. The types of distracters and their frequencies of use were identical to those in the picture condition with the exception of the use of the phonological and perceptual distracters, which was now equal (i.e., each type of distracter was used on 50% of the trials). Both the accuracy of responding and reaction times were measured. The items in the sign/spoken word condition had an average of 5.0 letters, 12.1 neighbor words, and a log frequency of 1.28.

Written words. This condition consisted of 20 experimental trials, preceded by three practice trials. The stimuli were drawn from the same categories as in the picture and sign/spoken-word conditions. The written word stimuli were presented as written letter strings. The response options were again four pictures presented simultaneously. And once again, the exact stimuli and response options differed from those used in the other two conditions. The types of distracters and their frequencies were identical to those in the picture condition. Both the accuracy of responding and reaction times were measured. And the items in this condition had an average of 4.6 letters, 13.9 neighbor words, and a log frequency of 1.29.

Apparatus and Procedure

All of the conditions were implemented in E-prime (Schneider, Eschman, & Zuccolotto, 2002), which is a psychology software tool. Spoken words were recorded using *Spraak* (i.e., "Speech") (Boersma & Weenink, 2004). The trials were presented on a laptop. First, a fixation stimulus (i.e., a "+" sign presented using a 50-point Times New Roman font) was presented on the screen for 1000 milliseconds. Immediately thereafter, the target stimulus (i.e., picture, sign/spoken word, or letter string) was presented. The target stimulus remained visible until a response was provided. Thereafter, the four response options (i.e., pictures) appeared simultaneously and the respondent had to decide which picture best matched the target stimulus, belonging to the same semantic category. The participants indicated their responses using four keys on the laptop keyboard with a position corresponding to the position of the response pictures on the screen (i.e., the keys "c," "b," "m," and "." were used). The relevant keys on the laptop were marked with white stickers. The participant was asked to keep his or her hands in front of the keyboard. The word stimuli were presented in white on a black background in the center of the screen in a lowercase 24-point Courier New font. There was a 1500 millisecond delay between the receipt of a response and the onset of the next trial. For each of the participants, the items were presented in a different (i.e., random) order.

The children performed the matching tasks in groups of 6 to 8 students. The order of administration for the three conditions was varied across participants such that each condition appeared an equal number of times as first, second, or third. Those children tested at the same time received the same order of conditions but not the same order of items within a given condition. The children were administered all of the conditions within a single session.

In order to measure word recognition speed, the children were instructed to press the space bar as fast as possible after reading the target word when performing the written word matching task. Once the space bar was pressed in the written word matching task, but also in the picture matching task, and the sign/ spoken word matching task, the four response options (i.e., pictures) were presented simultaneously on the screen and the reaction time was measured from the offset of the stimulus (i.e., the time that the space bar was pressed) to the provision of a response. The accuracy of the matching response provided by the child was also then recorded.

4.2.2 *Results*

The first set of analyses was aimed at answering the question of whether deaf children show equally specific semantic knowledge as hearing children for different ages (i.e., in both grades 3/4 and grades 5/6), and under different matching conditions or modalities (i.e., pictures, signs/spoken words, or written words as stimuli). The second set of analyses concerned the question of whether the deaf children showed differences in semantic skill when the stimuli were pictures, signs, or written words and in the lower versus higher elementary grades. The third set of analyses concerned the extent to which individual difference in the word recognition and reading comprehension skills of the deaf children related to variation in their semantic knowledge and access to this knowledge. Is there a correlation between semantic categorization at the exemplar level and word recognition speed or the deaf children's reading comprehension?

Semantic Knowledge of the Deaf and Hearing children

In the first set of analyses, Univariate analyses of variance and repeated measures were conducted in the participant analyses and repeated measures were used in the item analyses, using General Linear Model in SPSS (2002). Erroneous responses and also RTs that were more than two standard deviations away from the participant means and item means were omitted from any further RT analyses. In the presentation of the outcomes of the analyses, $F1$ values refer to participant analyses and $F2$ values refer to item analyses. Condition was treated as a between subjects factor in the $F1$ and as a between item factor in the $F2$ analyses. Grade (i.e., lower versus upper) and hearing status (i.e., deaf versus hearing) were treated as between subject factors in the *F*1 and as within item factors in the *F*2. As already mentioned the results for the deaf and hearing children were compared in each of the stimulus conditions separately.

Table 1

Means and Standard Deviations for Reaction Times and Accuracy of Responding for Deaf versus Hearing Children in Three Conditions from Experiment 1 also according to Grade Level

GRADE LEVEL		Lower elementary				Upper elementary			
PARTICIPANTS		Deaf (n=24)		Hearing (n=41)		Deaf (n=35)		Hearing (n=47)	
CONDITION		RT	Accuracy	RT	Accuracy	RT	Accuracy	RT	Accuracy
Written word									
	M	3522	52.7	1542	76.8	3127	57.9	1137	80.6
	SD	1363	20.5	546	9.6	1029	19.7	494	11.3
Picture									
	M	2917	65.5	3147	78.8	2910	71.1	2344	82.5
	SD	878	21.5	1425	12.6	989	18.2	617	13.0
Sign/spoken word									
	M	3858	57.6	3203	65.9	4275	49.9	2819	68.6
	SD	1455	18.0	934	15.0	2088	22.0	783	11.5

Reaction times (RTs). There was a three-way interaction between condition, grade, and hearing status ($F1(2,135) = 3.087$, $p < .05$; $F2(2,57) = 4.502$, $p < .05$). A two-way interaction was found between condition and hearing ($F1(2,135) = 9.244$, $p < .001$; $F2(2,57) = 4.736$, $p < .05$), between grade and hearing in the item analysis ($F1(2,135) = 2.209$, $p > .1$; $F2((1,57) = 7.013$, $p < .05$), but not between condition and grade ($F1(2,135) = 2.294$, $p > .1$; $F2(2,57) = .605$, $p > .1$). There were main effects for condition ($F1(2,135) = 22.651$, $p < .001$; $F2(2,57) =$

4.746, $p < .05$), grade ($F1(1,135) = 3.701$, $p < .1$; $F2(1,57) = 22.105$, $p < .001$) and hearing status ($F1(1,135) = 17.373$, $p < .001$; $F2(1,57) = 34.471$, $p < .001$).

Analyses of the RTs for the deaf versus hearing children in each of the separate conditions revealed highly significant differences in favor of the hearing children in the sign/spoken word condition ($F1(1,140) = 20.98$, $p < .001$; $F2(1,19) = 12.188$, $p <. 01$). No effect was found for grade ($F1(1,140) = .005$, $p > .1$; $F2(1,19) = 1.659$, $p > .1$), and the interaction between grade and hearing status was marginal in the participant analysis ($F1(1,40) = 3.023$, $p < .1$; $F2(1,19) = .587$, $p > .1$). In the written word condition there was a main effect for hearing status ($F1(1,146) = 24.35$, $p < .001$; $F2(1,19) = 35.45$, $p <. 001$), and for grade ($F1(1,143) = 6.611$, $p < .05$; $F2(1,19) = 17.289$, $p < .001$). No interaction was found between grade and hearing status in the written word condition ($F1(1,143) = .001$, $p > .1$; $F2(1,19) = .885$, $p > .1$). In the picture condition, an interaction was found between hearing status and grade level ($F1(1,142) = 5.05$, $p< .05$; $F2(1,19) = 49.95$, $p > .1$). The interaction showed that there was no increase across grades for the deaf children, in contrast to the hearing children who responded much faster in upper grades versus lower grades.

In the lower elementary grades, significant differences between the deaf and hearing children also occurred in the sign/spoken word condition ($F1(1,63) = 4.82$, $p < .05$; $F2(1,19) = 7.11$, $p < .05$) but only a marginal effect in the item analysis of the picture condition ($F1(1,64) = .51$, $p > .1$; $F2(1,19) = 3.27$, $p < .1$). In the upper elementary grades, the differences between the deaf and hearing children in the two conditions were consistently significant in advance of the hearing children: picture condition ($F1(1,77) = 9.71$, $p < .01$; $F2(1,19) = 66.73$, $p < .001$); sign/spoken word condition ($F1(1,79) = 19.13$, $p < .001$; $F2(1,19) = 15.23$, $p <. 001$. As the non presence of an interaction between grade and hearing status in the written word condition already suggests, effects for the lower and upper grades are comparable; lower grades : ($F1(1,64) = 8.79$, $p < .01$; $F2(1,19) = 11.03$, $p < .01$); upper grades: ($F1(1,81) = 17.07$, $p < .001$; $F2(1,19) = 25.42$, $p < .001$).

Error data. There was a three-way interaction between condition, grade, and hearing status ($F1(2,135) = 4.056$, $p < .05$). Two-way interactions were found between condition and hearing status ($F1(2,135) = 7.083$, $p < .001$; $F2(2,57) = 2.810$, $p < .1$) and condition and grade ($F1(2,135) = 5.253$, $p < .01$; $F2(2,57) = 4.872$, $p < .05$), but not between grade and hearing ($F1(2,135) = .196$, $p > .1$; $F2(1,57) = 1.437$, $p > .1$). Main effects were found for condition, in the participant analysis only ($F1(2,135) = 51.537$, $p < .001$; $F2(2,57) = 2.101$, $p > .1$) and for hearing status ($F1(1,135) = 52.453$, $p < .001$; $F2(1,57) = 76.196$, $p < .001$), but not for grade ($F1(1,135) = 1.176$, $p > .1$; $F2(1,57) = 2.782$, $p > .1$).

The results for the individual conditions showed highly significant differences between the children in favor of the hearing children in all of the conditions: picture condition ($F1(1,142) = 20.07$, $p < .001$; $F2(1,19) = 37.135$, $p < .001$; sign/spoken word condition ($F1(1,145) = 22.39$, $p < .001$; $F2(1,19) = 12.744$, $p < .01$; written word condition ($F1(1,146) = 83.81$, $p < .001$; $F2(1,19) = 56.483$, $p < .001$). The largest general difference between the deaf and hearing children occurred in the written word condition (see Table 1), in favor of the hearing participants. Grade effects in the written condition were marginal in the participants analysis and in the item analysis ($F1(1,143) = 3.057$, $p < .1$; $F2(1,19) = 4.219$, $p < .1$), and were significant in the item analysis and marginal in the participant analysis in the picture condition ($F1(1,139) = 2.818$, $p < .1$; $F2(1,19) = 9.439$, $p < .001$), in favor of the upper grades, and was not significant in the sign/spoken condition ($F1(1,140) = .766$, $p > .1$; $F2(1,19) = 1.623$, $p > .1$). The interaction between grade and hearing status was not found in the written condition and the picture condition, and in sign/spoken condition, effects were marginal in the participant analysis, and significant in the item analysis ($F1(1,140) = 3.389$, $p < .1$; $F2(1,19) = .9.426$, $p > .001$).

For the children in the lower elementary grades, effects in the sign/spoken word condition were significant in the item analysis and marginal in the participant analysis ($F1(1,63) = 3.73$, $p < .1$; $F2(1,19) = 5.789$, $p <.05$), in favor of the hearing children. In the upper elementary grades, significant differences were found in the participant and the item analysis in the sign/spoken word; again in favor of the hearing children ($F1(1,79) = 24.71$, $p < .001$; $F2(1,19) = 19.52$, $p < .001$). Effects for hearing status in the written word condition and picture condition were comparable across grades (lower grades: the written word condition ($F1(1,63) = 41.61$, $p < .001$, $F2(1,19) = 43.96$, $p < .001$), in favor of the hearing children; picture condition ($F1(1,64) = 9.74$, $p < .01$, $F2(1,19) = 25.33$, $p < .001$), again in favor of the hearing children; upper grades: picture condition ($F1(1,77) = 10.26$, $p < .01$; $F2(1,19) = 14.07$, $p < .001$); written word condition ($F1(1,81) = 43.73$, $p < .001$; $F2(1,19) = 53.01$, $p < .01$).

In the Levene's Test of Equality of Error significant different Standard Deviations were found for the results of the deaf children versus the hearing children. The difference was largest for the written word test. The comparison between deaf and hearing children therefore ought to be interpreted with some caution.

Modality and Semantic Skills of the Deaf Children

The following parts concern deaf children only. In a repeated-measures analysis based upon a General Linear Model in SPSS, condition was treated as a within subjects factor and between item factor. Grade level (i.e., lower versus upper) was treated as a between subjects factor and within items factors.

Reaction times. In the repeated-measures analysis on the speed of the deaf children's responding, a main effect of condition was found ($F1(2,49) = 12.066$, $p< .001$; $F2(2,57) = 4.98$, $p < .01$) but not of grade level ($F1(1,50) = .049$, $p > .1$; $F2(1, 57) = 2.43$, $p > .1$). The deaf children responded quickest in the picture condition and slowest in the sign condition irrespective of grade level. The interaction between condition and grade level was not significant ($F1(2,49) = 1.587$, $p > .1$; $F2(2,57) = 1.10$, $p > .1$).

Error data. In the analysis on the accuracy of the deaf children's responding, a main effect of condition was found ($F1(2,49) = 20.370$, $p < .001$; $F2(2,57) = 2.41$, $p < .1$) but not of grade level ($F1(1,50) = .092$, $p > .1$; $F2(1,57) = .011$, $p > .1$). Responses in the picture condition were most accurate when compared to the written word and the sign condition. The interaction between condition and grade level was significant ($F1(2,49) = 4.623$, $p < .05$; $F2(2,57) = .6.80$, $p < .001$). In the lower grades, written words were responded to least accurately, and pictures most accurately. The main effect for condition in the lower grades was significant ($F1(2,21) = 5.123$, $p < .001$, $F2(2,57) = 3.361$, $p < .05$. In the upper grades, signs were responded to least accurately, and pictures most accurately. The main effect for condition in the upper grades was also significant ($F1(2,27) = 18.373$, $p < .001$; $F2(2,57) = 6.353$, $p < .01$).

Semantic Skills, Word Recognition, and Reading Comprehension of the Deaf Children

The semantic knowledge of the deaf children was assumed to be best reflected by their knowledge of pictures and signs, which means that the results for the written word condition were excluded from the third set of analyses. In SPSS, partial correlations were thus calculated between the accuracy and speed of the deaf children's matching at the exemplar level for pictures and signs (i.e., their semantic knowledge) and their word recognition speed and reading comprehension (i.e., reading age equivalent; REA) after having controlled for age.

Reading comprehension score. As might be expected, the reading comprehension of the deaf children, with a RAE of 12.0, was generally lower than the reading comprehension of the hearing children, with a RAE of 42.67 ($F(1,139) = 249.62$, $p < .001$). The deaf children in the lower grades showed lower RAE levels than the hearing children ($F(1,59) = 68.85$, $p < .001$; RAE = 11.9 vs. RAE = 32.1) and, similarly, the deaf children in the upper grades showed lower RAE levels than the hearing children ($F(1,79) = 607.64$, $p < .001$; RAE = 12.1 vs. RAE = 52.1). Whereas the reading comprehension of the hearing children clearly improved across grades, the reading comprehension of the deaf children remained the same across grades.

Table 2

Correlations between Semantic Knowledge of Deaf Children (i.e., Speed and Accuracy of Matching) and Reading Skill (i.e., Word Recognition Speed and Reading Comprehension) for Exemplar Level Assessment with Signs or Pictures after control for Age (Experiment 1)

		Word Recognition Speed	Reading comprehension
Sign Condition	RT	.37**	-.16
	% correct	-.12	.27^{MS}
Picture Condition	RT	.11	.03
	% correct	-.18	.38**

* = significant at the .05 level

** = significant at the .01 level

MS = marginally significant at the .1 level

Reaction times. A significant correlation was found between the speed of the deaf children's performance in the sign condition and their word recognition speed but not between the speed of their performance in the picture condition and their word recognition speed: sign condition ($r(52) = .37$, $p = .006$); picture condition ($r(52) = .11$, $p = .44$). No significant correlations were found between the performance of the deaf children in the sign or the picture conditions and their reading comprehension: sign condition ($r(47) = -.16$, $p = .28$); picture condition ($r(45) = .03$, $p = .86$).

Error data. None of the partial correlations between the accuracy of the deaf children's matching in the picture or sign conditions with their word recognition speed were significant: sign condition ($r(51) = -.12$, $p = .38$); picture condition ($r(52) = -.18$, $p = .19$). The correlation was significant for the accuracy of the children's performance in the picture condition in relation to their reading comprehension and marginal for the accuracy of the children's performance in the sign condition in relation to their reading comprehension: sign condition ($r(47) = .27$, $p = .062$); picture condition ($r(47) = .38$, $p = .008$) (see also Table 2).

Conclusions

In sum, both the reaction time data and the error data showed largest differences between the deaf and hearing children in the written word condition, which might be expected. Responses in the other two conditions were also less accurate for the deaf children, and longer reaction times were seen for the deaf children, apart from the picture condition in the lower levels where deaf children did not fall behind the hearing children (see Table 1). Differences in all conditions between the deaf and hearing children were more apparent in the upper elementary grades than in the lower elementary grades. The hearing children also showed consistent improvement with grade level across the three conditions while the performance of the deaf children sometimes stayed the same or even declined with grade level depending on the condition (see Table 1). Importantly, semantic knowledge of the deaf children does not appear to increase significantly with grade level, which was observed in response speed as well as accuracy. For these children, performance in the picture condition was clearly easiest.

Significant correlations were found between the speed of the deaf children's responding in the sign condition and their word recognition speed but not their reading comprehension. For the accuracy of their responding, significant correlations with their reading comprehension were found in the picture condition and marginal correlations were found in the sign condition. In other words, the deaf children's reading comprehension correlated with the accuracy of their responding on the semantic tests and word recognition speed correlated with the speed of their responding on the semantic tests.

4.3 Experiment 2: Superordinate Categorization

In Experiment 2, the deaf and hearing children's knowledge of such superordinate/subordinate relations as a "bee" being part of the category of "insects" or a "chair" being part of the category of "furniture" was tested using two types of stimuli: signs/spoken words and written words. Pictures could not be used due to difficulties with the pictorial representation of superordinate/subordinate category information. Similar to Experiment 1, the speed and accuracy of the deaf versus hearing children's performances were first compared for each of the conditions separately. The performance of the deaf children in the different conditions and in the two grade levels was next examined, followed by an analysis of the relations between the measures of the deaf children's semantic knowledge and their word recognition speed and reading comprehension, respectively. We expected the hearing children to outperform the deaf children in the written words condition but not in the spoken/sign conditions. The deaf-bilingual children were expected to encounter the most difficulties in the written word condition relative to the sign conditions, in line with the often found reading difficulties for deaf children. And finally, both the deaf children's categorical superordinate knowledge and speed of access to this knowledge were expected to show associations to their word recognition and reading comprehension skills.

4.3.1 *Method*

Participants

The participants were the same as in Experiment 1.

Materials

The children's knowledge of taxonomic relations (i.e., superordinate/subordinate categories) was tested using signs/spoken words and written words (i.e., two conditions).

Signs/spoken words. This condition consisted of 12 experimental trials, preceded by two practice trials. The name of a (superordinate) semantic category was presented as a sign or a spoken word, followed by the simultaneous presentation of four pictures representing the target response and three distracters. The target response involved depiction of a member of the previously presented superordinate category. The superordinate categories included: residence, toys, drinks, cutlery, jobs, transport, musical instruments, tools, animals, clothes, sports, pets, birds, fruit, dairy products, head gear, insects, furniture, vegetables, limbs, mammals, writing tools, sense organs, numbers, and flowers. Of the 12 experimental trials, 8 trials included 2 semantic distracters (i.e. response options that did not depict a subordinate member of the superordinate category mentioned just prior, but, however, a semantically related response option) and 1 completely unrelated response option. The remaining four experiment trials included three completely unrelated response options. The criteria for the selection of the distracters were the same as in Experiment 1. Both the accuracy and speed of the children's responding were measured. The items had 4.98 letters on average, 12.36 neighbor words on average, and an average log frequency of 1.25.

Written words. This condition consisted of 25 experimental trials, preceded by two practice trials. The same superordinate categories as in the sign/spoken word condition were included. However, the stimuli in this condition were presented as written words. The response options were again pictures. The exact stimuli and response options differed from those used in the sign/spoken word condition (see Results section below). The types of distracters and their frequency of use were the same as in the sign/spoken word condition. Both the accuracy and speed of the children's responding were measured. The items had 5.1 letters on average, 11.4 neighbor words on average, and an average log frequency of 1.35.

Apparatus and Procedure

The same equipment and procedures were used as in Experiment 1.

4.3.2 *Results*

The first set of analyses concerned the question of whether significant differences exist at the different conditions in the semantic knowledge of the deaf versus hearing children. (see Table 3). The possible differences in their performance depending on grade level and/or condition (i.e., signs/spoken words, written words) were also examined. The second set of analyses concerned the question of whether the deaf children showed differences in their semantic knowledge (i.e., superordinate category knowledge) depending on the condition or grade level. The third set of analyses concerned the question of whether individual differences in the word recognition speed and reading comprehension of the deaf children related to variation in their semantic knowledge. Does speed or accuracy of the deaf children's superordinate categorization performance in specifically the sign condition relate to their word recognition speed or reading comprehension?

Semantic Knowledge of the Deaf and Hearing children

Univariate analyses of variance and repeated measures were conducted in the participant analyses and repeated measures were used in the item analyses, using General Linear Model in SPSS (2002). Condition was treated as a within subjects factor and between items factor and grade level (i.e., lower versus upper) and hearing status were treated as a between subjects factor and within subjects factor.

Error data. Analyses of the accuracy of the performances showed no three-way interaction between grade, condition and hearing status ($F1(1,128) = .285$, $p > .1$; ($F2(1,35) = .116$, $p > .1$). A two-way interaction was found between condition and hearing status ($F1(1,128) = 59.535$, $p < .001$; $F2(1,35) = 3.705$, $p < .1$), but not between condition and grade ($F1(1,128) = .404$, $p > .1$; $F2(1,35) = .129$, $p > .1$), or between hearing and grade ($F1(1,128) = 2.663$, $p > .1$; $F2(1,35) = 989$, $p > .1$). A main effect was found for condition ($F1(1,128) = 39.936$, $p < .001$; $F2(1,35) = 3.160$, $p < .1$), and for grade in the item analysis ($F1(1,128) = 1.106$, $p > .1$; $F2(1,35) = 4.225$, $p < .05$).

Table 3

Means and Standard Deviations for Reaction Times and Accuracy of Responding for Deaf versus Hearing Children in Two Conditions from Experiment 2 also according to Grade Level

GRADE LEVEL		Lower elementary				Upper elementary			
PARTICIPANTS		deaf (n=24)		hearing (n=41)		deaf (n=35)		hearing (n=47)	
CONDITION		RT	Accuracy	RT	Accuracy	RT	Accuracy	RT	Accuracy
Written word									
	M	2023	59.4	1662	86.7	2061	61.6	899	91.1
	SD	478	16.7	723	7.7	542	20.4	292	6.4
Sign/Spoken word									
	M	2390	76.1	2112	83.6	2250	77.1	1757	89.7
	SD	1243	17.3	431	10.8	668	16.8	302	7.0

Analyses of the accuracy of the performances of the deaf versus hearing children for each of the two conditions separately showed the hearing children to consistently outperform the deaf children with a larger difference in the written word condition than in the sign/spoken word condition: written word condition ($F1(1,132) = 128.900$, $p < .001$; $F2(1,24) = 36.823$, $p < .001$); sign/spoken word condition ($F1(1,145) = 21.061$, $p < .001$; $F2(1,11) = 21.218$, $p < .001$). No interaction was found between grade and hearing status in the written word condition ($F1(1,129) = .189$, $p > .1$; $F2(1,24) = .271$, $p > .1$), or in the sign/spoken condition ($F1(1,129) = 1.325$, $p > .1$; $F2(1,11) = 1.248$, $p > .1$). The differences in the accuracy of the performances of the deaf versus hearing children proved significant in both the lower and upper elementary grades.

Reaction times. There was no three-way interaction between grade, condition and hearing status ($F1(1,128) = .608$, $p > .1$; $F2(1,35) = .041$, $p > .1$). No two-way interactions were found between condition and hearing status, though a marginal effects was found in the item analysis ($F1(1,128) = .884$, $p > .1$; $F2(1,35) = 3.650$, $p < .1$), and no two-way interaction was found between condition and grade ($F1(1,128) = .268$, $p > .1$; $F2(1,35) = .142$, $p > .1$), but a significant two-way interaction was found between hearing status and grade ($F1(1,128) = 8.548$, $p < .01$; $F2(1,35) = 12.495$, $p < .001$). No main effect was found for condition ($F1(1,128) = .556$, $p > .1$; $F2(1,35) = .090$, $p > .1$), but main effects were found for grade and hearing status: a significant main effect for grade ($F1(1,128) = 4.137$, $p < .05$; $F2(1,35) = 29.001$, $p < .001$) , and a significant main effects in the participant analysis and a marginal effect in the item analysis for hearing status ($F1(1,128) = 2.971$, $p < .1$; $F2(1,35) = 15.227$, $p < .001$).

In the lower grades, the differences in the speed of the deaf and hearing children's responding were marginally significant in the written word condition: written word condition ($F1(1,52) = 2.819$, $p < .1$; $F2$ $(1,24) = .452$, $p > .1$); sign/spoken word condition: ($F1(1,63) = 1.722$, $p > .1$; $F2(1,11) = 1.56$, $p > .1$). In the upper grades, however, the differences in the speed of the deaf and the hearing children's responding were highly significant in both conditions: written word condition ($F1(1,79) = 13.29$, $p < .001$; $F2(1,24) = 44.64$, $p < .001$); sign/spoken word condition ($F1(1,81) = 20.08$, $p < .001$; $F2(1,11) = 28.33$, $p < .01$), in favor of the hearing children. More specifically, the difference in the speed of the deaf versus hearing children's responding is greater in the higher grades.

In the Levene's Test of Equality of Error significant different Standard Deviations were found for the results of the deaf children versus the hearing children. The difference was largest for the written word test. The comparison between deaf and hearing children therefore ought to be interpreted with some caution.

Modality and Semantic Skills of the Deaf Children

In a repeated-measures analysis based upon a General Linear Model in SPSS, condition at the superordinate level was treated as a within subjects factor and between items factor and grade level (i.e., lower versus upper) was treated as a between subjects factor and within subjects factor.

Error data. The deaf children showed a major gap in the accuracy of their performance in the written word condition (61.2%) relative to the sign condition (80.0%) ($F1(1,43) = 32.043$, $p < .001$; $F2(1,35) = 4.61$, $p < .05$). There was no effect of grade ($F1(1,43) = .07$, $p > .1$; $F2(1,35) = .851$, $p > .1$) and no interaction between grade and condition ($F1(1,43) = .475$, $p > .1$; $F2(1,35) = .01$, $p > .1$).

Reaction Times. No main effect of condition was found ($F1(1,43) = .664$, $p > .1$; $F2(1,35) = 1.25$, $p < .01$). There was also no effect of grade ($F1(1,43) = .209$, $p > .1$; $F2(1,35) = .95$, $p > .1$) and no interaction between grade and condition ($F1(1,43) = .084$, $p > .1$; $F2(1,35) = .12$, $p > .1$).

Semantic Skills, Word Recognition, and Reading Comprehension of the Deaf Children

Partial correlations between the two measures of the deaf children's superordinate semantic knowledge and their word recognition and reading comprehension with age as the control variable were calculated using SPSS (2002).

Table 4

Correlations between Semantic Knowledge of Deaf Children (i.e., Speed and Accuracy of Matching) and Reading Skill (i.e., Word Recognition Speed and Reading Comprehension) for Superordinate Level Assessment with Signs after control for Age (Experiment 2)

		Word identification	Reading comprehension
Sign condition	RT	.21	$-.27^{MS}$
	%	-.16	.37*

* = significant at the .05 level

** = significant at the .01 level

MS = marginally significant at the .1 level

Error data. The accuracy of the deaf children's responding in the sign condition—recall that the written word condition was omitted from these analyses as it was assumed to not be representative of their semantic knowledge—did not correlate with their word recognition speed, see Table 4 ($r(53) = -.16$, $p = .24$). However, the accuracy of the deaf children's responding in the sign condition did correlate significantly with their reading comprehension ($r(48) = .37$, $p = .009$).

Reaction Times. With regard to the speed of the deaf children's responding in the sign condition, a marginal correlation was found with their reading comprehension ($r(48) = -.27$, $p = .054$) but no significant correlation with their word recognition speed ($r(48) = .21$, $p = .12$).

Conclusions

To summarize the results of Experiment 2, the deaf children found the written word condition involving taxonomic semantic relations to be more difficult than the sign condition involving the same relations. This was not the case for the hearing children who showed more similar levels of accuracy in the two conditions (i.e., in the written versus spoken word conditions). The differences between the deaf and hearing children are particularly apparent in the upper elementary school grades where both the accuracy scores and reaction times in both conditions show marked differences in the performances of the deaf versus hearing children.

Across grade levels, the deaf children showed very similar reaction times and accuracy of responding in both the written word and sign conditions. No significant increase of semantic knowledge could be detected across grade level.

The accuracy of the deaf children's superordinate sign knowledge correlated significantly with their reading comprehension. The speed of the deaf children's superordinate/ subordinate sign responding showed a marginal correlation with their reading comprehension. Neither the accuracy nor speed of the deaf children's responding on the semantic superordinate category tests correlated significantly with word recognition speed. In other words, deaf children with lower word recognition speed did not respond slower on tests calling for knowledge of signed superordinate/subordinate semantic relations than deaf children with higher word recognition speeds. The deaf children's reading comprehension, however, did relate to the children's knowledge of signed superordinate/subordinate semantic relations. In other words, the deaf children's categorical knowledge was clearly related to their reading comprehension but not word recognition speed.

4.4 General Discussion

The purpose of the present study was twofold. On the one hand, the semantic knowledge of deaf children was compared to that of hearing children using different types of stimuli. On the other hand, the associations between the semantic skills of the deaf children being educated bilingually and their reading levels were explored. In Experiment 1, the children's knowledge of exemplar-level semantic relations was assessed. In Experiment 2, the children's knowledge of superordinate-level semantics relations was assessed. In both experiments, the hearing children outperformed the deaf children in each condition. The differences between the deaf and hearing children were smallest in the picture condition from Experiment 1. The deaf children performed better in the picture condition in this experiment than in the sign or written word conditions. These results support the assumption that using written words to assess the semantic-categorization skills of deaf children may underestimate their knowledge. Nevertheless, the results of Experiment 1 also show the deaf children to lag behind same-age hearing children when pictures are used to assess their semantic categorization skills. That is, the semantic-categorical knowledge of deaf children appears to be less precise or finely differentiated than the semantic-categorical knowledge of hearing children and, importantly, show less improvement across grades than hearing children do.

Apart from a relation between word recognition speed and signed superordinate/subordinate semantic knowledge, the deaf and hearing children showed relations between their categorization speed and accuracy on the one hand, and their word recognition speed and reading comprehension on the other hand in both Experiments 1 and 2. These results are partially in line with the results of a study by Gijsel et al. (submitted) who found a strong association between semantics and reading speed, but not accuracy, for hearing children. In the present study (i.e., Experiment 1), the deaf children also showed a strong association between the speed of semantic categorization at the exemplar level and word recognition speed. A significant association between the accuracy of semantic categorization and the deaf children's reading comprehension was also present. Those deaf children with lower reading-comprehension levels performed the semantic tasks less accurately than those deaf children with higher reading-comprehension levels. Somewhat better results were obtained for the different conditions in Experiment 2, and slightly stronger associations between the children's sign categorization and reading comprehension was found in Experiment 2 than in Experiment 1. The reverse held for sign categorization and word recognition speed, namely: a slightly stronger association was found in Experiment 1 than in Experiment 2. In general, we can conclude that the deaf children's knowledge of exemplar relations and superordinate category relations robustly relates to reading level and speed.

Factors that affect the Development of Semantic Knowledge

Nation and Snowling (1998) suggested that the reading experience of poor readers may result in limited semantic knowledge. More recently, however, it has been suggested that reading difficulties can stem from semantic deficits but, at the same time, semantic deficits can stem from reading difficulties (see Vellutino et al., 2004). Impoverished reading experiences can restrict an otherwise rich semantic environment and thereby lead to reduced semantic knowledge and elaboration. Note, however, Vellutino et al. suggested that for all bilingual (including deaf children) and special populations, the main cause of reading difficulties may be the result of semantic deficits rather than a cause.

Nevertheless, the reading experience for poor semantic knowledge may still hold for deaf children. Interactions in the home, at school, and in other settings can generally contribute to children's semantic knowledge but may be very different for deaf children as opposed to hearing children. That is, most deaf children grow up in hearing families in which their linguistic interactions are often limited. When parents learn to sign fluently, however, the deaf children are generally raised bilingually and their linguistic interactions may be more proficient than for children who are raised in a monolingual, non-signing environment. Deaf children who grow up in deaf families are usually part of an entire deaf culture and may thus experience very few limitations on and very different experiences with their linguistic interactions. In general, however, the reading experience in both populations of deaf children is relatively limited.

Semantic categorization can be affected by both cultural and bilingual influences (Peña, Bedore, & Zlatic-Giunta, 2002; Unsworth, Sears, & Pexman, 2005). The bilingual influences involve the fact that children in a bilingual language environment often learn two words for the same referent. The deaf children in the present study generally functioned as bilinguals and thus supposedly had access to both the sign and written Dutch word for a single referent. However, most bilingual deaf children only become bilingual after entrance into a bilingual deaf education setting around the age of three. The parents of most deaf children also still have to learn Sign Language after the discovery that their child is deaf, and this can take a considerable amount of time and have considerable consequences for the deaf child's development (Mayberry, 2002). The deaf child's semantic-categorical knowledge may certainly not emerge as it naturally does in hearing children. And, in fact, the accuracy of the deaf children's performance in the sign conditions in the present study was not equivalent to the accuracy of their performance in the picture conditions. In other words, even the oldest bilingual deaf children in the present study did not have their semantic knowledge organized in such a manner that they could accurately process the information conveyed by words or—for that matter—signs. And in this light, investigation of the development of semantic skills in deaf children growing up with signing parents who may or may not be deaf themselves is an important topic for future research.

In other research, Courtin (1997) found native-deaf signers not to perform worse than hearing controls on a semantic categorization task. Unfortunately, we do not know if the deaf signers were fluent readers or not. Whether or not Courtin's findings reflect patterns that hold for older deaf children or adolescents with presumably improved signing skills is also a question that needs to be answered. It is also possible that the deaf children's signing skills provide them with enhanced knowledge of categorical relations, which can subsequently transfer to their reading and writing skills. Nation and Snowling (1998) have suggested that impaired categorical knowledge may be mediated by poor phonological knowledge. If phonological knowledge is thus required or at least preferable to improve semantic-categorical knowledge, then deaf children may be at a disadvantage. That is, deaf elementary school children in the Netherlands have been found to have—not surprisingly—limited phonological knowledge for word recognition purposes (Ormel, et al., submitted). And deaf children must perhaps acquire semantic categorization information via other means.

One possible limitation on the present study is that the causal relations between children's semantic knowledge and their reading proficiency are still unclear. We have provided clear evidence of significant associations between semantics and reading under different conditions and for different grade levels, but future research must address the issue of causality. As yet, thus, it remains to be seen whether: a) the development of reading skills promotes the semantic development of deaf children, b) the development of semantic knowledge contributes to the development of reading in deaf children, or c) semantic knowledge and reading possibly interact throughout the deaf child’s development.

Word Recognition versus Naming

In the present study, clear associations between the semantic categorization skills of deaf children and their reading comprehension were found, which is in line with the results of previous work with reading-disabled but hearing children. Clear associations between the semantic categorization skills of the deaf children in the present study and word recognition speed were also found, which is line with the results of recent research with hearing children (see Gijsel et al., submitted) and work with hearing adults by—for instance—Howell and Manis (1986). In previous studies, different measures of reading have been used while, as Nation and Snowling (1998) have pointed out, some critical differences exist between different word reading tasks, e.g., word recognition and word decoding. Word decoding typically involves the naming of pseudowords. Word recognition typically involves the naming of real words. And in addition to the naming of pseudowords and real words, word reading may also involve the silent recognition of words or letter strings (i.e., pseudowords) in a so-called lexical decision (i.e., comparison) task. As opposed to the traditional word reading tasks (i.e., word decoding and word recognition tasks), the children in the present study had to also process semantic information as they had to access the meaning of the target word to complete the task. And this may explain the finding of significant associations of semantic categorization with both word recognition speed and reading comprehension in the present study. For purposes of comparison to past studies, thus, differences in the measures of word reading must be taken into account. That is, the naming of words must never be taken to necessarily imply the understanding of words.

To conclude, the present study showed semantics to play a highly important role in the reading of deaf children as well as limited semantic improvement across grade levels. If the significant role of semantics in the children’s reading is taken to imply that better reading can follow from improved semantic knowledge, then attempts should be made to make semantic information more explicit to young deaf children. One starting point could be to help deaf children develop both large written and large sign vocabularies. The next step, then, is to link either written or signed words together in such a manner that the underlying semantic relations are made more transparent. Such elaborated semantic networks can subsequently help the child learn to read more adequately and fluently, which can then—in turn—further promote the child's semantic knowledge. Deaf people may develop semantic networks that are different from conventional semantic networks, and this domain of inquiry therefore urgently requires further investigation. The importance of semantic knowledge, however, should not be underestimated.

References

Atchison, J. (1994). *Words in the mind. An introduction to the mental lexicon.* Oxford: Basil Blackwell Ltd.

Assink, E. M. H., van Bergen, F., van Teeseling, H., & Knuijt, P. P. N. A. (2004). Semantic priming effects in normal versus poor readers. *The Journal of Genetic Psychology, 165,* 67-79.

Baayen, R., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX Lexical Database. Technical report*, Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Ben-Dror, I., Bentin, S., & Frost, R. (1995). Semantic, phonologic, and morphologic skills in reading disabled and normal children: Evidence from perception and production of spoken Hebrew. *Reading Research Quarterly, 30,* 876-893.

Berent, I. & Perfetti, C. A. (1995). A rose is a REEZ: The two cycles model of phonology assembly in reading English. *Psychological Review, 102(1),* 146-184.

Blewitt, P., & Toppino, T. C. (1991). The Development of Taxonomic Structure in Lexical Memory. *Journal of Experimental Child Psychology, 51,* 296-319.

Boersma, P., & Weenink, D. (2004). *Praat: doing phonetics by computer*. University of Amsterdam: Institute of Phonetic Sciences.

Borghi, A. M., & Caramelli, N., 2003. Situation bounded conceptual organization in children: from action to spatial relations. *Cognitive Development*, *18*, 49-60.

Bosman, A., & de Groot. A., (1996). Phonologic mediation is fundamental to reading: Evidence from beginning readers. *The Quarterly Journal of Experimental Psychology, 49A(3),* 715-744.

Bosman, A. M. T., & van Hell, J. G. (2002). Orthography, phonology, and semantics. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.). *Studies in Written Language and Literacy, Precursors of Functional Literacy, 11,* 165-187.

Chamberlain, C., & Mayberry, R. I. (in press). ASL syntactic and narrative comprehension in good and poor deaf readers: Bilingual-Bimodal evidence for the linguistic basis of reading.

Courtin, C. (1997). Does sign language provide deaf children with an abstraction advantage? Evidence from a categorization task. *Journal of Deaf Studies and Deaf Education, 2,* 161 – 171.

Dijkstra, T., & van Heuven, W. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5,* 175-197.

Fortgens, C. (2003). *Taalkeuze van dove kinderen.* [Language choice of deaf children]. Gouda: Koninklijke Auris groep.

Gijsel, M., Ormel, E., Verhoeven, L., Hermans, D., & Bosman, A. (submitted). Semantic-categorization skills in relation to word decoding in primary grades.

Hagtvet, B. E. (2003). Listening comprehension and reading comprehension in poor decoders: Evidence for the importance of syntactic and semantic skills as well as phonological skills. *Reading and Writing: An Interdisciplinary Journal, 16,* 505-539.

Hanson, V. L. & Fowler, C. A. (1987). Phonological coding in word reading: Evidence from hearing and deaf readers. *Memory & Cognition, 15(3),* 199-207.

Hermans, D. Knoors, H., Ormel, E., & Verhoeven, L. (2008). A model of reading vocabulary acquisition for deaf children in bilingual education programs. *Journal of Deaf Studies and Deaf Education, 13,* 155-174.

Hino, Y., Pexman, P. M., & Lupker, S. J. (2002). Ambiguity and synonymy effects in lexical decision, naming, and semantic categorization tasks: Interactions between orthography, phonology, and semantics. *Journal of Experimental Psychology: Learning, memory, and Cognition, 28(4),* 686-713.

Hoffmeister, R. (2000). A piece of the puzzle: ASL and reading comprehension in deaf children. In C. Chamberlain, J. Morford & R. Mayberry (Eds.*), Language acquisition by eye* (pp. 143-163). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hoover, W. A., & Gough, P. B. (1990). The Simple View of Reading. *Reading and Writing: An Interdisciplinary Journal, 2*, 127-160.

Howell, M. J., & Manis, F. R. (1986). Developmental and reader ability differences in semantic processing efficiency. *Journal of Educational Psychology, 78(2),* 124-129.

Jerger, S. & Damian, M. F. (2005). What's in a name? Typicality and relatedness effects in children. *Journal of Experimental Child Psychology, 92,* 46-75.

Klatter-Folmer, J., van Hout, R., Kolen, E., & Verhoeven, L. (2006). Language development in deaf children's interactions with deaf and hearing adults: A longitudinal study. *Journal of Deaf Studies and Deaf Education,* 11(2), 238-251.

Knoors, H. (in press). Educational responses to varying objectives of deaf parents of deaf children: a Dutch perspective. *To appear in: Journal of Deaf Studies and Deaf Education*.

Kyle, F., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education, 11(3),* 273-288.

Leybaert, J., & Charlier, B. (1996). Visual speech in the head: The effect of Cued-Speech on rhyming, remembering, and spelling. *Journal of Deaf Studies and Deaf Education, 1(4)*, 234-248.

Lucariello, J., Kyratzis, A., & Nelson, K. (1992). Taxonomic knowledge : What kind and when? *Child Development, 63,* 978 – 998.

MacSweeney, M., Grossi, G., & Neville, H. (2004). Semantic priming in deaf adults: an ERP study. *Proceedings at the Cognitive Neuroscience Society Annual Meeting*, San Francisco.

Marschark, M., Lang., H. G., & Albertini, J. A. (2002). *Educating deaf students. From research to practice.* New York, Oxford University Press.

Marschark, M., Convertino, C., McEvoy, C., & Masteller, A. (2004). Organization and use of the mental lexicon by deaf and hearing individuals. *American Annals of the Deaf, 149(1),* 51-61.

Mayberry, R. I. (2002). Second language learning of sign languages. In B. Woll (Ed.), Sign Language. Encyclopedia of Language and Linguistics, 2nd Edition. Oxford: Elsevier.

Mayberry, R. I. (2002). Cognitive development in deaf children: the interface of language and perception in neuropsychology. In S. J. Segalowitz & I. Rapin (eds.), *Handbook of Neuropsychology*. Amsterdam: Elsevier. *Vol. 8, Part II:* 71-107.

Mayberry, R. I., Chamberlain, C., Waters, G., & Hwang, P. (2003, November). *Word recognition in children who use signed language.* Paper presented at the Boston University Conference on Language Development, Boston.

Merrills, J. D., Underwood, G., & D. J. Wood (1994). The word recognition skills of profoundly, prelingually deaf children. *British Journal of Developmental Psychology , 12,* 365-384.

Miller, P. (2006). What the processing of real words and pseuodohomophones can tell us about the development of orthographic knowledge in prelingually deafened individuals. *Journal of Deaf Studies and Deaf Education, 11 (1),* 21-38.

Nation, K., Adams, J. W., Bowyer-Crane, C. A., & Snowling, M. J. (2004). Working memory deficits in poor comprehenders reflect underlying language impairments. *Journal of Experimental Child Psychology, 73,* 139-158.

Nation, K., & Snowling, M. J. (1998). Semantic processing and the development of word-recognition skills: Evidence from children with reading comprehension difficulties. *Journal of memory and language, 39,* 85 – 101.

Nguyen, S., & Murphy, G. L. (2003). An apple is more than just fruit: cross-classification in children's concepts. *Child Development, 27,* 1783-1806.

van Orden, G. C. (1987). A ROWE is a ROSE: Spelling, sound, and reading. *Memory and Cognition, 15,* 181-198.

van Orden, G. C., & Goldinger, S. D. (1994). Interdependence of form and function in cognitive systems explains perception of printed words. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1269-1291.

van Orden, G. C., Johnston, J. C. & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, memory, and Cognition, 14(3),* 371-381.

Ormel, E., Hermans, D, Knoors, H., Hendriks, A., & Verhoeven, L. (submitted). Phonological activation in visual word recognition in deaf and hearing children.

Ormel, E., Hermans, D., Knoors, H., & Verhoeven, L. (submitted). Cross-language effects in visual word recognition: the case of bilingual deaf children.

Padden, C. & Ramsey, C. (1998). Reading ability in signing deaf children. *Topics in Language Disorders*, 18(4), 30-46.

Padden, C. & Ramsey, C. (2000). American Sign Language and reading ability in deaf children. In C. Chamberlain, J. Morford & R. Mayberry (Eds.), *Language acquisition by eye* (pp. 165-189). Hillsdale, NJ: Lawrence Erlbaum Associates.

Peña, E. D., Bedore, L. M., & Zlatic-Giunta, R. (2002). Category-generation performance of bilingual children: The influence of condition, category, and language. *Journal of Speech, Language, and Hearing research, 45,* 938-947.

Perfetti, C. A., & Sandak., R. (2000). Reading optimally builds on spoken language: Implications for Deaf readers. *Journal of Deaf Studies and Deaf Education, 5(1),* 32-50.

Planting, J. (2005). Zijn muggen en vliegen insecten?: Een onderzoek naar de categorisatievaardigheden van dove en horende kinderen. [Are mosquito's and flies insects?: An assessment into the categorization skills of deaf and hearing children]. MA Thesis.

Plaut, McClelland, Seidenberg, & Patterson (1996). Understanding normal and impaired word reading: Computational principals in quasi-regular domains. *Psychological Review, 103,* 56-115.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, 96(4), 523- 568.

Silva-Pereyra, J., Rivera-Gaxiola, M., Fernández, T., Díaz-Comas, L., Harmony, T., Fernández-Bouzas, A., Rodríguez, M., Bernal, J., & Marosi, E. (2003). Are poor readers semantically challenged? An event-related brain potential assessment. *International Journal of Psychophysiology, 49, 187-199.*

Schaerlaekens, A., Kohnstamm, G. A., & Lejaegere, M. (1999). *Streeflijst woordenschat voor zesjarigen: Derde herziene versie gebaseerd op nieuw onderzoek in Nederland en België*. [Target list vocabulary for 6-year-old children]. Lisse: Swets & Zeitlinger.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime. Psychology software tools, *Learning Research and Development Centre*, University of Pittsburgh, Pittsburgh.

SPSS for Windows, Rel. 11.0.0. 2002, Chicago: SPSS Inc.

Strong, M., & Prinz, P. M. (2000). Is American Sign Language related to English Literacy? In C. Chamberlain, J. Morford & R. Mayberry (Eds.), *Language acquisition by eye* (pp. 131-141). Hillsdale, NJ: Lawrence Erlbaum Associates.

Transler, C., Gombert, J. E., & Leybaert, J. (2001). Phonological decoding in severely and profoundly deaf children: Similarity judgment between written pseudowords. *Applied Psycholinguistics, 22,* 61-82.

Transler, C., Leybaert, J. & Gombert, J. E. (1999). Do Deaf children use phonological syllables as reading units? *Journal of Deaf Studies and Deaf Education, 4(2),* 124-143.

Treiman, R., & Hirsh-Pasek, K. (1983). Silent reading: Insights from second-generation Deaf readers. *Cognitive Psychology*, 15, 39-65.

Tweney, R. D., Hoemann, H. W., & Andrews, C. E. (1975). Semantic organization in deaf and hearing subjects. *Journal of Psycholinguistic Research, 4(1),* 61-73.

Unsworth, S. J., & Pexman, P. M. (2003). The impact of reader skill on phonological processing in visual word recognition. *The quarterly Journal of Experimental Psychology, 56A(1),* 63-81.

Unsworth, S. J., Sears, C. R., & Pexman, P. M. (2005). Cultural influences on categorization processes. *Journal of Cross-Cultural Differences, 36(6),* 626-688.

Vellutino, F.R., Scanlon, D. M., DeSetto, L., & Pruzek, R. M. (1981). Developmental trends in the salience of meaning versus structural attributes of written words. *Psychological Research, 43,* 131-153.

Vellutino, F. R., Scanlon, D.M., & Tanzman, M. S. (1990). Differential sensitivity to the meaning and structural attributes of printed words in poor and normal readers. *Learning and Individual Differences, 2,* 19-43.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45(1),* 2-40.

Vellutino, F. R., Scanlon, D. M., & Spearing, D. (1995). Semantic and Phonological Coding in Poor and Normal Readers. *Journal of Experimental Child Psychology,* 59, 76-123.

Waterman, B., & Lewandowski, L. (1993). Phonologic and semantic processing in reading-disabled and non-disabled males at two age levels. *Journal of Experimental Child Psychology, 55,* 87-103.

Waters, G. S., & Doehring., D. G. (1990). Reading acquisition in Congenitally Deaf Children Who Communicate Orally: Insights from an Analysis of Component Reading, Language, and Memory Skills. In T. H. Carr, & B. A. Levy (Eds.), *Reading and its development.*, San Diego, Academic Press**:** 323-373.

Wauters, L. N., van Bon, W. & Tellings, A. (2006). Reading comprehension of Dutch deaf children. *Reading and Writing, 19,* 49-76.

Predictors of Word and Text Reading Fluency in Deaf Children Learning to Read

Chapter 5

Abstract

In order to identify the relative predictive value of a number of abilities for the word reading and text reading fluency of deaf children, the present study was carried out across a period of three years. The following were assessed as potentially predictive abilities: sign vocabulary, speech vocabulary, finger spelling, sign phonological awareness, speech rhyme, short term memory, and word reading fluency. The word reading and text reading fluency of hearing children, who served as a control group, were also assessed. The hearing children generally outperformed the deaf children. The hearing children also showed significantly greater increases in text reading fluency across the years than the deaf children. Both word reading fluency and text reading fluency were predicted by age, speech vocabulary, and sign vocabulary for the deaf children after one year and also after two years. Of the two vocabulary measures, the predictive value of speech vocabulary proved strongest. Finger spelling was also found to be an exceptionally strong predictor of the deaf children's word and text reading fluency after both one or two years, and a special predictive role was detected for short term memory in interaction with rhyming skill.

5.1 *Introduction*

Fluency or the ability to read isolated words and connected text accurately and quickly is one of the critical components of reading (NRP, 2000). In most deaf children, this ability can be considered at risk (Kelly, 2003). Deaf children growing up bilingually are in the unique position of being exposed to both written and/or spoken language in addition to sign language. For the majority of deaf children, however, reading levels still remain fairly low (Karchmer & Mitchell, 2003; Kyle and Harris, 2006; Musselman, 2000; Wauters, van Bon, & Tellings, 2006). Deaf children generally experience difficulties with fluent word recognition and reading comprehension (Kelly, 2003; Merills, Underwood & Wood, 1994; Wauters, van Bon, & Tellings, 2006). As yet, it is unclear how the initial development of reading takes place in deaf children who obviously have a different linguistic background than their hearing peers when they start to read. To get a clearer picture of the causal factors underlying the reading difficulties encountered by deaf children, it would therefore be beneficial to observe the development of deaf children’s reading skills in greater depth. It is also important to examine how individual variation in the reading fluency of deaf readers can possibly explain their reading success or failure when studying their early reading development.

5.1.1 *The development of reading in deaf children*

Only very few people have studied the development of reading in deaf children. In a longitudinal study, Harris and Beech (1998) followed deaf children learning English for several years. The early reading progress of the deaf children fell far behind the early reading progress of hearing children. In a cross-sectional study of otherwise comparable groups of children with 1 to 10 years of education, Wauters, van Bon, and Tellings (2006) similarly found the reading levels of deaf children to increase much more slowly than the reading levels of hearing children.

In a number of other studies, the development of fluent word recognition has been found to be a problem for deaf children (Gaustad, 2000; Harris & Beech, 1998; McEvoy, Marschark, & Nelson, 1999; Marschark, Lang, & Albertini, 2002). In several studies, it has been made clear that word recognition must occur with not only sufficient accuracy but also fluency for proficient reading; word recognition must become more or less automatic for readers to comprehend what is being read (Kelly, 2003; Marschark, Lang & Albertini, 2002). Memory constraints limit the amount of time available for the extraction of semantic meanings from written passages and thus call for fluent word recognition (Kelly, 2003; Vellutino, Fletcher, Snowling, & Scanlon, 2004). If word recognition occurs less automatically, as is the case for many deaf children (Knoors, 2001), then the meanings of words read earlier in a sentence may be forgotten by the time the words at the end of the sentence are read (Marschark, Lang & Albertini, 2002). It is also possible that children may encounter difficulties using grammatical information as a result of extensive attention being paid to the word recognition process and the determination of word meanings (Fischler, 1985). In addition to the above, deaf children may show problems with reading comprehension due to a restricted vocabulary to start with (Paul, 1996).

5.1.2 *Predictors of reading success in deaf children*

With respect to the reading success of deaf children and the individual variation in the reading fluency of deaf readers, a number of variables appear to be of relevance. One of the most important predictors of reading success is vocabulary (Aarnoutse & van Leeuwe, 1998). Bilingual deaf children learn vocabulary in two languages: the one involves signs and the other involves written words (and sometimes spoken words). In several studies, the reading levels of deaf people have been found to be related to both their signed and written vocabulary knowledge (Hermans, Knoors, Ormel, & Verhoeven, 2008, submitted; Kyle & Harris, 2006). Several other studies have shown the vocabularies of deaf children and particularly their spoken language vocabularies to be limited (Blamey, 2003) Interestingly, several studies found a strong and positive relation between sign language proficiency of deaf individuals in relation to their written language proficiency (Chamberlain & Mayberry, 2000; Hoffmeister, 2000; Mayer & Wells, 1996; Padden & Ramsey, 2000; Parisot, Dubuisson, Lelievre, Vercaingne-Menard & Villeneuve, 2005; Strong & Prinz, 1997, 2000); and the two proficiencies have been found to correlate quite strongly at particularly the lexical level (Hermans et al., accepted for publication).

Another crucial predictor of reading success in deaf individual may be phonological awareness. In a number of studies, in fact, it has been argued that phonological awareness relates in a similar manner to the reading skills of deaf children as to the reading skills of hearing children (e.g., Dyer, MacSweeney, Sczerbinski, Green, & Campbell, 2003; Harris & Beech, 1998; Luetke-Stahlman & Nielsen, 2003). In a number of other studies, however, it has been concluded that phonological awareness is of no importance for the reading of deaf children (e.g., Izzo, 2002; Miller, 1997). However, whereas for hearing children, phonology is the key for gaining fluent word recognition, for deaf bilingual children, sign phonology may come into play in addition to a potential role for phonology.

The proficiency of deaf children’s finger spelling may also be of particular relevance for the prediction of their reading skills. Unfortunately, only a very few studies have examined the relations between finger spelling and reading (Harris & Beech, 1998; Treiman & Hirsch-Pasek, 1983) although teachers in bilingual education programs often explicitly link written words, finger spelling and signs when teaching deaf children new reading vocabulary. This technique has been referred to as chaining by Padden and Ramsey (2000). Given that not only Padden and Ramsey but also Evans (2004) and Humphries and MacDougall (2000) found teachers to explicitly link written words, finger spelling, and signs together during reading instruction, it seems very likely that finger spelling plays a major role in deaf children’s early reading development.

Short term memory span clearly relates to reading fluency in hearing children and is often limited in deaf children. More specifically, speech coding facilitates short term memory in hearing individuals (Perfetti & Sandak, 2000) and a compromised ability to use phonological codes due to hearing impairment is therefore likely to affect short term memory in deaf individuals (Marschark et al., 2002) Several studies have shown deaf people to perform at least as well as hearing people on tasks that require the spatial processing of information (Wilson & Emmorey, 1997) but not as well as hearing people on tasks that require the sequential processing of information (Bebko, 1998; Marschark et al., 2002; Waters & Doehring, 1990; Wilson & Emmorey, 1997). Hearing individuals generally remember sequential information via speech coding (Bebko, 1998; Marschark et al., 2002; Miller, 2002). In several studies, it has been suggested that deaf people may have different memory architectures than hearing people (Wilson & Emmorey, 1997; 2003; Wilson, Bettger, Niculae, & Klima, 1997; MacSweeney, Campbell, & Donlan, 1996). The role of short term memory in deaf people’s reading thus remains unclear just as the relations between short term memory and phonological codes or other codes remain unclear for deaf people.

The limited research on the individual variation in the reading skills of deaf children to date shows many different skills to be predictive in addition to the skills already mentioned for hearing children. The *relative importance* of the various predictors remains unclear, however, while the relative importance of different predictors of reading and the interrelations between the different predictors have been intensively studied for hearing children. Phonological awareness, vocabulary, and fluent word recognition have been frequently shown to be strong predictors of reading skill in hearing children. In deaf children, the relative contributions of these skills have only been investigated on a few occasions (Harris & Beech, 1998; Kyle & Harris, 2006). Word reading accuracy, moreover, has been studied much more often than word reading *fluency* despite the fact that fluent word processing is essential for the development of good reading skills (Kelly, 2003; Marschark, Lang, & Albertini, 2002). It is thus of importance that the *relative* values of different factors for the prediction of the reading *fluency* of deaf children be examined in an attempt to answer the question of why so many deaf children make insufficient reading progress.

5.1.3 *Present study*

In the present study, the reading fluency of 62 deaf children was studied in elementary schools which provide bilingual deaf education. To start with, the extent to which the levels of reading fluency for the deaf children differed from the levels of reading fluency for hearing peers in the age range of 8 to 12 years was examined. For this purpose, the reading fluency at the word and text levels was compared for two cohorts of hearing and deaf children aged 8 and 10 years one occasion and then a year later on a second occasion.

The reading fluency results for the deaf children were next related to the following predictor measures: sign vocabulary, speech vocabulary, sign phonological awareness, speech rhyme, finger spelling, and short-term memory. A multi-variable design was adopted to identify which variables appeared to have the greatest predictive value for the deaf children's reading fluency at the word and text levels. Given the limited number of children in the study, the deaf children from both cohorts were included in all of the analyses with age then partialled out. The predictive values of speech vocabulary and sign vocabulary for the deaf children's word and text reading fluency after one and then two years were first assessed, following a hierarchical multiple regression procedure. In the next block, the predictive values of speech rhyme skill, sign phonological awareness, finger spelling skill, and short term memory skill were analyzed stepwise. For the prediction of text reading fluency, the added predictive value of earlier word reading fluency was also examined.

5.2 *Method*

Participants

A total of 62 deaf children, including 18 children with a cochlear implant, in bilingual deaf education in the Netherlands, and a total of 55 hearing children in regular elementary education in the Netherlands participated in the present study. The schools for the deaf provide bilingual deaf education with a curriculum including a combination of the Sign Language of the Netherlands (SLN) and Sign Supported Dutch (SSD). All of the children received sign language instruction typically by a deaf teacher specialized in SLN for approximately four hours in the week from the age of four. The teachers of the deaf all used SLN or SSD as the language of instruction in the classroom. In the Netherlands, many deaf children enroll in a sign-oriented preschool program from the age of 2 or 3 years. Most of the deaf children participating in the present experiment had indeed attended such a preschool. All deaf children had a hearing loss more than 80 dB on the best ear, and had normal non-verbal intelligence. Thirty of the deaf children were initially (at Time 1) eight years of age (mean age: 95 months, *SD*: 0.49 months) and thirty-two of the deaf children were initially 10 years of age (mean age: 119 months, *SD*: 0.47 months). At Time 2, when the hearing children were included in the study, the deaf children’s mean age was 107 and 131 months respectively. The hearing children who had a typical development were of similar ages, and participated either in grade 3 or in grade 5 (at Time 2) in a regular elementary school. None of these children had repeated a school year. The two grades were included in order to test whether hearing children versus bilingual deaf children show similar patterns of word and text reading acquisition. The children with a cochlear implant all received the implant relatively late in their lives, after the age of two. Comparison of the results on each of the study measures for the deaf children either with or without a cochlear implant revealed no significant differences in their scores. All of the deaf children were therefore treated as a single group in the remainder of the analyses.

Procedure

The children were tested on three occasions (see Table 1): Time 1 (year 1), Time 2 (year 2), and Time 3 (year 3). The six predictive measures of Sign Vocabulary, Speech Vocabulary, Sign Phonological Awareness, Speech Rhyme, Finger Spelling, and Short Term Memory were assessed for only the deaf children at Time 1. The two measures of reading fluency, namely Text Reading Fluency and Word Reading Fluency, were assessed for the both the deaf and hearing children at Times 2 and 3.

Table 1

	Time 1	*Time 2 (one year later)*	*Time 3 (two years later)*
hearing		word and text fluency	word and text fluency
deaf	predictor variables	word and text fluency	word and text fluency

The assessments occurred individually in a separate room in the children’s school. A computer was used to test for word reading fluency, speech rhyme, and sign vocabulary. A video and TV monitor were used to test for finger spelling. The first author administered all but the sign vocabulary test to the children. The second author administered the sign vocabulary test to the children. At Time 1, the children were tested on three different occasions. Each assessment lasted around 15-20 minutes.

Tests materials

Word reading fluency. In a self-constructed visual word recognition test, the children read 72 one-syllable letter strings on a computer screen, one at a time; 36 six-letter strings were words and 36 were pseudo words. The children had to decide whether the presented word was a real word or a pseudo word. The log frequency of the words in the test ranged from 1.11 to 3.53 (mean log frequency of 2.05) according to the Celex database (Baayen, Piepenbrock, & van Rijn, 1993). In order to be sure that the written words would be familiar, only words that have been shown to have a 90% speech familiarity for 6-year-old hearing children were selected for use (Schaerlakens, Kohnstam, & Lejaegre, 1999). The frequencies of the words were also checked and controlled for using the database for written words in children's literature from Staphorsius, Krom, and de Geus (1988). Words with a frequency of at least 10 (out of 202.526 words in the corpus) were adopted for use. All of the words and pseudowords were between 3 and 6 letters (with an average of 4.0 for the words and 4.3 for the pseudowords). The number of neighboring words was 16.03 for the words and 15.64 for the pseudowords, according to the Celex database and based upon one letter difference to the source word (Baayen, Piepenbrock, & Rijn, 1993).

In addition to the speed and accuracy of the children's word recognition, a *word reading fluency score* was computed in terms of their word recognition speed and accuracy: The children's word reading fluency score was a combination of their reading speed and reading accuracy: response speed / (percentage correct score * 60).

Text reading fluency. To evaluate the children's text reading fluency, a test that is administered on a nationwide basis to hearing children about halfway through second grade was used (Krom, 2001) The children were presented a short story of around 1000 words. At different places in the text, but after about every 10 words, three orthographically minimally distinctive words were presented in the story, with a line beneath them. Only one the three words is correct and fits into the context. The children are then asked to select that word which fits into the context of the sentence by drawing a circle around it. A total of 100 target words were tested. The children were instructed, after a series of 10 practice trials, to continue for eight minutes. After this time, they were instructed to stop. The test score is the number of items answered correctly within the 8 minutes relative to the total number of items responded to and corrected for guessing: Score = number performed correctly * (number performed correctly – total number of items completed/3) / (total number of items completed – total number of items completed/3).

Speech vocabulary. Speech vocabulary was measured using the standardized Passive Vocabulary Test, which is part of the *Taaltest Alle Kinderen* [*Language Test for All Children*] (Verhoeven & Vermeer, 2001). While sitting across from the child, the test administrator clearly pronounced a word whilst facing the child. Four pictures were next presented to the child who was then instructed to choose the matching picture out of the four pictures. The test contains 96 items and was administered to the deaf children only.

Sign vocabulary. The sign vocabulary test is part of a sign language assessment battery that has been constructed for elementary school-aged children by Hermans, Knoors, and Verhoeven (2007). The sign vocabulary test is a sign language translation of part of the *Taaltest Alle Kinderen* [*Language Test for All Children*] (Verhoeven & Vermeer, 2001). The child was presented a video of a sign language sign on a computer screen. Four pictures were then presented on the screen, and the child was instructed to choose the matching picture from the four pictures. The test contained 60 items and was administered to the deaf children only.

Speech rhyme. In a self-constructed rhyme test, the deaf children were presented a picture of an object at the top of the computer screen and three pictures from left to right in the middle of the computer screen. The pictures were taken from the Dutch *Leesladder* ["Reading Ladder"], which is a computer program for children with reading disabilities (Irausquin & Mommers, 2001). The words associated with the pictures were all one-syllable short CV(C) words of 3 to 6 letters. The children were instructed to choose that picture from the row of pictures for which the corresponding Dutch *word* had the same final rhyme as the Dutch word pictured at the top of the screen; the children were explicitly instructed to pay particularly careful attention to the *pronunciation* of the words (i.e. sound or lip pattern if the word were to be pronounced). Both the target picture and the three response pictures were accompanied by a video of a sign equivalent on the computer screen.

The test contained 5 practice trials and 40 items. In the practice trials, the children were given feedback in the left corner of the screen on the correctness of the selected response. The target picture and the selected picture both moved to the left corner of the screen and the associated words later appeared below them. The initial part of the target word appeared first and then the final rhyme part in either green, when the child's response was correct, or red, when the child's response was incorrect. In such a manner, the final rhyme part of the target word was emphasized. The initial part of the second word (i.e., child's response) next appeared under the second picture and then the final rhyme part of the second word in either green, when the child's response was correct, or red, when the child's response was incorrect.

After five practice trials, no more rhyme feedback was given. The child continued to work at his or her own speed until the test was finished. For most of the items, at least one of the two distracters contained the same vowel (V) in the middle of the target word or contained the same initial consonant or final consonant (C). The average log frequency for the words corresponding to the pictures was 1.63 according to the Celex database (Baayen, Diepenbrock, & Rijn, 1993). The mean length of the one-syllable words was 3.88 letters. The number of neighbor words was 17.88 and based upon a one letter difference to the source word (Baayen, Diepenbrock, & Rijn, 1993). The Cronbach 's Alpha coefficient for the 40 item scores was also calculated to estimate the internal consistency of the rhyme test and found to be .91. The test was only administered to the deaf children.

Sign phonological awareness. The sign phonological awareness test is part of the sign language assessment battery that has been developed for elementary school-aged children by Hermans et al. (2008). In the sign phonological awareness test, two sign language signs are presented simultaneously on a computer screen. The signs are either identical or not but overlap with respect to sign phonology when not identical. The distinction between the dissimilar signs can thus be due to different hand shape, location, orientation, movement, or lip pattern. The child is instructed to indicate whether the two presented signs are the same or not. The test contained 36 pairs of items—half identical and half not identical—and was administered to the deaf children only.

Finger spelling. In a self-constructed finger spelling test, a string of letters was finger spelled in a video that was presented on a 22-inch monitor. For each test item, four strings of written letters were then presented on a separate piece of paper and the child was asked to indicate which of the four letter strings was identical to the finger-spelled string of letters. Three of the four letter strings were thus distracter strings and one was identical to the letter-signed string of letters. The test contained 26 items, which started with easy items involving two letters and ended with more difficult items involving eight letters. The items had an average of 4.12 letters (SD is 1.49).

The distracter strings of letters could differ from the target string of (signed) letters in terms of: letter order, substitution, omission, or no overlapping letters. Substitution involved either a vowel or a consonant, and each of the 26 target items had one or two substitution distracters; for 7 of the target items, one of the distracters involved a changed letter order; for 14 of the target items, an omission distracter was included; and for 18 of the target items, no overlapping letters occurred in one of the distracters. The mean item frequency for the words was 2.03 log frequency (SD is 1.26) based on Celex (Baayen, Piepenbrock, & Rijn, 1993). On the basis of Schaerlakens, Kohnstam, and Lejaegre (1999), the frequency was 90.8% (SD of 16.04), which meant that the words were familiar to 90.8% of 6-year old hearing children. The Cronbach ’s Alpha coefficient was calculated to estimate the internal consistency of the items on the finger spelling test and found to be .90. The test was administered to only the deaf children.

Short term memory. The short tem memory test consisted of 7 simple line drawings that included the colors red and green. The pictures represented an apple, a fish, a tree, a flower, a butterfly, a chair, and a bird. The children were shown a series of pictures on a card for the duration of 5 seconds. After removal of the card, they were then asked to arrange plastic items that were identical to the items in the pictures in the same sequence. The test started with three sequences of 2 pictures; after three correct trials, one more picture was added to the sequence. This process was repeated until three sequences of seven pictures were presented. All of the children received the same picture orders. The test contained 18 items and was administered to the deaf children only.

Data analyses

In order to evaluate the differences in the development of reading fluency for the deaf versus hearing children, a one-way analysis of variance (ANOVA) was conducted using SPSS. The correlations were also computed with age partialled out among the various predictor variables for the deaf children as well as the predictor variables and the measures of word and text reading fluency for the deaf children. Stepwise hierarchical multiple regression analyses were next conducted using SPSS with the word reading fluency and text reading fluency of the deaf children as the dependant variables to be explained by Sign Vocabulary, Speech Vocabulary, Sign Phonological Awareness, Speech Rhyme, Finger Spelling, and Short Term Memory. In the analyses, we controlled for age, and for the contribution of vocabulary. Age was entered in the first block, followed by the two vocabulary variables in the second block, followed by the remainder of the predictor variables.

Vocabulary has often been found to be a strong predictor of text reading. In our case, we were interested to see which of the two vocabularies was most predictive, and how much the other four variables could predict in addition to vocabulary. The role of vocabulary for word reading fluency is not as evident as it is for text reading fluency. We therefore also examined the contribution of vocabulary to word reading fluency, followed by the additional contribution of short term memory, speech rhyme skill, finger spelling, and sign phonological awareness. Given that the exact role of short term memory has not been specified in detail either, we were interested in the complementary predictive interactions between short term memory and the other predictors. Finally, whether word reading fluency at Time 2 had predictive power in addition to the other predictors for the deaf children's text reading fluency at Time 3 was assessed in the regression analyses as well.

5.3 *Results*

5.3.1 *Comparison of deaf versus hearing children's reading fluency*

As can be seen from Table 2, the *younger* hearing children outperformed the *younger* deaf children on some but not all of the measures of word reading and text reading. The one-way ANOVA results show significant differences for text reading fluency between the younger deaf and younger hearing children on both the testing occasions for reading; one year later (Time 2) and two years later (Time 3). At Time 2: ($F(1,49) = 205.09$, $p < .001$); and at Time 3: ($F(1,49) = 88.41$, $p < .001$) The word recognition accuracy scores show significant differences between the younger deaf and the younger hearing children on both testing occasions for reading (Time 2 ($F(1,49) = 30.164$, $p < .001$; Time 3 ($F(1,49) = 18.411$, $p < .001$), in favor of the hearing children. Significant differences were also found for the word recognition *speed* of the younger deaf children versus the younger hearing children after two years (Time 3) but not after one year (Time 2 ($F(1,49) = 1.116$, $p > .1$; Time 3 ($F(1,49) = p < .05$). The deaf children respond faster than the hearing children. The combined word reading fluency score showed a significant difference between the younger deaf and younger hearing children on the first testing occasion, in favor of the hearing children, but not on the second (Time 2 ($F(1,49) = 8.374$, $p < .01$; Time 3 ($F(1,49) = .606$, $p > .1$).

Table 2

Mean scores on predictor variables assessed at Time 1 for deaf children only and measures of word reading accuracy, word reading speed, word reading fluency (combined score), and text reading fluency assessed at Time 2 and one year later at Time 3 for both deaf and hearing children from two age cohorts (younger, older)

	Deaf		Hearing	
	Younger[1]	Older[2]	Younger[1]	Older[2]
Sign vocabulary Time 1	21.49 (13.2)	35.52 (13.5)		
Speech vocabulary Time 1	21.07 (16.4)	43.78 (24.9)		
Sign phonological awareness Time 1	28.74 (4.9)	31.25 (2.8)		
Speech rhyme Time 1	43.61 (.21)	68.93 (20.3)		
Fingerspelling Time 1	18.48 (5.1)	23.45 (3.4)		
STM Time 1	6.58 (2.3)	7.98 (2.2)		
Word recognition % Time 2	75.4 (11.9)	87.5 (8.0)	92.4 (8.6)**	95.2 (2.3)**
Word recognition % Time 3	82.1 (9.4)	90.8 (7.4)	91.6 (3.9)**	93.7 (3.2)
Word recognition RT Time 2	1695 (753)	1418 (878)	1499 (414)	963 (176)*
Word recognition RT Time 3	1107 (297)	965 (193)	1303 (300)*	917 (230)
Word Reading Fluency Time 2	.50 (.19)	.74 (.29)	.65 (.15)**	1.02 (.16)**
Word Reading Fluency Time 3	.78 (.21)	.98 (.22)	.74 (.19)	1.07 (.23)
Text Reading Fluency Time 2	17.35 (18.2)	37.73 (23.3)	66.24 (17.7)**	79.6 (11.8)**
Text Reading Fluency Time 3	24.68 (17.7)	47.12 (24.29)	90.64 (12.8)**	97.04 (3.0)**

[1] Younger children were approximately 8 years of age at Time 1, 9 years at Time 2 and 10 years at Time 3.

[2] Older children were approximately 10 years of age at Time 1, 11 years at Time 2, and 12 years at Time 3.

** = significant difference between deaf and hearing children per age group at .01 level.

* = significant difference between deaf and hearing children per age group at .05 level.

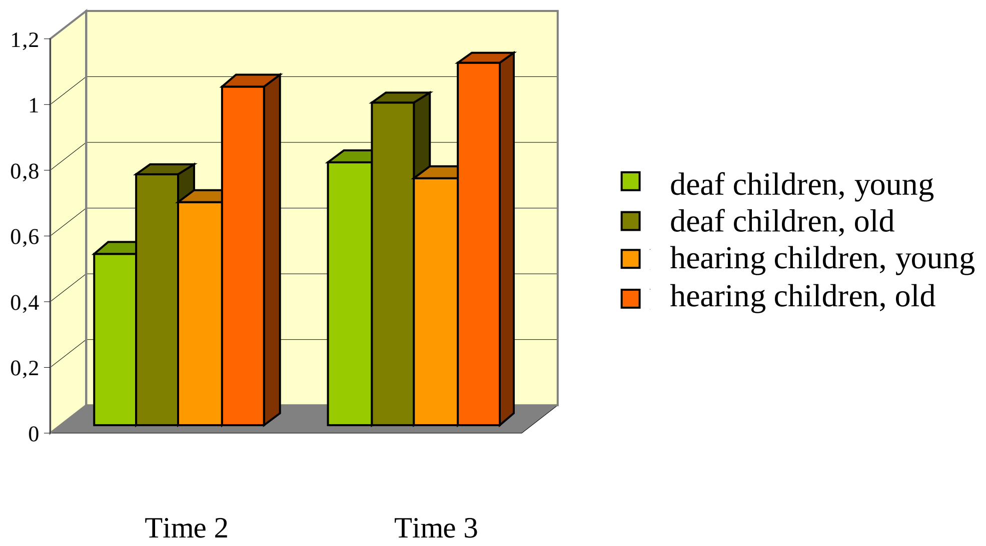
The results for the *older* children also showed significant differences for the deaf versus hearing children in favor of the hearing children on some but not all of the measures of word reading and text reading. The *text* reading fluency scores showed a significant difference between the older deaf and the older hearing children at both measurements (Time 2 (F(1,51) = 83.044, $p < .001$; Time 3 (F(1,51) = 55.40, $p < .001$), in favor of the hearing children. The word recognition *accuracy* scores showed a significant difference between the older deaf and older hearing children on the first testing occasion for reading (Time 2) but not on the second one (Time 2: (F(1,49) = 17.649, $p < .001$; Time 3 (F(1,50) = 2.752, $p > .1$). Significant differences were also found for the word recognition speed of the older deaf children versus the older hearing children after only one year (Time 2), in favor of the hearing children, but not two years (Time 2 (F(1,49) = 5.207 , $p < .05$; Time 3 (F(1,50) = .625, $p > .1$). The scores for word reading fluency similarly showed a significant difference between the deaf and hearing children after only one year (Time 2), in favor of the hearing children, but not two years (Time 2 (F(1,49) = 14.198, $p < .001$; Time 3 (F(1,50) = 1.974, $p > .1$).

5.3.2 *Development of word reading fluency across a period of two years*

Word reading fluency as the dependant variable was assessed on two occasions (Time 2 and Time 3, see Figure 1). Results of a (GLM) repeated measures analysis with the two occasions as a within subject factor and hearing status and age as the between subject factors revealed a significant interaction between hearing status and word reading fluency (F(1,95) = 18.442, $p < .001$). The hearing children showed less of an increase over time than the deaf children, but this was mainly due to the closer to ceiling word reading fluency of the older hearing children. Large increases were observed for three of the four groups of children between measurement Times 2 and 3 (deaf young children, F(1,29) = 42.929, $p < .001$, deaf old children, F(1,29) = 24.692, $p < .001$, hearing young children, F(1,19) = 13.203, $p < .01$, hearing old children, F(1,18) = 3.537, $p < .1$). The three-way interaction between word reading fluency, hearing status, and age was not significant (F(1,95) = .018, $p > .1$).

Figure 1

Word reading fluency scores at Times 2 and 3 for deaf and hearing children of two different ages. The word reading fluency score is response speed / (percentage correct score * 60).



5.3.3 *Development of text reading fluency across a period of two years*

In a General Linear Model (GLM) repeated measures analysis of the children's text reading fluency scores, with the two test occasions as the within subject factor and hearingstatus and age as the between subject factors, a marginally significant three-way interaction was detected for the text reading fluency gain from measurement Time 2 to measurement Time 3 ($F(1,98) = 3.871$, $p < .1$). There was also a significant two-way interaction between text reading fluency and hearing status ($F(1,98) = 29.821$, $p < .001$). When the text reading fluency results for the deaf versus hearing children were compared (see Table 2 and Figure 2), the increases in the scores were found to be larger for the hearing children than for the deaf children (deaf children: $F(1,60) = 34.155$, $p < .001$; hearing children: $F(1,38) = 133.614$, $p < .001$). When the younger deaf, younger hearing, older deaf, and older hearing groups of children were analyzed separately, significant increases from the first time that text reading fluency was measured to the second time were detected for all of the groups (deaf young children: $F(1,29) = 13.744$, $p < .01$, deaf old children: $F(1,31) = 20.774$, $p < .001$), hearing young children: ($F(1,19) = 82.160$, $p < .001$, and hearing old children: $F(1,19) = 51.933$, $p < .001$).

Figure 2

Text reading fluency scores at Times 2 and 3 for deaf and hearing children of two different ages. The score is number performed correctly * (number performed correctly – total number of items completed/3) / (total number of items completed – total number of items completed/3).

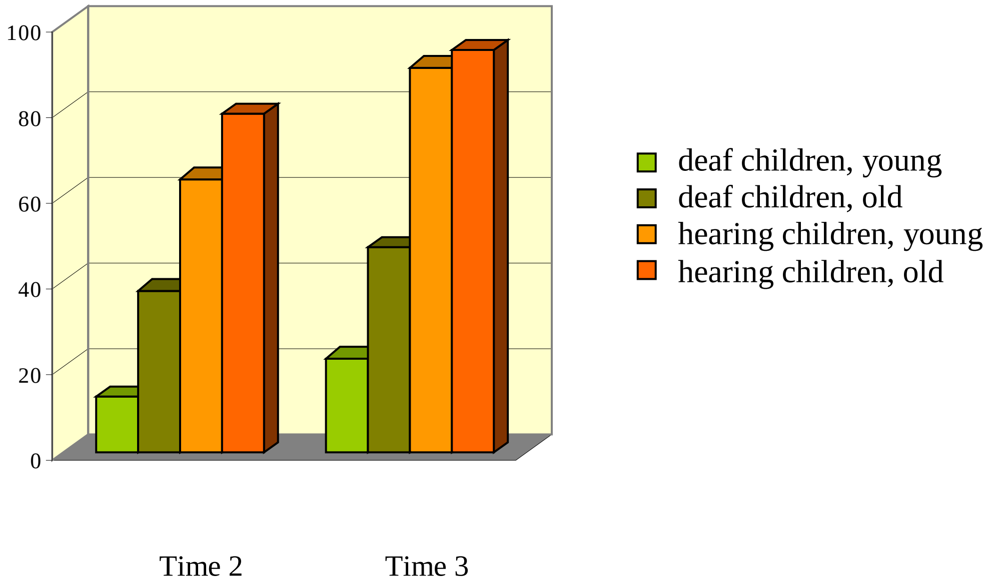


Table 3

Correlations between predictor variables, with age partialled out, for deaf children at Time 1

	1	2	3	4	5	6
1 Sign vocabulary	1.0	.39**	.29*	.28*	.38**	.19
2 Speech vocabulary		1.0	.18	.48*	.21	.20
3 Sign phonological awareness			1.0	.47**	.26*	.16
4 Speech rhyme				1.0	.40**	.33**
5 Finger spelling					1.0	.47**
6 STM						1.0

1. Sign vocabulary: Receptive vocabulary at Time 1
2. Speech vocabulary: Receptive vocabulary (speech reading) at Time 1
3. Sign phonological awareness (detecting sign phonology overlap) at Time 1
4. Speech Rhyme (choosing two pictures with speech rhyme word match) at Time 1
5. Finger spelling (choosing a written word that corresponds with a finger spelled word) at Time 1
6. STM: Short term memory span (memorizing sequence of pictures) at Time 1

5.3.4 *Predicting deaf children's reading performance*

In Table 3, the correlations between the different predictor variables with age partialled out are presented for the deaf children alone[1]. In Table 4, the partial correlations between the predictor variables and the measures of word reading and text reading fluency after one year and two years are presented for the deaf children alone.

Table 4

Correlations, with age partialled out, between predictor variables for deaf children at Time 1 and measures of word and text reading fluency at Time 2 (one year later) and Time 3 (two years later)

	Time 2		Time 3	
	Word[1]	Text	Word[1]	Text
Sign vocabulary	.314*	.360**	.189	.418**
Speech vocabulary	.358**	.583**	.099	.661**
Sign phonological awareness	.150	.189	.339**	.264*
Speech rhyme	.421**	.544**	.329*	.580**
Finger spelling	.396**	.451**	.398**	.465**
STM	.033	.254[MS]	.260*	.185

1. Sign vocabulary: Receptive vocabulary at Time 1
2. Speech vocabulary: Receptive vocabulary (speech reading) at Time 1
3. Sign phonological awareness (detecting sign phonology overlap) at Time 1
4. Speech Rhyme (choosing two pictures with speech rhyme word match) at Time 1
5. Finger spelling (choosing a written word that corresponds with a finger spelled word) at Time 1
6. STM: Short term memory span (memorizing sequence of pictures) at Time 1

[1] Word Reading Fluency = percent correct / (response time x 60)

** = significant difference between predictor variable and reading measure at .01 level.
* = significant difference between predictor variable and reading measure at .05 level.
MS = marginally significant between predictor variable and reading measure at the .1 level.

As can be seen, a number of the intercorrelations between the predictor variables were significant and significant correlations with the measures of word and text reading fluency were found for the predictor variables sign vocabulary, speech vocabulary, sign phonological awareness, speech rhyme, and finger spelling. Short term memory correlated significantly with word reading fluency at Time 3, but only marginally with text reading fluency, and only at Time 2.

Prediction of word reading fluency after one year

The multiple hierarchical regression analyses for word reading fluency after one year (see Table 5) showed that the predictor variables explained 33.9 % the deaf children's scores (Adjusted R Square): 17.6 % predictive value for age, another 8.8 % by speech vocabulary, and an additional 7.5 % for finger spelling explained the main effects.

Table 5

The contribution of the predictive variables toward word reading fluency after one year

	Beta coefficient	P-value	Adjusted R^2
Step 1			
Age	.060	.633	.176
Step 2			
Speech vocabulary	.292	.033	.088
Step 3			
Finger spelling	.419	.003	.075

Prediction of word reading fluency after two years.

In the hierarchical multiple regression analyses for word reading fluency after two years (see Table 6), 38% of the total variance was explained (Adjusted R Square). Age explained 15.3% of the total variance. No predictive value was found for the receptive speech or sign vocabulary measures. Finger spelling explained an additional 12% of the total variance and sign phonological awareness explained a further 4%. When the predictive value of the deaf children's word reading fluency at Time 2 was examined, this was found to have an additional predictive value of 6.4%. In the total model, age did not contribute significantly, and finger spelling contributed marginally.

Table 6

The contribution of the predictive variables toward word reading fluency after two years

	Beta coefficient	P-value	Adjusted R^2
Step 1			
Age	.086	.491	.153
Step 2			
Finger spelling	.224	.097	.120
Sign phonological awareness	.229	.045	.040
Step 3			
Word reading fluency	.322	.012	.064

Prediction of text reading fluency after one year.

In the regression analyses for the deaf children's text reading fluency after one year (see Table 7), age explained 18.2% of the total variance (Adjusted R Square). When sign vocabulary and speech vocabulary, which were both receptive measures, were added simultaneously to the analyses, an additional 26.9% of the total variance in the children's text reading fluency after one year was explained. When only sign vocabulary was entered in addition to age, only an additional 11% of the total variance was explained. When only speech vocabulary was entered in addition to age, the additional percentage was 27%, which shows speech vocabulary to be the strongest predictor of text reading fluency after one year. That is, the additional predictive power of sign vocabulary virtually disappears when the deaf children's receptive speech vocabulary is also entered into the regression equation in addition to age. When finger spelling, speech rhyme, sign phonological awareness, and short term memory were added stepwise to the regression equation, finger spelling explained an additional 8.7% of the total variance in the deaf children's text reading fluency after one year and speech rhyme explained an additional 2.5%. Again, age did also not contribute significantly.

Table 7

The contribution of the predictive variables toward text reading fluency after one year

	Beta coefficient	P-value	Adjusted R^2
Step 1			
Age	-.033	.756	.182
Step 2			
Speech Vocabulary	.423	.000	.269
Step 3			
Finger spelling	.280	.011	.087
Speech rhyme	.251	.042	.025

Prediction of text reading fluency after two years.

In the regression analyses for text reading fluency after two years (see Table 8), age explained 22.5% of the total variance (Adjusted R Square). When receptive sign vocabulary and receptive speech vocabulary were next added stepwise, an additional 33% of the total variance in the children's text reading fluency after two years was explained. When only sign vocabulary was entered after age, only an additional 16% of the total variance could be explained. When only speech vocabulary was entered after age, however, this percentage increased to 32.9%, which shows both of the vocabulary measures to have predictive power for the deaf children's text reading fluency after two years but receptive speech vocabulary to be a relatively stronger predictor. When finger spelling, speech rhyme, sign phonological awareness, and STM were next added stepwise as predictors, finger spelling was found to be the strongest additional predictor (8.2%), followed by speech rhyme (2.4%). In contrast to the significant contribution of finger spelling, speech rhyme did not contribute significantly.

The deaf children's word reading fluency at Time 2 (i.e., after one year) was also found to have predictive power for their text reading fluency at Time 3 (i.e., after two years). When word reading fluency at Time 2 was entered into the regression analyses after the other predictor variables, it was still found to explain an additional 3.6% of the variance in the deaf children's text reading fluency at Time 3. In other words, 69.7 % of the variance in the text reading fluency of the deaf children after two years was explained by the predictor variables studied here. In line with the prediction of the previous three reading measures, age did not contribute significantly.

Table 8

The contribution of the predictive variables toward text reading fluency after two years

	Beta coefficient	p-value	Adjusted R^2
Step 1			
Age	-.064	.457	.225
Step 2			
Speech vocabulary	.493	.000	.329
Step 3			
Finger spelling	.249	.017	.082
Speech rhyme	.146	.152	.024
Step 4			
Word reading fluency	.268	.006	.036

5.4 General Discussion

In this longitudinal study, the text reading fluency and word reading fluency of both deaf and hearing elementary school-aged children were examined on two occasions. The predictive values of several variables assessed when the children were either 8 or 10 years of age for their later word reading fluency and text reading fluency were also examined. In many studies, the difficulties that deaf children encounter when learning to read are described (e.g., Golden-Meadow & Mayberry, 2001; Harris & Beech, 1998; Marschark et al., 2002; Miller, 2006; Wauters, van Bon, & Tellings, 2006). It is claimed that the reading fluency of deaf children is hampered in particular (e.g., Kelly, 2003). However, only one or two variables are typically examined in connection with the word and text reading of deaf children. That is, very few studies have addressed the predictive value of *various* skills for the development of deaf children's reading skills (see Harris & Beech, 1998, and Kyle & Harris, 2006, for exceptions). The *fluency* of deaf children's reading has also not been studied sufficiently to date. In the present study, a combination of skills was thus used to predict both deaf children's word reading and text reading fluency.

For reading comprehension in general, individual word reading and vocabulary are known to be strong predictors although a number of other skills also predict reading comprehension (e.g. phonological awareness and short term memory). Within the context of the present study, we thus studied the contributions of a number of variables in addition to vocabulary to the prediction of deaf children's word reading fluency (i.e. word recognition) and their text reading fluency. We were also particularly interested in the roles of sign versus spoken vocabulary knowledge.

While both sign and speech vocabulary showed fairly strong and consistent correlations with the deaf children's word and text reading fluency, speech vocabulary assessed in terms of speech reading skill was generally found to be the strongest predictor of the children's word reading fluency and text reading fluency. The relative importance of the different vocabularies fits with the fact that most deaf children in bilingual education settings in the Netherlands are being thought using a so-called chaining technique (Padden & Ramsey, 2000) in which the teacher explicitly links written words, signs, finger spellings, and—sometimes—mouth patterns to improve the deaf children's knowledge of written words (Hermans et al., 2008). This drawing of explicit links between words and signs highlights the difficulty of pinpointing the causal relations between knowledge of speech or sign vocabulary and other skills. In the present study, speech vocabulary turned out to be the strongest predictor. It is, however, likely that speech vocabulary would not be as predictive without presence of a sign vocabulary. We assume that for many bilingual children, lexical knowledge in sign language facilitates the acquisition of written (and spoken) vocabulary (Hermans et al., 2008). Strong correlations between predictor variables are quite common in studies of research questions related to the present ones, and it is thus important to keep in mind that the predictive power of one variable that is significantly correlated with another predictor variable may actually mask the predictive power of the other variable (or vice versa). The complicated interactions that occur between predictor variables are also often ignored in research studies but again highlight the significant interrelations between variables.

Kyle and Harris (2006) examined productive vocabulary, phonological awareness, short term memory, speech reading, spelling, single word reading and sentence comprehension. Speech reading and (productive) vocabulary were found to be the strongest predictors of single word reading as well as sentence comprehension. The (receptive) speech vocabulary task in our study was similar to speech reading test by Kyle and Harris, both requiring speech reading and speech vocabulary knowledge. For that reason, the strongly predictive role for speech vocabulary in our study is in line with the findings by Kyle and Harris.

For the prediction of word reading fluency after one year, age, speech vocabulary, and finger spelling were most predictive. Interestingly, less of the variance in word reading fluency after two years could be explained than after one year. It appears that other variables in addition to those examined in the context of this study may play a role in the development of deaf children's word reading fluency and/or their later word reading fluency. To summarize the results of the present study, speech vocabulary was predictive—in addition to finger spelling—of word reading fluency after one year. One year later, speech vocabulary was predictive, and next to finger spelling, sign phonological awareness was found to be a predictor of word reading fluency.

For the prediction of text reading fluency after one year, finger spelling proved to be the strongest predictor—after age and the vocabulary measures were already entered into the regression equation—and was followed by speech rhyme. The predictive value of these skills for reading two years later shows a similar but slightly different picture than for reading after one year. The present results suggest that for the prediction of later text reading fluency after age and both speech and sign vocabulary have been taken into consideration, again finger spelling and speech rhyme knowledge play a role. However, speech rhyme did not contribute significantly. Word reading fluency also predicts subsequent text reading fluency. In other words, finger spelling, and word reading fluency in addition to age and receptive vocabulary knowledge play important roles in the development of deaf children's text reading fluency.

Marschark, Lang, and Albertini, 2002 pointed out the role of phonology for memory for sequences (see also Durand, Hulme, Larkin, & Snowling, 2005). In other words, speech rhyme and short term memory may potentially play an interactive role towards reading. As already mentioned in the introduction, the relations between short term memory and phonological codes or other codes remain unclear for deaf people. To achieve further insight in the possible role for short term memory, the predictive power of short term memory was additionally examined in interaction with finger spelling, speech rhyme, and sign phonological awareness, as a separate further step in the stepwise regression.

When including interactions with short term memory in the stepwise regression analysis for word reading fluency after one year, short term memory played a predictive role in interaction with speech rhyme. Because of the interaction between rhyme and short term memory, it was required to assess the contributions of short term memory and speech rhyme separately as well (Aitken & West, 1991). Short term memory and rhyme added 5 % of predictive power together, after which the additive contribution of the interaction between short term memory and speech rhyme could be determined: explaining a further 4.2 % (Beta coefficient =.233, p = .029, Adjusted R^2 = .042). The interaction showed that speech rhyme becomes more predictive when short term memory capacity was also large. For word reading fluency after two years, the interactions between short term memory and rhyme, finger spelling, and sign phonological awareness had no predictive value. In the stepwise regression of text reading fluency after one year, similarly no predictive value was found for interaction with short term memory. However, in the regression analysis for text reading fluency after two years, short term memory played a predictive role, again in interaction with speech rhyme. Given the significant interaction between short term memory and speech rhyme for the text reading fluency of the deaf children after two years (i.e. the tendency of those deaf children with a smaller STM capacity to perform lower on the measure of text reading fluency, but even more so when performing poorly on the receptive speech rhyme test), it was required to have short term memory and speech rhyme into the regression model before we could interpret the interaction between rhyme and short term memory. Speech rhyme was already found to be predictive in the initial analysis. Short term memory was entered in the analyses and contributed only an additional 0.8% to the total amount of variance explained, and did not contribute significantly. The significant interaction between short term memory and rhyme contributed an additional 3.3% to text reading fluency after two years, and was found to contribute marginally (Beta coefficient = .137, p = .070, Adjusted R^2 = .033). The interaction revealed that the predictive value of rhyme was even stronger when short term memory capacity was also large.

Four implications of the present findings can be identified. First, the role of finger spelling will be discussed. Second, the role of sign phonological awareness will be discussed. Third, the role of short term memory in interaction with other skills will be discussed. And fourth, the role of vocabulary and word reading fluency in text reading fluency will be discussed.

Finger spelling was most predictive of word and text reading fluency both one and two years later. Padden and Ramsey (2000) have stressed the importance of finger spelling as a linking tool for signs and written words. The role of finger spelling in the reading development of deaf individuals has not been investigated intensively but appears to be a highly important skill for deaf children. Finger spelling may often indeed be the key to understanding written words.

Sign phonological awareness was also found to have strong predictive power for the deaf children's word reading fluency (i.e., written word recognition) after two years in addition to the predictive power of finger spelling. Although the results should be interpreted with a certain amount of caution and this is always the case for novel findings, it is very interesting that sign phonological awareness in addition to finger spelling, has proved strongly predictive of written word reading fluency. In a different study, sign phonology overlap has been found to play a role during the visual word recognition of elementary school children in the Netherlands (Ormel, Hermans, Knoors, & Verhoeven, submitted). This suggests that the sub-lexical role of the sign in relation to reading may be larger than previously acknowledged.

It is possible, for example, that sub-lexical sign (i.e. sign phonology) awareness provides children with linguistic skills that are also helpful for vocabulary building. The role of sign phonological awareness in the development of deaf children's reading should therefore be studied in greater detail in the future.

In hearing studies just as in the present study, short term memory and rhyming skills have been shown to be highly correlated. Children with good short term memory skills tend to be the children with good phonological skills. Conversely, encoding can enhance memory skills (Alloway et al., 2005; Marschark, Lang, & Albertini, 2002). According to some authors, short term memory only plays a role in word or text reading to the extent that phonological skill does (Durand et al., 2005). As Marschark et al. (2002) have pointed out, for instance, there appears to be a relation between phonology-based memory for sequences and other phonological skills (also see Durand et al., 2005). For deaf children, the connections between speech rhyme and short term memory are complicated by the fact that speech rhyme appears to be even more predictive for word and text reading when short term memory is also good. When only speech rhyme knowledge or short term memory are considered, neither appears to be as predictive of word and text reading fluency as does the joint effect of speech rhyme and short term memory skills. Kyle and Harris (2006) found no strong correlations between their reading measures and short term memory or phonological awareness. Possibly, the predictive role for short term memory and phonological awareness becomes only fully visible for deaf children when taken into account simultaneously.

This joint effect of speech rhyme and short term memory skill is not typical of hearing children. For hearing children, phonological awareness and rhyming skill as part of this phonological awareness are found to be highly or even most predictive of reading skill (Durand et al., 2005; Goswami, 1999). Nevertheless, recent studies of hearing children do suggest that phonemic awareness and phonological short term memory are strongly interconnected and may therefore jointly predict reading ability (Durand et al, 2005; Hulme, 2002). In the present study, the finding that speech rhyme skill predicts word and text reading fluency more strongly as short term memory improves provides similar evidence for a significant interconnection

The present data also clearly show the importance of word reading fluency for later text reading fluency. In addition to the other predictive factors, word reading fluency explained an additional great part of the variance in text reading fluency. Our data also point out that the difference between hearing and deaf children is the most pronounced in the area of text reading fluency, much less so in word reading fluency. In addition, the importance of spoken language vocabulary as a crucial factor in text reading fluency is supported by our data. Taken together, does this mean that in the end visual word recognition is less of a problem for deaf children than first thought? And do we need to interpret these data in the direction that language, i.e. spoken language vocabulary, is the crucial factor if one wants to enhance reading proficiency in deaf readers (cf. Vermeulen, 2007)? Not quite so. Of course we do not mean to suggest that word recognition can completely explain the reading difficulties of deaf children. However, as we have shown, word reading fluency— together with vocabulary and a number of other skills including finger spelling—certainly facilitates the text reading fluency of deaf children. The importance of word reading fluency should not be underestimated, thus. In addition to this, it should be noted that we measured visual word recognition through a lexical decision test using high frequent, monosyllabic words. It might well be the case that deaf readers experience considerable difficulties recognizing far less frequent, orthographic more complex polysyllabic words. Or, to put it in other words, we cannot rule out the possibility that the word reading fluency of deaf children appears adequate for a limited number of relatively high frequency words, but less so for less frequent words and polysyllabic words. Finally, additional analyses into the type of errors of word recognition made by deaf and hearing children show that the deaf children reveal a different error pattern compared to the hearing children. The hearing children appeared to make a percentage of false negative errors (judging an existing word as a pseudo word) more equal to or slightly smaller than the percentage of false positive errors (judging a pseudo word as a word). The deaf children on the other hand showed a larger percentage of false negatives when compared to false positives[2]. The deaf children did not appear to judge as many pseudo words as real words when compared to judging words as (non existing) pseudo words. In other words, the results showed that a relatively large number of real words were seemingly not yet recognized as indeed being real words by the deaf children. This pattern was found for both age groups of deaf children. The error patterns indicate that deaf children may process (relatively high, mono syllabic) words differently from hearing children, possibly related to less complete word knowledge for the deaf children. In future research of lexical decision with deaf children, more in depth investigation of false alarm rates (i.e. false positives vs. false negatives) would be advised. A first formal analysis on the response bias for types of errors in the present data (Creelman & Macmillan, n.a.) indicated that poorer outcomes were found for the deaf children when compared to the hearing children, for both age groups at both Time 2 and Time 3.

One aspect of the children's language knowledge that we did not measure was grammar. As Marschark, Lang and Albertini (2002) argue, grammar cannot be used adequately when a number of other skills have not developed sufficiently. And one important skill for grammar is vocabulary (Marschark, Lang, & Albertini, 2002). The process of accessing word meanings with limited or qualitatively less well-defined word knowledge can overload memory and thereby hinder grammatical processing as well, according to Marschark and colleagues. In the present study, the basis for successful grammatical processing, namely vocabulary and also short term memory, was shown to be less than fully developed for deaf children.

On the grounds of past and present studies, it seems feasible to conclude that a combination of skills is required for fluent reading, that some skills are relatively more important than others, and that some skills may not develop without the development of other —possibly but not necessarily underlying—skills. Many bilingual deaf children develop a language system on the basis of both signed and spoken language input. It therefore seems reasonable that a combination of skills should also be taught to deaf children starting with a large and strong vocabulary in terms of both signs and written words followed by exposure to finger spelling but also to speech and sign phonology knowledge and other relevant types of information. Deaf children may *need* a particularly wide variety of skills in order to become fluent readers, and it is important to note in this light that many deaf children are raised and educated in environments *without* accessible language input. Children who have access to language—whether signed or spoken—from birth can become fluent readers (Mayberry, 2000), which means that such language input is essential for deaf children. The language input can come from deaf parents or hearing parents, but most important is that it be provided.

Note 1: Significant associations occurred between several of the predictor variables. Given that the predictor variables were selected as likely to be related to literacy skills, the chances of significant interrelations were large. The strength of the correlations in the present study did not give rise to multi- collinearity. Nevertheless, the predictive values may have been influenced to some extent by the strong intercorrelations and should therefore be interpreted with caution.

Note 2
Error rates for different types of responses

	Deaf children			
	Time 2		Time 3	
	younger	older	younger	older
False positives	43.15	33.33	42.91	43.45
False negatives	56.85	66.67	57.09	56.55
	Hearing children			
	Time 2		Time 3	
	younger	older	younger	older
False positives	54.08	57.00	51.24	44.49
False negatives	45.92	43.00	48.76	55.51

References

Aarnoutse, C., & van Leeuwe, J., (1998). Relation between reading comprehension, vocabulary, reading pleasure, and reading fluency. *Educational Research and Evaluation, 4,(2)*, 143-166.

Aitken, L. S., & West, S. G. (1991). *Multiple Regression: Testing and interpreting Interactions*. Thousand Oaks: Sage Publications.

Baayen, H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX Lexical Database*. Technical report, Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Bebko, J. M., (1998). Learning, language, memory, and reading: The role of language automatization and its impact on complex cognitive activities. *Journal of Deaf Studies and Deaf Education, 3(1),* 4-14.

Blamey, P .J. (2003). Development of spoken language by deaf children. In M. Marschark & P. Spencer (Eds.). *The Oxford handbook of deaf studies, language and education* (pp 232-246). New York: Oxford University Press.

Caravolas, M., Hulme, C., & Snowling, M. J. (2001). The foundation of spelling ability: Evidence from a 3-year longitudinal study. *Journal of Memory and Language, 45(4),* 751-774.

Chamberlain, C., & Mayberry, R. I. (2000). Theorizing about the relation between American Sign Language and reading. In C. Chamberlain, J. P. Morford, & R. I Mayberry (Eds.). *Language acquisition by eye.*

Creelman, C. D., & Macmillan, N. A., DPRIME-PLUS, programs for detection theory measures of sensitivity and bias. Distributed through World Wide Web, as supplement to the book *Detection Theory: A User's Guide*, 1996.

Dickinson, D. K., McGabe, A., Anastapoulos, L., Peisner-Feinberg, E. S., & Poe, M. D. (2003). The comprehensive language approach to early literacy: the interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool-aged children. *Journal of Educational. Psychology, 95,* 465-481.

Dijkstra, T., & van Heuven, W. J. B., (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5(3),* 175-197.

Durand, M., Hulme, C., Larkin, R., & Snowling, M. (2005). The cognitive foundations of reading and arithmetic skills in 7- to 10-year olds. *Journal of Experimental Child Psychology, 91(2),* 113-136.

Dyer, A., MacSweeney, M., Szczerbinski, M., Green, L. & Campbell, R. (2003). Predictors of reading delay in deaf adolescents: The relative contributions of rapid automatised naming speed and phonological awareness and decoding. *Journal of Deaf Studies and Deaf Education, 8(3),* 215-229.

Evans, C. (2004). Literacy development in deaf students: Case studies in bilingual teaching and learning. *American Annals of the Deaf, 149(1),* 17-27.

Fishler, I. (1985). Word recognition, use of context, and reading skill among deaf college students. *Reading Research Quarterly,* 203-215.

Gallagher, A., Frith, U., & Snowling, M. (2000). Precursors of literacy delay among children at genetic risk of dyslexia. *Journal of Child Psychology and Psychiatry, 41(2),* 203-213.

Gathercole, S. (1999). Cognitive approaches to the development of short-term memory. *Trends in Cognitive Science, 3(11),* 410-419.

Gathercole, S. E., & Baddeley, A. D., (1990). The role of phonological memory in vocabulary acquisition: A study of young children learning new names. *British Journal of Psychology, 81,* 439-454.

Gaustad, M. G. (2000). Morphological analysis as a word identification strategy for deaf readers. *Journal of Deaf Studies and Deaf Education, 5(1),* 60-80.

Goswami, U. (1999). Causal connections in beginning reading: the importance of rhyme. *Journal of Research in Reading, 2 (3),* 217-240.

Harris, M., & Beech, J. R. (1998). Implicit phonological awareness and early reading development in prelingually deaf children. *Journal of Deaf studies and Deaf Education, 3(3),* 205-216.

Harris, M., & Moreno, C. (2004). Deaf children’s use of phonological coding: Evidence from reading, spelling and working memory. *Journal of Deaf Studies and Deaf Education, 3,* 205-216.

Harris, M., & Moreno, C. (2006). Speech reading and learning to read: a comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education, 11(2), 189*-200.

Hermans, D., Knoors, H., Ormel E., & Verhoeven, L. (2008). A model of reading vocabulary acquisition for deaf children in bilingual education programs. *Journal of Deaf Studies and Deaf Education, 13*, 155-174.

Hermans, D., Knoors, H., Ormel, E., & Verhoeven, L. (accepted for publication). The relation between the reading and signing skills of deaf children: the role of vocabulary, *Journal of Deaf Studies and Deaf Education*, Advance access published on April 8, 2008. doi.10.1093/deafed/enn009.

Hermans, D., Knoors, H., & Verhoeven, L. (2007). Testbatterij voor de Nederlandse Gebarentaal [Assessment tool for Sign Language of the Netherlands].

Hirsch-Pasek, K. (1987). The metalinguistics of fingerspelling: An alternative way to increase reading vocabulary in congenitally deaf readers. *Reading Research Quarterly*, *22,* 455-474.

Hoffmeister, R. (2000). A piece of the puzzle: ASL and reading comprehension in deaf children. In C. Chamberlain, J. Morford & R. Mayberry (Eds.*), Language acquisition by eye* (pp. 143-163). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hulme, C. (2002). Phonemes, rimes, and the mechanisms of early reading development. *Journal of Experimental Child Psychology, 82,* 58-64.

Irausquin, R., & Mommers, C. (2001). *Leesladder. Een programma voor kinderen met leesmoeilijkheden.* [Reading ladder. A program for children with reading difficulties]. Zwijsen.

Izzo, A. (2002). Phonemic awareness and reading ability: An investigation with young readers who are deaf. *American Annals of the Deaf, 147(4),* 18-28.

Karchmer, M. A., & Mitchell, R. E. (2003). Demographic and achievement characteristics of deaf and hard-of-hearing students. In M. Marschark & P. Spencer (Eds.), *The oxford handbook of deaf studies, language and education* (PP 21-37). New York: Oxford University Press.

Kelly, L. P. (2003). The importance of processing automaticity and temporary storage capacity to the differences in comprehension between skilled and less skilled college-age Deaf readers. *Journal of Deaf Studies and Deaf Education, 8(3),* 230-249.

Knoors, H. (2001). Taalontwikkelingsstoornissen ten gevolge van doofheid [Language Development Disorders as a result of deafness]. *Stem-Spraak-Taalpathologie*, *16*, 3-31.

Krom, R. S. H (2001). Leestechniek & Leestempo. Arnhem: Citogroep.

Kyle, F., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education, 11(3),* 273-288.

Luetke-Stahlman, B. & Nielsen, D. C. (2003). The contribution of phonological awareness and receptive and expressive English to the reading ability of deaf students with varying degrees of exposure to accurate English. *Journal of Deaf Studies and Deaf Education, 8(4),* 464-484.

MacSweeny, M., Campbell, R., & Donlan, C. (1996). Varieties of short-term memory coding in deaf teenagers. *Journal of Deaf Studies and Deaf Education, 1(4),* 249-262.

Marschark, M., Lang., H. G., & Albertini, J.A. (2002). *Educating deaf students. From research to practice.* New York, Oxford University Press.

Mayer, C., & Wells, G. (1996). Can the linguistic interdependence theory support a bilingual-bicultural model of literacy education for deaf students? *Journal of Deaf Studies and Deaf Education*, *1*, 93-107.

Mayne, A., Yoshinago-Itano, C., Sedey, A., & Carey, A. (2000), Expressive vocabulary development of infants who are deaf or hard of hearing. *Volta Review*, *100,* 1-28.

McDougall, S., Hulme, C., Ellis, A., & Monk, A. (1994). Learning to read: The role of short-term memory and phonological skills. *Journal of Experimental Child Psychology, 58(1),* 112-133.

McEvoy, C., Marschark, M., & Nelson, D. L. (1999). Comparing the mental lexicons of deaf and hearing individuals. *Journal of Educational Psychology, 91*, 312 – 320.

Merrills, J. D., Underwood, G., & Wood, D. .J. (1994). The word recognition skills of profoundly, prelingually deaf children. *British Journal of Developmental Psychology , 12,* 365-384.

Miller, P. (1997). The effect of communication mode on the development of phonemic awareness in prelingually deaf students. *Journal of Speech, Language, and Hearing Research, 40*, 1151-1163.

Miller, P. (2002). Communication mode and the processing of printed words: Evidence from readers with prelingually acquired deafness. *Journal of Deaf Studies and Deaf Education, 7(2),* 312-329.

Miller, P. (2006). What the processing of real words and pseudohomophones can tell us about the development of orthographic knowledge in prelingually deafened individuals. *Journal of Deaf Studies and Deaf Education, 11 (1),* 21-38.

Musselman, C. (2000). How do children who can't hear learn to read an alphabetic script: A review of the literature of reading and deafness. *Journal of Deaf Studies and Deaf Education, 5(1),* 9-31.

National Reading Panel (NRP) (2000). Report of the National Reading Panel: Teaching Children to Read; An Evidence-based assessment of the scientific research literature on reading and its implications for reading instruction.

Ormel, E., Hermans, D., Knoors, H., & Verhoeven, L. (submitted). Cross-language effects in visual word recognition: the case of bilingual deaf children.

Padden, C. & Ramsey, C. (2000). American Sign Language and reading ability in deaf children. In C. Chamberlain, J. Morford & R. Mayberry (Eds.), *Language acquisition by eye* (pp. 165-189). Hillsdale, NJ: Lawrence Erlbaum Associates.

Parisot, A-M., Dubuisson, L., Lelievre, A., Vercaingne-Menard, A., & Villeneuve, S. (2005). Bilingualism and deafness: Correlations between deaf students mastery of Quebec Sign Language (LSQ) and their performance in reading French. *Paper presented at the fifth international symposium of bilingualism,* Barcelona.

Paul, P. (1996). Reading vocabulary knowledge and deafness. *Journal of Deaf Studies and Deaf Education, 1 (1),* 3-14.

Perfetti, C. A. (1991). Representations and awareness in the acquisition of reading competence. In: Rieben and Perfetti (Eds.), *Learning to read: Basic research and its implications* (p.33-44). Hillsdale, NJ: Lawrence Erlbaum Associates.

Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for Deaf readers. *Journal of Deaf Studies and Deaf Education, 5(1),* 32-50.

Schaerlaekens, A., Kohnstamm, G. A., & Lejaegere, M. (1999). *Streeflijst woordenschat voor zesjarigen: Derde herziene versie gebaseerd op nieuw onderzoek in Nederland en België* [Target list vocabulary for 6-year-old children]. Lisse: Swets & Zeitlinger.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96(4),* 523- 568.

SPSS for Windows, Rel. 11.0.0. 2002, Chicago: SPSS Inc.

Staphorsius, G. K., Krom, R. S. H., & de Geus, K. (1988). *Frequenties van woordvormen en letterposities in jeugdlectuur* [Frequenties of word forms and letter positions in books for the youth], Instituut voor Toetsontwikkeling (CITO), Arnhem (1988).

Strong, M. & Prinz, P. M. (1997). A study of the relationship between ASL and English literacy. *Journal of Deaf Studies and Deaf Education*, 2, 37-46.

Strong, M. & Prinz, P. M. (2000). Is American Sign Language related to English Literacy? In C. Chamberlain, J. Morford & R. Mayberry (Eds.), *Language acquisition by eye* (pp. 131-141). Hillsdale, NJ: Lawrence Erlbaum Associates.

Treiman, R., & Hirsh-Pasek, K. (1983). Silent reading: Insights from second-generation Deaf readers. *Cognitive Psychology*, *15,* 39-65.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades. *Journal of Child Psychology and Child Psychiatry, 45(1),* 2-40.

Vellutino, F. R., Scanlon, D., Sipay, E. R., Small, S. G., Pratt, A., Chen, R., & Denkla, M. B. (1996). Cognitive profiles of difficult-to-remediate readers: early intervention as a vehicle for distinguishing between cognitive and experiential deficits as basic causes of specific reading disability. *Journal of Educational Psychology, 88,* 601-638.

Verhoeven, L., & Vermeer, A. (2001). Taaltoets Alle Kinderen. [Language Test All Children]. Arnhem: CITO.

Vermeulen, A. M. (2007). *Reading skills after cochlear implantation*, doctoral dissertation, Radboud University Nijmegen.

Wauters, L. N., van Bon, W., & Tellings, A. (2006). Reading comprehension of Dutch deaf children. *Reading and Writing, 19,* 49-76.

Wilson, M., & Emmorey, K. (1997). Working memory of sign language: A window into the architecture of the working memory system. *Journal of Deaf Studies and Deaf Education, 2(3),* 123-132.

Wilson, M., & Emmorey, K. (2003). The effects of irrelevant visual input on working memory for sign language. *Journal of Deaf Studies and Deaf Education, 8(2),* 97-103.

Wilson, M., Bettger, J. G., Niculae, I., & Klima, E. S. (1997). Modality of language shapes working memory: Evidence from digit span and spatial span in ASL signers. *Journal of Deaf Studies and Deaf Education, 2(3),* 150-160.

General Discussion

Chapter 6

The majority of deaf children experience reading difficulties (e.g., Wauters, van Bon, & Tellings, 2006). Although a large number of studies confirmed the existence of reading difficulties in deaf children, only a relatively limited number of studies focused on visual word recognition as one of the essential components of reading. No consensus was found in the different studies on visual word recognition, in particular concerning the role of phonology during word recognition. In addition to the three components involved in visual word recognition for hearing children; orthography, phonology, and semantics (Bosman & van Hell, 2002), a fourth component may play a role in visual word recognition for deaf children: A sign component (Perfetti & Sandak, 2000). The various components may play different roles for bilingual deaf children compared to hearing children. In order to get a better understanding of reading of deaf children, it is essential to examine which components are involved during visual word recognition. It is also critical to gain better insights into the relative influence of different variables on word reading fluency and text reading fluency. As yet, only a small number of studies have addressed the relative contribution of different variables towards reading (Harris & Beech, 1998; Harris & Moreno, 2004, 2006; Kyle & Harris, 2006). These respective studies all examined reading of deaf children learning English as opposed to the deaf children in the present thesis learning Dutch, and did not focus on reading fluency.

In the present study, the process of reading acquisition was examined in deaf children educated in bilingual programs in the Netherlands. The first question of the study was: What *codes* do deaf children use during the process of word recognition in order to achieve access to the meaning of written words? The next question concerned the *relative contribution* of different *variables* towards word and text reading fluency of deaf children. In the present thesis, the activation of sign phonology, sign iconicity, and phonology during the process of visual word recognition were examined in a series of experiments (*Chapter 2 and Chapter 3*).

In two additional experiments, semantic categorical knowledge was examined in relation to visual word recognition and text reading levels (*Chapter 4).* Finally, a longitudinal study provided insight into the relative predictive role of a series of variables towards word reading fluency and text reading fluency (*Chapter 5*).

6.1 *Word recognition in deaf children*

In *Chapter 2*, pseudohomophones were used in word-picture verification experiments to examine the activation of phonology. The results in Experiment 1 showed that bilingual deaf children generally did not activate phonology when they were instructed to rely on orthography in a visual lexical decision test. In experiment 1, pseudohomophones were to be rejected. That is, task performance was *hindered* by phonological recoding of the words. When the deaf children were explicitly instructed to rely on phonological information in Experiment 2, they showed major difficulties in doing so. Pseudohomophones were to be accepted an the task now *required* phonological recoding. In contrast to the hearing children, the results of the deaf children imply that they process words without (much) use of phonology, even when explicitly instructed to activate phonological information.

Although some studies have provided evidence that deaf people can activate phonology during word recognition, this was particularly true for participants older than the children in our experiments. Perhaps, the younger deaf children in our study will similarly develop phonological activation during word reading once they grow older. Despite the results of little phonological activation during visual word recognition (*Chapter 2*), deaf children of similar ages were able to judge final speech rhyme above chance levels in the longitudinal study (*Chapter 5).* Although final speech rhyme skills were not at all perfect, some amount of phonological awareness was found in these children, similar to deaf children who were acquiring English (e.g., Dyer, MacSweeney, Szczerbinski, Green, & Campbell, 2003). Nevertheless, the deaf children showed difficulties in judging pseudohomophones (Chapter 2), when the instruction was to decide whether a pseudohomophone and a picture represent the same concept. One of the possible explanations for the lack of phonological activation in the word-picture verification task is that the detection of phonology in pseudohomophones requires a more fine-grained level of phonological knowledge when compared to judgments of final rhyme.

In *Chapter 3*, the role of signs in SLN during word recognition in Dutch was examined. We concluded that the bilingual deaf children processed written words in a language non-selective manner, by showing that deaf children activated the corresponding sign during visual word recognition. In addition, not only correct sign translation equivalents of the presented words were activated, but also multiple signs with sub-lexical sign feature overlap. Furthermore, words with strong iconic sign translation equivalents were processed faster and more accurately. The first experiment involved a s*ign*-picture verification paradigm, aiming to determine the roles of sign iconicity and sign phonology during the processing of signs. Additionally, results of a *word*-picture verification experiment showed that bilingual deaf children activated sign features, not only during sign recognition, but also during word recognition. The results showed that language non-selective activation does not only hold when languages are similar with respect to orthography and phonology, but also for two largely distinct languages of which one is a sign language and one is an alphabetical written/spoken language. It can be assumed that sign activation remains part of word processing in deaf and hearing signing bilinguals to some extent, irrespective of their reading proficiency levels. However, further research is needed to uncover (the extent of) sign activation during visual word recognition in different groups of signing bilinguals.

Many would argue that some amount of phonological knowledge is beneficial in order to learn to read fluently. In different studies, including our own (Chapter 2), phonological awareness was found to be related to reading levels in deaf children (Harris & Beech, 1998; Luetke-Stahlman & Nielsen, 2003; Dyer et al., 2003). Although no direct evidence for phonological activation was found, the deaf bilingual children seemed to activate signs during word recognition. In order to find out to what extent sign activation during word recognition occurs once readers become older and more proficient, an additional study was carried out with high school students, who similarly showed activation of signs during word recognition (Hermans, Ormel, Knoors, & Verhoeven, in preparation). Furthermore, the data from our longitudinal study (Chapter 5) showed that sign phonology may play a role in the development of reading fluency. However, more research is needed to unravel the role of sign features (e.g., sign phonology and sign iconicity) in the acquisition of reading in deaf children.

6.2 *The role of semantics*

In *Chapter 4*, the importance of semantics in relation to reading was shown. A significant link was found between the results for semantics and their reading results; Deaf children with higher word or text reading scores generally showed higher scores on the semantic tasks. This relation was also found for hearing children (e.g., Gijsel, Ormel, Verhoeven, Hermans & Bosman, submitted).

Semantic categorical relations were first examined at two levels: Exemplar level (both ‘bee’ and ‘midge’ as part of the category insects), and sub/ superordinate level (‘bee’ as part of the category insects or vice versa, the category insects includes ‘bee’). Different types of stimuli were used: Written words, pictures, and signs for deaf children/ spoken words for hearing children. Bilingual deaf children were compared to hearing children. The hearing children outperformed the deaf children overall. The difference between the deaf and hearing children was clearly largest for written words, in favor of the hearing children. In comparison to the other types of stimuli, the deaf children performed least accurately at written word stimuli. The difference between the deaf and hearing children in favor of the hearing children was less evident for the pictures. The deaf children performed best at the pictures when compared to written words and signs.

A subsequent important finding was the severely restricted improvement of semantic knowledge across grades for the deaf children compared to hearing children. This restricted improvement was not only true for semantic knowledge when written words were used but also when pictures or signs were used, in other words, it turned out to be irrespective of input source. This finding could imply a major concern for the development of relations between concepts in deaf children. Alternatively, it may imply that deaf children develop an entirely distinct semantic system compared to hearing children. Both interpretations have educational implications; if knowledge of relations between concepts does not develop adequately, a strong educational emphasis will be needed on individual words, signs, and relations between different words and signs; if, on the other hand, an entirely distinct semantic system is created by deaf children, it would be helpful for educational purposes to identify what that system is, and next, to identify how such a system evolves. It is feasible that deaf children categorize concepts based on visible features, for example, ‘flat objects’, ‘round objects’, ‘objects that can contain things’, ‘activities with a circular movement’, ‘activities with an alternating movement', and so forth. These features are often perceptible in signs, and might for this reason influence children's conceptual knowledge. Whether such a distinct semantic system provides sufficient semantic knowledge for the deaf children to support reading, and whether more conventional semantic relations ought to be given prominent attention, are important questions for future research. Beside this, the role of semantics should ideally be assessed in relation to the role of iconic information in sign and word processing. After all, iconic information provides the deaf child with semantic clues about a sign. Irrespective of those two interpretations, it would be highly beneficial for reading of deaf children if word meanings, sign meanings, and knowledge of relations between different concepts would increase.

An important follow-up study on the role of semantics in deaf children learning to read could focus on the processing of systematically controlled dissimilar types of semantic information, e.g., including semantic categorizations, semantic associations, and semantic features which are visible in signs. Moreover, the activation of different types of information (i.e., semantics, sign phonology, sign iconicity, phonology, and even orthography) during word recognition might then be compared.

6.3 *The emergence of reading fluency*

In contrast to abundant studies of reading of hearing children, only very few studies provided insight into the relative contribution of predictive variables for reading of deaf children in primary schools. Without fluency of reading, reading will remain a slow and laborious process. As a first attempt to explore the predictors of reading fluency in deaf children, we conducted a longitudinal study as described in *Chapter 5*. In the first year of the study, the following possible predictive skills for reading fluency were assessed: sign vocabulary, speech vocabulary, speech rhyme, finger spelling, short term memory, and sign phonological awareness. In the second and third year of the study, word and text reading fluency were assessed. Word and text reading fluency were both predicted by speech vocabulary. Speech vocabulary correlated strongly with sign vocabulary, suggesting the importance of speech vocabulary for deaf children. However, it is feasible that without knowledge of sign language, speech vocabulary would not have been such a strong predictor, since many bilingual deaf children initially activate the meaning of words through signs (Hermans, Knoors, Ormel, & Verhoeven, accepted for publication). In addition, finger spelling was a strong predictor for word and text reading fluency after one year. After two years, a similar predictive pattern was observed. A predictive role was also found for sign phonological awareness for word reading fluency after two years. Important to note here is the inclusion in Chapter 5 of pairs which share movement, hand shape, and location, but differ with respect to lip pattern only. In future research, the different types of sign phonological overlap require in-depth attention. For text reading fluency, a predictive role was found for speech rhyme. A special role was found for speech rhyme in interaction with short term memory; speech rhyme showed to be more predictive for reading when short term memory was relatively large. This was seen for word reading after one year and for text reading after two years; word reading levels of the deaf children in the second year of the study and text reading levels of the deaf children in the third year of the study were predicted by the interaction between speech rhyme and short term memory in the first year. Finally, text reading fluency was found to be predicted by word reading fluency. The present findings are highly contributive to the field since not many studies have examined a series of predictive skills concurrently.

6.4 *The reading of deaf children revisited*

Based on the present thesis, one of the conclusions is that signs are indeed activated during word recognition in deaf children. In addition, sign features also appeared to contribute to word and text reading fluency. In other words, on top of the three components already known to influence word recognition in hearing children; ‘phonology’, ‘orthography’, and ‘semantics’, a fourth component, ‘sign features’, indeed seems to play a role in reading of bilingual deaf children.

The component ‘semantics’ was found to be related to word and text reading of deaf children, in line with findings for hearing children (e.g., Gijsel et al, submitted). Semantic knowledge of the deaf children fell largely behind semantic knowledge of hearing children. This difference between deaf and hearing children was not only restricted to written words, but was also found for pictures and signs versus spoken words. Semantic networks of deaf children may not be as well defined as semantic networks in hearing children. Although the causal role of semantics towards reading needs to be explored further, the results in the longitudinal study, where vocabulary scores predicted a large chunk of word and text reading fluency, confirm the importance of semantic knowledge for reading of deaf children. Enlarging knowledge of word and sign meanings and meaning relations could influence deaf children's reading proficiency positively. In the present study, vocabulary knowledge of the deaf children was not compared directly to vocabulary knowledge in hearing children. However, when the spoken vocabulary scores of the children in Chapter 5 were compared to norms for hearing children (part of the TAK, Verhoeven & Vermeer, 2001), a major delay in spoken vocabulary scores was detected for the deaf children.

Evidently, vocabulary size is of great importance for the recognition of words. It should be noted that the word recognition results of the deaf children, again, fell behind their hearing peers. In the present study, word-picture verification measures and lexical decision measures were used. In a word-picture verification test one can only perform the test adequately if the correct semantic meaning is activated. In Chapter 2 and Chapter 3, results of the word-picture verification test show delays for the deaf children. In both chapters, the deaf children consistently performed less accurately than the hearing children, not only compared to peers, but also when compared to younger hearing children. Furthermore, the deaf children generally did not show an increase in accuracy and response times across grades, in contrast to the hearing children. Moreover, despite the similar results for the oldest children (12 year olds) for the lexical decision task in Chapter 5, a careful distinction needs to be made between different word reading measures. In a lexical decision test, it is unclear whether the children activate the correct semantic meaning of the lexical item. Despite the seemingly adequate word reading performance of the oldest deaf children as measured in the lexical decision test, different patterns of error types were found for the deaf versus the hearing children; relatively more false negatives were found for the deaf children. Perfetti and Sandak (2000) suggested that deaf readers who can not profit sufficiently from phonological coding may use semantic information gained from context as back-up systems during reading. In short, our data do not rule out the possibility that semantic knowledge may play a compensating role during reading for children who do not have adequate phonological skills. However, as long as semantic knowledge remains limited for deaf children, the compensating or back-up role for semantic knowledge can not be used to its full potential. The data in the present study indeed show very limited increase in semantic knowledge across grades. In other words, although the enlargement of children's knowledge of word and sign meanings is highly important, it may be equally important to encourage the enlargement of meaning relations to influence deaf children's reading proficiency positively.

One other important finding of the present study was the contribution of phonological knowledge to word and text reading fluency. A related finding was the lack of detection of phonological decoding during word recognition in deaf children. In research among hearing children, the benefit of phonological decoding during word recognition has repeatedly been shown. In the research concerning deaf children reported on in this dissertation, children with cochlear implants were excluded in the study investigating phonological activation. However, in recent years, an increasing number of deaf children received a Cochlear Implant (CI), often at a very early age. Cochlear implantation seems very promising, resulting in e.g., increased speech perception (Snik, Vermeulen, Brokxs, Beijk, & van den Broek, 1997) and increased receptive speech vocabulary (Vermeulen, Hoekstra, Brokxs, & van den Broek, 1999) in many, but certainly not all implanted children. Furthermore, implants are continuously technically improving (Damen, 2007). For many deaf children with CI, the implant eventually results in (at least some) access to spoken language phonology. As a consequence of this enhanced access, several studies have also provided evidence for a significant improvement of reading comprehension of deaf children with a CI, compared to deaf children with conventional hearing aids (e.g., Vermeulen, 2007; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). Given this improvement of reading proficiency in deaf children with CI, is there still a role to play for sign language in general educational programs and for signs in visual word recognition in particular or is the potential benefit of sign language for this new generation of implanted children limited? I would like to argue for the benefit of providing sign language to deaf children without *and* with a CI, both from the perspective of reading instruction as well as from a general developmental perspective.

Firstly, it is important to acknowledge that reading results of deaf children with a CI as a group do still fall significantly behind the reading achievements of their hearing peers. This performance gap with hearing peers is also shown in a recent study about quality of life of children with an implant (Damen, 2007). In mainstream elementary schools, children with a CI were found to perform significantly below hearing class mates "on communication, engagement in group discussion, and displaying turn taking abilities of a leadership role" (Damen, 2007, p. 39).

Secondly, deaf children who learned a large sign vocabulary can interpret the meaning of written words by creating associations between known signs and unknown reading vocabulary (Hermans, Knoors, Ormel & Verhoeven, 2008). Hermans et al. discussed this possibility for bilingual deaf children who do not have a CI. However, the same creation of associations can arguably take place for deaf children who have a CI. Although evidence is available for the benefits of increased access to phonology as a result of a CI, benefits are arguably more profound if sign language is provided too, not only for their social development, but also for the improvement of reading skills. An extensive sign vocabulary can positively affect the size of reading vocabulary, and reading vocabulary is an essential component for reading comprehension.

Thirdly, an increasing amount of research in the field of bilingualism has shown that knowledge of more than one language provides people with important advantages (e.g., Bialystok et al., 2005; Bialystok & Martin, 2004). Bilingual children are generally more proficient in a number of essential cognitive functions, e.g., selective attention and inhibitory control for linguistic and nonlinguistic tasks (e.g., Bialystok, Luk, & Kwan, 2005).

Finally, from a more general developmental perspective, I would like to argue that many deaf children with a CI often fall in between the deaf culture and the hearing society (Isarin, 2007; Wheeler, Archbold, Gregory, & Skipp, 2007). On the basis of a study with deaf adolescents who have a CI, Isarin concluded that many children with a CI miss out on important auditory information, and as a consequence, suffer from cognitive and social delays. In other words, merely a medical treatment does not seem sufficiently beneficial. Thus, it seems very logical to provide deaf children with as many communication sources as possible, which can involve a CI if preferred, *but* at the same time should also involve access to a sign language as soon as possible (Isarin, 2007; Sleeboom, 2007, personal communication). For a long time, there has been the misunderstanding that children with a CI no longer need a sign language and vice versa; children who have a Deaf identity should not have a CI. Tijsseling (2005) highlights the existing misconception about deaf children with a CI; the misconception is that these children will develop as hearing children once the development of a spoken language has taken off. Tijsseling argues for the need to offer a sign language to deaf children with a CI, in order to provide these children with the opportunity to choose their own language of preference. One of the reasons she and others provide is that a deaf child with a CI will not be able to hear the same as a hearing child. Similarly, Wheeler et al. (2007) interviewed adolescents who have a CI. The majority of the participants perceived themselves as deaf. Tijsseling (2005) explained that the only unrestricted and optimal development for deaf children without but also *with* a CI is characterized by a primary visual orientation. For education to deaf children, this implies a bilingual focus, including full access to sign language. This bilingual oriented vision of deaf education is shared by a large number of professionals, adults of deaf children, and deaf students who have a CI (e.g., Blume, 2006; FODOK, 2007; de Geus, 2006; Isarin, 2006; Sleeboom, personal communication). Sign language should ideally be made accessible to these children without *and* with a CI, in one way or another.

Taken together, the essential role for semantics, sign, and phonology towards reading seem to imply an approach where detailed lexical meanings and meaning relationships should be optimally provided, for signs, spoken words, and written words. Sign language might well provide a good foundation for deaf children who have difficulty accessing phonology of the spoken language. Moreover, knowledge of sign phonology might provide the deaf child with beneficial insights into language. For deaf children who can access phonology of the spoken language, phonological knowledge is likely to provide the child with a great additional benefit while learning to read, given graphemes to phonemes mappings. From our longitudinal data (chapter 5), in addition to our speech vocabulary data, finger spelling was found to be most contributive towards word and text reading fluency. Finger spelling seems to offer an important function for the understanding that words can be divided into constituent graphemes. The answer for optimal literacy education for deaf children seems to lie in a combined broad variety of input sources, e.g.,: extensive vocabulary in sign, written words and spoken words; associations between signs and words; (semantic) meaning and meaning relations; access to phonology; good sign language skills and finger spelling skills; and good word reading skills.

6.5 *Theoretical implications*

Interactive activation models (e.g., BIA+, Dijkstra & van Heuven, 2002) show that orthography, phonology, and semantics are interactively activated in visual word recognition. We would like to argue that sign is interactively activated with semantics, phonology, and orthography for many bilingual deaf children. In the present study, we showed that signs are interactively activated in a language non-selective way while accessing word meanings. The activation of sign phonology during sign processing is currently a major topic of research. The current work adds to this area of research by showing that sign phonology does not only play a significant role during processing of a sign but also during visual word processing. To what extent activation of sign features during word recognition continues as children grow older and their reading skills improve, is a vital area of research. The role for iconicity during visual word recognition in deaf people has also only recently become a recognized relevant area of research. The current study has shown that iconicity plays a role not only during sign recognition but also has consequences for the recognition of written words in deaf children.

The present study showed that deaf bilingual children have major difficulties with the activation of phonology of the spoken language during visual word recognition. On the other hand, the role of semantics and sign was established in relation to visual word recognition. At this stage, I suggest this research area should be continued in order to uncover the precise role of phonology, semantics, orthography and sign, in particular at a sub-lexical level in word reading in deaf people, and in a developmental perspective.

A simplified version of the Bilingual Interactive Activation+ model (Dijkstra & van Heuven, 2002) could potentially serve as a framework for the support of visual word recognition in bilingual deaf readers. In Figure 1, the Bilingual Interactive Activation+ Model is complemented with a sign language component: the *Deaf Bilingual Interactive Activation model*.

Currently, the question whether sub-lexical word and sub-lexical sign information are interrelated for deaf bilinguals is still open. The same is the case for the question to what extent connections between sign and phonology could be excitatory. As proposed in Chapter 3, one of the possibilities during visual word recognition is the activation of multiple signs which have an overlap at the sub-lexical level.

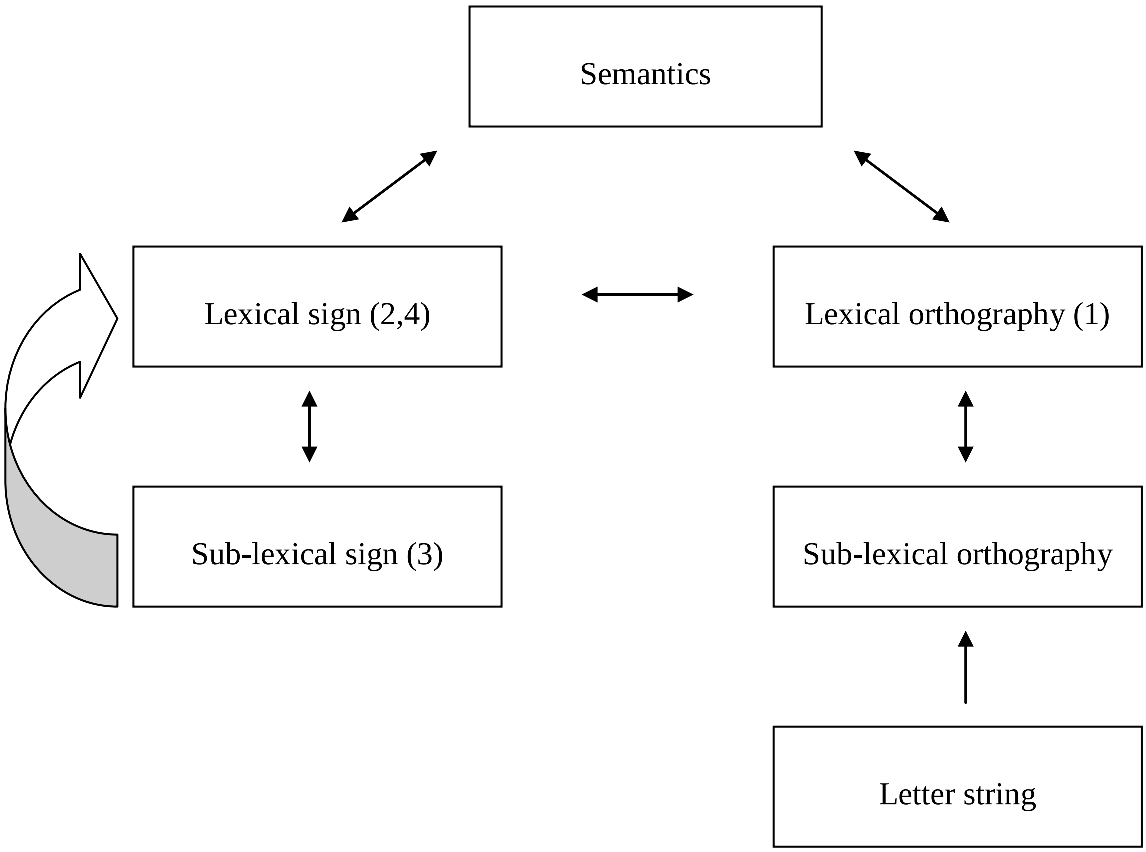


Figure 1. Deaf Bilingual Interactive Activation Model

In our experiments, we examined the activation of signs which have an overlap for hand shape, movement, location, or orientation, and the contribution of sign iconicity towards the recognition of word translation equivalents. It would be valuable if this line of research were to be continued and further specified, in combination with a study on the role of morphology at the lexical and sub-lexical level, and in different populations of bimodal bilinguals.

References

Bialystok, E., Craik, F. I. M., Grady, C., Chau, W., Ishii, R., Gunji, A., & Pantev, C. (2005). Effect of bilingualism in cognitive control in the Simon task: Evidence from MEG. *NeuroImage, 24*, 40-49.

Bialystok, E., Luk, G., & Kwan, E. (2005). Bilingualism, biliteracy, and learning to read: Interactions among languages and writing systems. *Scientific studies of reading, 9(1),* 43-61.

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science, 7(3),* 325-339.

Blume, S. (2006). *CI en de toekomst van Dovencultuur: Alles wat u zou moeten weten over CI*. [CI and the future of Deaf culture: Everything you should know about CI.] Conference Proceedings, June 2006.

Bosman, A. M. T., & van Hell, J. G. (2002). Orthography, phonology, and semantics. In Verhoeven, L., Elbro, C., & Reitsma, P. (Eds.). *Studies in Written Language and Literacy, Precursors of Functional Literacy, 11,* 165-187.

Damen, G. W. J. A. (2007). *Cochlear implantation and quality of life assessment*, doctoral dissertation, Radboud University Nijmegen.

Dijkstra, T., van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5(3),* 175-197.

Dyer, A., MacSweeney, M., Szczerbinski, M., Green, L., & Campbell, R. (2003). Predictors of reading delay in deaf adolescents: The relative contributions of rapid automatised naming speed and phonological awareness and decoding. *Journal of Deaf Studies and Deaf Education, 8(3),* 215-229.

FODOK (Nederlands Federatie van Ouders van Dove Kinderen [Dutch Federation of Parents of Deaf Children]). *Over communicatie met dove en slechthorende kinderen met of zonder CI*. [About communication with deaf and hard of hearing children with and without CI].

de Geus, M. (2006). *CI en de toekomst van Dovencultuur: Alles wat u zou moeten weten over CI.* [CI and the future of Deaf culture: Everything you should know about CI.] Conference Proceedings, June 2006.

Gijsel, M., Ormel, E., Verhoeven, L., Hermans, D., & Bosman, A. (submitted). Semantic-categorization skills in relation to word decoding in primary grades.

Harris, M., & Beech, J. R. (1998). Implicit phonological awareness and early reading development in prelingually deaf children. *Journal of Deaf Studies and Deaf Education, 3*, 205-216.

Harris, M., & Moreno, C. (2004). Deaf children 's use of phonological coding: Evidence from reading, spelling, and working memory. *Journal of Deaf Studies and Deaf Education, 3*, 205-216.

Harris, M., & Moreno, C. (2006). Speech reading and learning to read: A comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education*, *11*, 189-201.

Hermans, D., Knoors, H., Ormel, E., & Verhoeven, L. (2008). A model of reading vocabulary acquisition for deaf children in bilingual education programs. *Journal of Deaf Studies and Deaf Education*, *13*, 155-174.

Hermans, D., Knoors, H., Ormel, E., & Verhoeven, L. (accepted for publication). The relation between the reading and signing skills of deaf children: The role of vocabulary. *Journal of Deaf Studies and Deaf Education,* Advance access published on April 8, 2008. doi.10.1093/deafed/enn009.

Hermans, D., Ormel, E., Knoors, H., & Verhoeven, L. (in preparation). Word recognition in bilingual deaf secondary school children: The use of multiple information sources.

Isarin, J. (2006). *CI en de toekomst van Dovencultuur: Alles wat u zou moeten weten over CI.* [CI and the future of Deaf culture: Everything you should know about CI.] Conference Proceedings, June 2006.

Isarin, J. (2007). *Onderzoeksverslag 'Zo hoort het': Participatieonderzoek naar de ervaringen van kinderen en jongeren met een Cochleair Implantaat* [Research Report "This is how it should be": Participation research into the experiences of children and youngsters who have a Cochlear Implant].

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education, 11*, 273-288.

Luetke-Stahlman, B., & Nielsen, D. C. (2003). The contribution of phonological awareness and receptive and expressive English to the reading ability of deaf students with varying degrees of exposure to accurate English. *Journal of Deaf Studies and Deaf Education, 8(4),* 464-484.

Perfetti, C., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for deaf readers. *Journal of Deaf Studies and Deaf Education, 5*, 32-50.

Tijsseling, C. (2005). *Anders doof zijn: Een nieuw perspectief op dove kinderen*. Twello: Van Tricht uitgeverij.

Sleeboom, I. (2007). Personal communication.

Snik, A. F. M., Vermeulen, A. M., Brokxs, J. P. L., Beijk, C., & van den Broek, P. (1997). Speech perception performance of children with a cochlear implant compared to that of children with conventional hearing aids. *Acta Otolaryncholologica Stockholm, 117*, 750-754.

Verhoeven, L., & Vermeer, A. (2001). *Taaltoets Alle Kinderen*. [Language Test All Children]. Arnhem: CITO.

Vermeulen, A. M., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with cochlear implants. *Journal of Deaf Studies and Deaf Education, 12(3),* 283-302.

Vermeulen, A. M., Hoekstra, C., Brokxs, J., & van den Broek, P. (1999). Oral language acquisition in children assessed with the Reynell Developmental language Scales. *International Journal of Pediatric Otorinolaryncholology, 47,* 153-155.

Vermeulen, A. M. (2007). *Reading skills after cochlear implantation*, Doctoral dissertation, Radboud University Nijmegen.

Wauters, L. N., van Bon, W. & Tellings, A. (2006). Reading comprehension of Dutch deaf children. *Reading and Writing, 19,* 49-76.

Wheeler, A., Archbold, S., Gregory, S., & Skipp, A. (2007). Cochlear Implants: The young people's perspective, *Journal of Deaf Studies and Deaf Education, 12(3),* 303-316.

Summary

In the present study, visual word recognition was examined in bilingual deaf children. In order to get a better understanding of reading of deaf children, it is essential to examine which components are involved during visual word recognition. It is also critical to gain better insights into the relative influence of different variables on word reading fluency and text reading fluency. The first question of the study was: What *codes* do deaf children use during the process of word recognition in order to achieve access to the meaning of written words? The next question concerned the *relative contribution* of different *variables* towards word and text reading fluency of deaf children. In the present thesis, the activation of sign phonology, sign iconicity, and phonology during the process of visual word recognition was examined in a series of experiments (*Chapter 2* and *Chapter 3*). In two additional experiments, semantic categorical knowledge was examined in relation to visual word recognition and text reading levels (*Chapter 4).* Finally, a longitudinal study provided insight into the relative predictive role of a series of variables towards word reading fluency and text reading fluency (*Chapter 5*). In the final chapter (*Chapter* 6), a discussion of the results from the various studies was presented.

The role of phonological activation during visual word recognition was studied in deaf bilingual and hearing children in two word-picture verification experiments (*Chapter 2*). Deaf bilingual children in grade 5 mastering both Sign Language of the Netherlands and Dutch, as well as hearing children in grades 3 and 5 participated in the study. The word stimuli presented were pseudohomophones, orthographic control words, and filler words. In Experiment 1, the task was to indicate whether the word presented was spelled correctly and whether it corresponded to the picture. While the pseudohomophones sounded like the words depicted by the line drawings, they had to be rejected. That is, task performance was *hindered* by phonological recoding of the words. In Experiment 2, the task was to indicate whether the stimulus word sounded like the picture, which meant that task performance now *required* phonological recoding of the stimulus words. The results showed the hearing children to automatically activate phonology during visual word recognition irrelevant of whether they were explicitly instructed to ignore the information (Exp 1) or focus on the information (Exp 2). The deaf children showed little automatic phonological activation. Phonological information was not activated automatically during Experiment 1 and, when the deaf children

were explicitly instructed to utilize phonological information in Experiment 2, they showed major difficulties doing this. The conclusion is that the bilingual deaf children used a different word processing mechanism than the hearing children.

To investigate the activation of sign features during visual word recognition in bilingual deaf children, the role of sign phonology and sign iconicity was examined using two experimental paradigms: sign-picture verification and word-picture verification (*Chapter 3*). Participants had to make decisions about sign-picture and word-picture pairs manipulated according to phonological sign features (i.e. hand shape, movement, and location) and iconic sign features (i.e., transparent depiction of meaning or not). Sign phonology and sign iconicity were strongly activated for the deaf children during both of the verification tasks. We concluded that the bilingual deaf children processed written words in a language non-selective manner, by showing that deaf children activated the corresponding sign during visual word recognition. In addition, not only correct sign translation equivalents of the presented words were activated, but also multiple signs with sub-lexical sign feature overlap. Furthermore, words with strong iconic sign translation equivalents were processed faster and more accurately.

In addition to phonology, semantic knowledge can facilitate word recognition and reading comprehension. In *Chapter* 4, the quality of the semantic knowledge of both deaf and hearing children was therefore examined for different types of stimuli: Written words, pictures, signs (deaf children only), and spoken words (hearing children only). The importance of semantic knowledge for the word recognition and reading comprehension of children in the middle and higher elementary school grades was also examined. More specifically, the exemplar and superordinate levels of semantic categorization were examined in terms of reaction times and accuracy. The results showed the hearing children to outperform the deaf children on each type of stimulus and particularly on written word stimuli. The results also revealed positive correlations between semantic performance and word recognition and reading comprehension, respectively, showing the importance of semantic knowledge in relation to these reading measures.

In order to identify the relative predictive value of a number of abilities for the word reading and text reading fluency of deaf children, a longitudinal study was carried out across a period of three years (*Chapter 5*). The following variables were assessed as potentially predictive abilities: sign vocabulary, speech vocabulary, finger spelling, sign phonological awareness, speech rhyme, short term memory, and word reading fluency. For hearing children, who served as a control group, the word reading and text reading fluency of were also assessed. The hearing children generally outperformed the deaf children. The hearing children also showed significantly greater increases in text reading fluency across the years than the deaf children. Both word reading fluency and text reading fluency were predicted by age, vocabulary, finger spelling, and speech rhyme for the deaf children after one year and also after two years. Of the two vocabulary measures, the predictive value of speech vocabulary proved strongest. A predictive role was also detected for sign phonological awareness and for short term memory in interaction with rhyming skill.

Based on the present thesis, one of the conclusions is that sign features appeared to contribute to word and text reading fluency. In addition, signs are activated *during* word recognition in deaf children. In other words, on top of the components known to influence word recognition in hearing children; ‘phonology’, ‘orthography’, and ‘semantics’, a fourth component, ‘sign features’, indeed seems to play a role in reading of bilingual deaf children. One other important finding of the present study was the contribution of speech rhyme, which is part of phonological knowledge, to word and text reading fluency. Although phonological knowledge predicted word and text reading, phonological activation *during* word recognition was not found in deaf children. Furthermore, although the causal role of semantics towards reading needs to be explored further, the results in the longitudinal study, where vocabulary scores predicted a large chunk of word and text reading fluency, confirm the importance of semantic knowledge for reading of deaf children. In addition, semantic networks of deaf children did not seem to be as well defined as semantic networks in hearing children. The data in the present study showed very limited increase in semantic knowledge across grades. Enlarging knowledge of word and sign meanings, but also enlarging knowledge of meaning relations between concepts could influence deaf children’s reading proficiency positively.

Taken together, the essential role for sign, phonology, and semantics towards reading seem to imply an approach where detailed lexical meanings and meaning relationships should be optimally provided, for signs, spoken words, and written words. Sign language might provide a good foundation for deaf children who have difficulty accessing phonology of the spoken language. Moreover, knowledge of sign phonology might provide the deaf child with beneficial insights into language. For deaf children who can access phonology of the spoken language, phonological knowledge is likely to provide the child with a great additional benefit while learning to read, given graphemes to phonemes mappings. In our longitudinal study (*Chapter 5*), in addition to our speech vocabulary data, finger spelling contributed most towards word and text reading fluency. Finger spelling seems to offer an important function for the understanding that words can be divided into constituent graphemes.

Interactive activation models (e.g., Bilingual Interactive Activation+ model (BIA+), Dijkstra & van Heuven, 2002) show that orthography, phonology, and semantics are interactively activated in visual word recognition. We would like to argue that sign is interactively activated with semantics, phonology, and orthography for many bilingual deaf children. In the present study, we showed that signs are interactively activated in a language non-selective way while accessing word meanings. A simplified version of the BIA+ (Dijkstra & van Heuven, 2002) could potentially serve as a framework for the support of visual word recognition in bilingual deaf readers.

Samenvatting

In de huidige studie is visuele woordherkenning bij tweetalige dove kinderen onderzocht. Om lezen door dove kinderen beter te kunnen begrijpen is het essentieel om de componenten die tijdens visuele woordherkenning betrokken zijn te onderzoeken. Het is bovendien wezenlijk om betere inzichten te verwerven in de invloed van verschillende variabelen op automatische woordherkenning en vlot teksten lezen. De eerste vraag van deze studie luidde: Welke *codes* gebruiken dove kinderen tijdens het proces van visuele woordherkenning om toegang te krijgen tot de betekenis van geschreven woorden? De volgende vraag betrof de *relatieve bijdrage* van verschillende variabelen aan automatische woordherkenning en vlot teksten lezen door dove kinderen. In dit proefschrift werd de activering van gebaren fonologie, gebaren iconiciteit en fonologie tijdens visuele woordherkenning bestudeerd in een serie experimenten (*Hoofdstuk 2 en 3*). In twee aanvullende experimenten werd semantische categorische kennis bestudeerd in relatie tot automatische visuele woordherkenning en vlot teksten lezen (*Hoofdstuk 4*). Tot slot verschafte een longitudinale studie inzicht in de relatief voorspellende rol van een aantal variabelen voor automatische woordherkenning en vlot tekst lezen (*Hoofdstuk 5*). In het slothoofdstuk (*Hoofdstuk 6*) werden de resultaten uit verschillende studies bediscussieerd.

Aan de hand van twee woord-plaatje verificatie experimenten werd de rol van fonologische activatie bestudeerd tijdens visuele woordherkenning bij dove tweetalige kinderen en horende kinderen (*Hoofdstuk 2*). Dove tweetalige kinderen in groep 7 die zowel Nederlandse Gebarentaal als Nederlands beheersten namen deel aan de studie. Daarnaast namen horende kinderen in groepen 5 en 7 deel. De gepresenteerde woordstimuli waren pseudohomofonen, orthografische controle woorden en ‘fillers’. In Experiment 1 moest door de kinderen worden aangegeven of het gepresenteerde woord correct was gespeld en of het woord bovendien correspondeerde met het plaatje. Terwijl de pseudohomofonen hetzelfde klonken als de woorden die door de plaatjes werden weergegeven moesten deze worden verworpen. Kortom, taak performance werd *gehinderd* door fonologische hercodering van de woorden. In Experiment 2 moest worden aangegeven of de stimuli hetzelfde klonken als de plaatjes, wat betekende dat de taak performance nu juist fonologische hercodering van de woordstimuli *vereiste*. De resultaten lieten zien dat de horende kinderen automatisch

fonologie activeren tijdens visuele woordherkenning, afgezien van de vraag of zij expliciet geïnstrueerd waren om deze informatie te negeren (Experiment 1) of zich hier juist op te richten (Experiment 2). De dove kinderen lieten weinig fonologische activatie zien. Fonologische informatie werd niet automatisch geactiveerd tijdens Experiment 1 en bij expliciete instructie om fonologische informatie te gebruiken in Experiment 2 lieten de dove kinderen hierbij grote problemen zien. De conclusie is dat de tweetalige dove kinderen andere mechanismen voor woordverwerking gebruikten dan de horende kinderen.

Om de activatie van gebarenkenmerken tijdens visuele woordherkenning door tweetalige dove kinderen te bestuderen werd de rol van gebarenfonologie en gebareniconiciteit onderzocht aan de hand van twee experimentele paradigma's: gebaar-plaatje verificatie en woord-plaatje verificatie (*Hoofdstuk 3*). Deelnemers moesten beslissingen nemen over gebaar-plaatje en woord-plaatje paren waarvoor gebarenfonologische kenmerken (o.a. handvorm, beweging en locatie) en gebaren iconiciteit (d.w.z. transparante weergave van de betekenis of niet) gemanipuleerd waren. Tijdens beide verificatietaken werden gebarenfonologie en gebareniconiciteit sterk geactiveerd door de dove kinderen. We concludeerden dat de dove tweetlagie kinderen woorden op een taal non-selectieve manier verwerkten, door aan te tonen dat het corresponderende gebaar actief werd tijdens woordherkenning. Bovendien werd niet alleen de correcte gebaar vertaalequivalent van het woord geactiveerd maar ook meerdere gebaren die sub-lexicale overlap vertonen. Daarnaast resulteterden iconische gebarenparen in relatief kortere reactietijden en minder fouten.

Naast fonologie kan ook emantische kennis woordherkenning en begrijpend lezen faciliteren. In *Hoofdstuk 4* werd de kwaliteit van semantische kennis bestudeerd van zowel dove als horende kinderen, waarin verschillende typen stimuli werden gebruikt: Geschreven woorden, plaatjes, gebaren (alleen dove kinderen) en gesproken woorden (alleen gesproken woorden). Ook werd het belang van semantische kennis voor woordherkenning en begrijpend lezen van kinderen bestudeerd in zowel de middelste als de oudste groepen van de basisschool. Semantische categorisatie werd bestudeerd op het exemplaar niveau en het superordinate niveau in termen van reactietijden en accuratesse scores. De resultaten lieten zien dat de horende kinderen voor elk van de typen stimuli hoger scoorden dan de dove kinderen, in het bijzonder voor de geschreven woorden. De resultaten lieten ook positieve correlaties zien tussen semantische kennis enerzijds en woordherkenning en begrijpend lezen anderzijds.

Een studie van drie jaar werd uitgevoerd om de relatief voorspellende waarde te kunnen achterhalen van een aantal vaardigheden die zouden kunnen bijdragen aan woordherkenning en vlot teksten lezen van dove kinderen (*Hoofdstuk 5*). De volgende vaardigheden werden onderzocht als zijnde mogelijk voorspellende vaardigheden: gebarenschat, gesproken woordenschat, vingerspelling, fonologisch bewustzijn in gebarentaal, gesproken rijm, korte termijn geheugen en automatische woordherkenning. Woordherkenning en vlot teksten lezen werd ook onderzocht bij horende kinderen die als controlegroep diende. De horende kinderen lieten over het algemeen hogere leesscores zien dan de dove kinderen. De horende kinderen lieten over de jaren heen bovendien grotere toenames in leesscores zien dan de dove kinderen. Zowel automatische woordherkenning als vlot tekst lezen werd voorspeld door leeftijd, gesproken woordenschat en gebarenschat, vingerspelling en gesproken rijm voor dove kinderen na een jaar en ook na twee jaar. Van de beide vocabulairematen was de voorspellende waarde van de gesproken woordenschat het grootst. Ook werd een voorspellende rol gevonden voor fonologisch bewustzijn in gebarentaal en voor korte termijn geheugen in interactie met rijm.

Een van de conclusies die op basis van het huidige proefschrift getrokken kan worden is dat gebarenkenmerken bij bleken te dragen aan automatische woordherkenning en vlot tekst lezen. Bovendien werden gebaren geactiveerd *tijdens* woordherkenning door dove kinderen. Met andere woorden, naast de drie componenten waarvan bekend is dat die woordherkenning bij horende kinderen beïnvloeden; ‘fonologie’, ‘orthografie’ en ‘semantiek’, lijkt een vierde component, ‘gebarenkenmerken’, een rol te spelen bij het lezen door dove kinderen.

Een andere belangrijke bevinding van deze studie was de bijdrage van fonologische kennis aan automatische woordherkenning en vlot tekst lezen. Hoewel fonologische kennis voorspellend bleek voor woordherkenning en vlot tekst lezen werd fonologie niet geactiveerd *tijdens* woordherkenning. Daarnaast moet de causale invloed van semantiek op lezen verder worden onderzocht. De resultaten van de longitudinale studie, waarin vocabulaire scores een groot deel van automatische woordherkenning en vlot teksten lezen voorspellen, bevestigen het belang van semantische kennis voor lezen van dove kinderen. Verder laten de resultaten zien dat de semantische netwerken van dove kinderen mogelijk niet zo goed zijn gedefinieerd als semantische netwerken van horende kinderen. De gegevens in de huidige studie lieten bovendien een erg beperkte toename zien van semantische kennis over verschillende leeftijdsgroepen. Het vergroten van kennis van de betekenissen van woorden en gebaren maar ook het vergroten van kennis van betekenisrelaties tussen concepten zou de leesvaardigheid van dove kinderen positief kunnen beïnvloeden.

Alles samen genomen lijkt de essentiële rol van semantiek, gebaren en fonologie voor lezen een benadering te impliceren waarin gedetailleerde lexicale betekenissen en betekenisrelaties optimaal verstrekt zouden moeten worden, voor gebaren, gesproken woorden en geschreven woorden. Gebarentaal zou een goede basis kunnen vormen voor dove kinderen die problemen ondervinden met het verkrijgen van toegang tot de fonologie van de gesproken taal. Bovendien zou kennis van gebarenfonologie het kind goede inzichten kunnen verschaffen in taal. Voor dove kinderen die toegang kunnen krijgen tot de fonologie van de gesproken taal is de kans groot dat fonologische kennis een groot voordeel oplevert tijdens het leren lezen door gebruik te maken van grafeem-foneem koppelingen. In de longitudinale data (*Hoofdstuk 5*) werd naast de voorspellende waarde van gesproken woordenschat de sterkst voorspellende bijdrage aan woordherkenning en vlot teksten lezen geleverd door vingerspelling. Vingerspelling lijkt een belangrijke functie te hebben voor het besef dat woorden opgedeeld kunnen worden in afzonderlijke grafemen.

Interatieve activatie modellen (e.g., Bilingual Interactive Activation+ model (BIA+), Dijkstra & van Heuven, 2002) laten zien dat orthografie, fonologie en semantiek interactief geactiveerd worden tijdens visuele woordherkenning. We beargumenteren dat voor veel tweetalige dove kinderen ook gebaren interactief geactiveerd worden met semantiek, fonologie en orthografie. In deze studie lieten we zien dat gebaren interactief geactiveerd werden op een taal non-selectieve manier tijdens het verkrijgen van toegang tot woordbetekenissen. Een versimpelde versie van de BIA+ (Dijkstra & van Heuven, 2002) zou potentieel als raamwerk kunnen dienen voor visuele woordherkenning van tweetalige dove kinderen.

Curriculum Vitae

Ellen Ormel is geboren op 15 juni 1975 te De Heurne, gemeente Dinxperlo. Na het behalen van haar VWO diploma op de Christelijke Scholengemeenschap Aalten in 1993, startte zij de opleiding Pedagogische Wetenschappen aan de Katholieke Universiteit Nijmegen (KUN). ‘Stichting Nijmeegs Universiteits Fonds’ (SNUF) steunde een stage in een bilinguale dovenonderwijssetting te Christchurch, Nieuw Zeeland. Na het succesvol afronden van deze studie in 1998, ontving zij een ‘VSB-beurs’ voor het volgen van een aansluitende Research Master opleiding (MSc) in Psychologie te Aberdeen, Schotland, waarin de nadruk kwam te liggen op de cognitieve ontwikkeling van dove kinderen. Naast deze opleidingen verrichtte zij werkzaamheden als groepswerker bij Aberlour Child Care en ook als groepswerker en vervangend groepshoofd bij Sense Scotland, instellingen voor verstandelijk en meervoudig (zintuiglijk) beperkte jongeren. In 2001 rondde zij haar opleiding in Psychologie succesvol af en vervolgde zij in Nederland op verschillende locaties haar werkzaamheden met jongeren die verstandelijke en communicatieve beperkingen hebben. In 2002 startte zij haar onderzoekswerkzaamheden bij de sectie Orthopedagogiek: Leren en Ontwikkeling aan de Katholieke Universiteit Nijmegen, tegenwoordig de Radboud Universiteit (RU). Vanaf 2006 heeft zij naast haar werkzaamheden voor haar promotieonderzoek werkzaamheden verricht als docent op de RU. Vanaf 2007 is ze werkzaam als onderzoekster bij Pontem, Viataal, een instelling voor zorg en onderwijs aan mensen met beperkingen in horen, zien en communicatie. De onderzoekswerkzaamheden bij Pontem richten zich momenteel op de ontwikkeling en het onderzoeken van onderwijsmaterialen voor kinderen die (een tweede) taal leren met ondersteuning van gebaren; op de ontwikkeling en het onderzoeken van verschillende vormen van visuele en auditieve ondersteuning in de thuisomgeving voor mensen die slechthorend zijn; en op de doelgroep mensen met een auditieve en een verstandelijke beperking. Bovendien is ze op de RU betrokken bij de een aantal studies naar (bimodale) taalverwerking, onder meer door tolken Nederlandse Gebarentaal.

Studies on Atypical Communication

Ludo Verhoeven & Hans van Balkom (Editors)

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