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What is This?
Sign Facilitation in Word Recognition

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The purpose of this article was a dual one: first, to provide a comprehensive literature review, and second, to report one study to extend that literature. That study investigated whether signs from the Sign Language of the Netherlands would facilitate word recognition by deaf children. Participants were 6- to 10-year-old deaf children who attended a school for the deaf at which they received bilingual education. The mean hearing loss was 104 dB. Participants attended a training in which they were taught to match written words with pictures. Before and after training, they were tested in word recognition by means of a computer-based test. Results indicated a significant increase in accuracy of word recognition after training. If words were learned through speech, accompanied by the relevant sign, accuracy of word recognition increased to a greater extent than if words were learned solely through speech.

Deaf children can experience enormous problems in the process of learning to read. Providing a literature review, this article considers reading problems of deaf children and possible explanations for these problems. One major problem concerns the process of word recognition. Following this literature review, one study is reported that concentrates on word recognition, in which the central question is whether signs can facilitate written word recognition by deaf children.

Deafness is a condition with so serious a hearing loss that perception of spoken language by primary auditory means is impossible, even with the strongest amplification equipment, such as powerful individual hearing aids. Instead, the primary means for language perception is the visual channel, for example, speech reading. Through speech reading, however, it is impossible to achieve a complete image of the spoken language input because speech is visible only for approximately 40% of all phonemes (Davis & Silverman, 1978).

In the Netherlands we speak of deafness in cases where the mean hearing loss of the better ear exceeds of 80 dB. Occurrence of this condition very early in life (before or soon after birth), is called prelingual deafness. The process of language development is threatened to a great extent by the fact that the deaf child has little or no access to the spoken language input. Consequently, in many families with deaf children, communicative compensation takes place; deaf children rely for a prolonged period on gestural communication with their environment. After a while, this gestural communication can become so sophisticated and rich in meaning that even deaf adults become enthusiastic about it. For more than 2 centuries a debate took place in deaf education about whether this gestural communication should be avoided and all efforts put in rehabilitation through the fitting of hearing aids and the implementation of speech and hearing training, or if this latter approach should in some way be supplemented by the use of gestures and signs (Tellings, 1995).

During the main part of this century, education for deaf children in the Netherlands essentially consisted of oral education. Speech, speech reading, and the use of residual hearing were emphasized to such an extent that the use of manual communication became more or less a taboo (Van Uden, 1970). In the late seventies and early eighties, many parents, deaf adults, and professionals became convinced that the oral approach was too one-sided for most deaf children. Early, fluent, and rich communication between parents and deaf child, a precondition for subsequent language development, was almost impossible if one had to rely solely on an input of spoken language. Therefore, signs were reintroduced in most institutes for the deaf in our country. Parents and teachers were encouraged to speak Dutch and to support their spoken language with as many signs as possible. Sign Supported Dutch (SSD) became the prevalent way of communication with deaf children. The signs in SSD were used in accordance with the grammatical rules of Dutch. The signs themselves were taken from the communication systems many deaf adults used in communication with other deaf people (Harder & Knoors, 1987).

In the 1980s, research started on these communication systems. As in other countries, researchers soon found out that these systems in fact constitute a sign language, in our case Sign Language of the Netherlands (SLN). By now, we have some knowledge about the structural aspects of SLN (Bos, 1994; Coerts, 1991; Schermer, 1990) and about the way in...
One line of reasoning is that deaf children will improve their reading proficiency in bilingual contexts because of the transfer of knowledge and abilities in sign language to written language. Frequent referral is made to theories about linguistic interdependence (Cummins, 1976, 1999; Verhoeven, 1994). These theories state that the level of proficiency in the second language is positively related to the attained level of proficiency in the first language. Recently, several authors have indicated that these theories are often misinterpreted in the field of deaf education (Knoors, 1993; Mayer & Wells, 1996). For example, although there is substantial evidence that transfer between two languages can happen because of a common underlying proficiency (Bossers, 1991; Snow, Cincino, de Temple, & Schley, 1991), Cummins (1999) clearly stated that this transfer (and thus the correlation between attained levels of proficiency in the first and second language) occurs under specific conditions: “To the extent that instruction in Lx is effective in promoting proficiency in Ly, transfer of this proficiency to Ly will occur provided there is adequate exposure to Ly (either in school or environment) and adequate motivation to learn Ly” (p. 32). Interdependence between the spoken form of the first language and the written form of the second language has never been proved. Instead, interdependence and transfer seem to occur specifically in the domain of cognitive-academic language use and reading and writing. In the latter case, the correlation is weak or nonexistent if the two languages do not share an orthographic system (Bossers, 1991). If we take Dutch and SLN, we first have to notice that deaf children’s exposure to Dutch can hardly be labeled “adequate” because the spoken form of the language is not very accessible to them. Neither do these two languages share an orthographic system. To expect linguistic interdependence to occur under these conditions seems unwarranted. This does not mean that SLN is of no use whatsoever in the reading and writing process; yet, the relationships may not be as clear and straightforward as implied by Cummins’s theory.

A possible beneficial effect of the use of SLN might be the increased transparency of reading instruction thanks to the improved access to the instructional language. Another possible positive effect might be in the field of word recognition.

## Word Recognition

Word recognition is the process of linking the written form of a word with a representation in the mental lexicon. At this moment, two theories of word recognition are dominant: the dual-route theory and the recurrent network theory of Van Orden and Goldinger (1994).

The dual-route theory (Castles & Coltheart, 1993; Coltheart, 1980) claims that the reader can use two different mental routes or procedures to recognize words: the direct or lexical route and the indirect or phonological route. The first route addresses the mental lexicon immediately. Relatively large clusters with graphic features of words-on-paper (e.g., letter patterns, morphemes, whole words) are compared directly with those of words in the lexicon. After a match has been found, the pronunciation of the word concerned is being activated. It is clear that this route or procedure implies experience with reading the written word (print exposure). The phonological route, on the other hand, consists of the trans-
formation or decoding of printed letter strings into a phonemic code (Perfetti, 1985). Relatively small units with graphic codes (graphemes or letters) are transformed in phonemic codes or sounds. Within this theory, Frith (1985) and Ehri (1991) distinguish three stages or phases in learning how to read and to spell: the logographic stage, the alphabetic stage, and the orthographic stage. At first, beginning readers recognize a written word on the basis of the form or length of the word. This stage is called the logographic stage. Then, beginning readers learn to parse the printed word into graphemes and subsequently assign phonemes to the different graphemes. When these readers are able to represent a letter or a combination of letters by their phonemes, they utilize the alphabetic principle (Stanovich, 1986). The application of this principle partially depends on sensitivity of phonemes as units of speech. Later on, in the third stage, alphabetic reading is supplemented by orthographic word recognition. Words are then recognized on the basis of their orthographic forms. The students make use of lexical strategies: They access words directly from their lexicon rather than use grapheme-phoneme conversion rules.

In the opinion of Van Orden (1987), the direct route of the dual-route theory is unsatisfactory because skipping phonological mediation in word recognition is impossible. In the recurrent network theory (see Figure 1) of Van Orden and Goldinger (1994), phonological mediation plays a central role. This theory represents a written word in the mental lexicon as a network of semantic, orthographic, and phonological features. Phonological mediation is considered to be the central aspect of the activation of networks in order to establish lexical access. This theory distinguishes three types of features: orthographic, phonological, and semantic features. When a word is read, the orthographic features are activated. These features send their activation to the phonological and semantic features. The latter ones send their activation to each other (feedforward-activation) and back to the orthographic features (feedbackward-activation). When the feedforward and feedbackward activation match, the network has found a phonological and semantic interpretation of the written word.

The connections between the different features are not of the same strength. The connection between the orthographic and phonological features is the strongest, due to the consistent relationships between graphemes (orthographic features) and phonemes (phonological features). The connections between phonological and semantic features on one hand and between semantic and orthographic features on the other are weaker.

**Word Recognition of the Deaf**

Many beginning readers make use of context when they are reading. By using prior knowledge, they compensate for inefficient word recognition. Deaf children also use this strategy but lack the necessary prior knowledge. They are caught in a vicious circle here: Their poor vocabulary limits their reading comprehension, and their poor reading strategies and skills limit their ability to acquire adequate vocabulary knowledge from context (Paul, 1996).

Deaf children start the reading process with less world knowledge, less cognitive and linguistic knowledge, and less knowledge of the spoken language. Hearing children have access to the spoken language when they start elementary reading instruction. This implies that they know the sounds and grammatical structures of words. For deaf children, however, reading achievement develops simultaneously with spoken language. Their lack of spoken language leads to reading problems, especially problems of decoding and word recognition.

Van Orden’s (1987) recurrent network model assumes, as already stated, a strong connection between orthographic and phonological features. This means that phonological mediation plays an important role in decoding. This phonological mediation is a difficult concept for deaf children because they lack spoken language. Deaf children have to rely on visual recognition. The connection between the orthographic and phonological features is not as strong as it is for hearing readers. For deaf children a stronger connection should exist between orthographic and semantic features. With the use of signs, a direct connection could be made between the word and its meaning.

Treiman and Hirsh-Pasek (1983) investigated whether deaf adults use a decoding strategy when reading printed...
words or derive meaning directly from print. They assumed the existence of three decoding possibilities for the deaf: decoding through articulation, decoding through fingerspelling, and decoding through signs. The participants in their study were native ASL (American Sign Language) signers. The participants were given a task in which they had to decide whether a sentence was correct or incorrect. Results did not indicate the use of a phonological code because the participants showed no difficulties with sentences containing homophones. The participants also did not use fingerspelling in decoding. They did not experience problems in sentences that would be confusing when using fingerspelling. Hirsh-Pasek (1987) found that deaf children use fingerspelling in the same way hearing children use phonemes, that is, by connecting them to written words.

The participants in Treiman and Hirsh-Pasek’s (1983) research did experience difficulties in deciding whether a sentence was correct or incorrect when the sentence consisted of words represented by similar signs in sign language. This result indicated the use of signs in decoding. A problem with this research is that we do not know if the results would have been the same should non-native signers have been tested.

Schaper (1990, 1991) investigated whether deaf children, ages 6 to 8, can be instructed to use speech in recalling written words. During 4 months, the experimental group was trained in associating meaning with words and given the instruction to read aloud. The control group was also trained in associating meaning with words yet not instructed to read aloud. To test whether the instruction to read aloud leads to the use of an articulatory code, a task was administered in which the children had to associate meaning with different lists of pseudowords. Different word lists were used: one list on which the words had a comparable pronunciation but were visually different and another list on which the words were visually comparable but different in pronunciation. Results showed that the experimental group experienced more difficulties with the articulatory comparable words, whereas the control group experienced more difficulties with the visually comparable words. In earlier research in which the same task was used, Schaper and Reitsma (1986) found that most young deaf children use a visual strategy to remember pseudowords, but that 45% of the 12-year-olds use an articulatory strategy.

Schaper (1990, 1991) applied another task to test word recognition. In this task pictures had to be matched with written words. The target word had to be chosen from four visually comparable words. This task was administered once after 8 weeks and again after 16 weeks. After 8 weeks, the experimental group needed less time to accomplish this task, but no difference in accuracy between the groups was found. After 16 weeks, no difference at all was established between the experimental and control group. Findings showed that young deaf children can be instructed in using an articulatory code. The children instructed to read aloud during training used an articulatory code to recall written words. No effect was found for instruction to read aloud on learning word-meaning associations.

Bonvillian (1983) tested the effects of signability and imagery on word recall of deaf and hearing children. In his research he used a recall task with four lists of words. The lists consisted of high-imagery and low-imagery words. Half of the high-imagery and half of the low-imagery words had a close sign language equivalent. Every word on the list was shown for 5 seconds. After having been shown the lists, the participants had to write the words they remembered. Five minutes later they received a delayed recall test. Results showed that signability and imagery are important in word recall of deaf children; for hearing children, only imagery is important.

Conlin and Paivio (1975) came to the same conclusion. They used a paired-associate task in which the subjects got to see two words during 4 seconds. After that, only the first word of the pair was shown, and the participants had to recall the other word. The deaf students were better at recalling high-imagery words with a sign language equivalent. Odom, Blanton, and McIntyre (1970) investigated the effect of signability on word recall. In their experiment participants had to recall which word belonged to which number. Their performance was better in the case of words with a sign language equivalent.

Another study demonstrating the use of sign decoding is that of Stoefen-Fisher and Lee (1989). They showed the effect of graphic representation of signs on word identification. Participants were shown written words. In one condition the written word was accompanied by a graphic representation; in the other condition it was not. After the words were shown, participants had to recall the words they had seen. The written form of the words was unknown before the study started, although the meaning of the words was known. Words that were accompanied by a graphic representation were recognized better than words that were not. These results showed that the use of signs affects word identification of written words.

In the Netherlands, few studies have been done on the role of signs in word recognition of the deaf. Pijfiers (1989) investigated whether Dutch deaf children (ages 3–8) used an articulatory code or a sign code in reading and which code led to the best results. She used a lexical decision task in which children had to judge whether a word was real or not. Results indicated that the children’s knowledge of the signs for the words is of more importance to word recognition than their pronunciation knowledge.

Across these studies, evidence suggests that deaf children use signs in decoding written words and that their word recognition is correlated with the signability of written words, at least for recall tasks. In the Netherlands, only Pijfiers (1989) found some evidence of a sign- decoding strategy.

The second purpose of this study was to compare two networks. The first is a connectionist network in which the connections between the semantic and phonological features on one hand and the semantic and orthographic features on the other are relatively weak. The second is a framework in which both connections are deliberately made much stronger.
Our purpose was to find out which type of network is more effective for word recognition with deaf children.

This study differs from previous work in that we used a training experiment. In earlier studies, except for Schaper's (1990) study, an assessment was made of word recognition or word recall. In our study, we tried to find a way to improve word recognition of the deaf. To do so, training in word recognition was given. In this way, the current study went beyond assessing the strategy or level of word recognition and investigated the effects of training in word recognition. Should training be effective, this would have major implications for deaf education.

In this study we investigated whether signs from SLN, used in connection with speech, facilitate word recognition by deaf children. This implies two subquestions:

1. Do deaf children recognize written words learned through signed and spoken language correctly (accuracy) more frequently than written words learned solely through speech?
2. Do deaf children recognize written words learned through signed and spoken language faster (speed) than written words learned solely through speech?

We tried to answer these questions by means of a training experiment in which we trained deaf children to match written words with corresponding pictures.

We expected that the signs of SLN would facilitate word recognition by deaf children. Van Orden's (1987) recurrent network includes the possibility for word recognition through the linkage of semantic and orthographic knowledge. By using signs (semantic knowledge), one can make a direct connection between the word and its meaning. So, we predicted that the participants would recognize written words more accurately and faster when learned through signed and spoken language than when learned solely through spoken language.

Method

Participants

Participants were 16 pupils, 12 boys and 4 girls. They attended the same school, at which they received bilingual deaf education (i.e., in both spoken language and SLN). The mean age was 8.4 years, ranging from 6 to 10 years old. The mean Fletcher Index, indicating hearing loss, was 104 dB (range 75–130 dB). The mean performance IQ was 95, ranging from 57 to 115. Thirteen participants were deaf from birth, and 3 had acquired deafness. Two children had a cochlear implant. Four children were of non-Dutch origin. Participants came from four different classrooms and attended the research project with their own classmates.

Material

Participants received training in word recognition of written words. Before and after this training, they were tested in word recognition by means of a computer-based test. The participants were trained and tested in recognizing written words from six word lists. Every list consisted of 10 words. The lists were comparable in terms of word frequency, word length, and imaginability. For the test, three more lists were added, each with 10 untrained words.

All words were taken from the Kohnstamm list, a list of spoken Dutch words that hearing children are supposed to know at the age of 6 (Kohnstamm, Scherlaeke, De Vries, Akkerhuis, & Frooninckx, 1981).

Procedure

Training was delivered groupwise. The participants came from four different classrooms and attended the research project in the same group every session. They were trained in two conditions: (a) together with the written word, the spoken word was offered, and (b) together with the written word, both the spoken word and the relevant sign were offered.

The items were presented on a computer screen. First, a picture appeared, and the trainer pronounced the word or pronounced and signed the word. Second, the word appeared on the screen, character by character. Third, the participants had to pronounce or pronounce and sign the word. Fourth, the trainer repeated the word in spoken language or in spoken language accompanied by the sign.

All children attended three training periods, each consisting of four training sessions. Each session lasted approximately 15 minutes. During each period, subjects were trained to recognize two word lists (20 words). One list was trained in the first condition (speech only) and the other list in the other condition (speech and sign).

Before and after each training period, participants were tested. The test consisted of the trained words; to each test, a different list with 10 extra words was added. These extra words were included to see if generalized training effects would occur.

The test was administered individually on a computer. A picture appeared on the screen, surrounded by four written words. One word matched the picture; one word resembled the target word phonologically-orthographically; the third word was semantically related to the target word; and the fourth word was a phonologically possible but nonexistent word (a pseudo-word). The child had to choose the target word and press the correct key on the keyboard. Each keyboard had four keys, spatially corresponding to the position of the words on the screen.

Experimental Design

Four groups, consisting of three to four children, were randomly assigned to one of the four training situations as de-
TABLE 1. Experimental Design

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest</th>
<th>Training</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wordlist 1 and 2 +</td>
<td>List 1 in Condition A</td>
<td>Wordlist 1 and 2 +</td>
</tr>
<tr>
<td></td>
<td>Nontrained list 1</td>
<td>List 2 in Condition B</td>
<td>Nontrained list 1</td>
</tr>
<tr>
<td>2</td>
<td>Wordlist 1 and 2 +</td>
<td>List 1 in Condition A</td>
<td>Wordlist 1 and 2 +</td>
</tr>
<tr>
<td></td>
<td>Nontrained list 1</td>
<td>List 2 in Condition B</td>
<td>Nontrained list 1</td>
</tr>
<tr>
<td>3</td>
<td>Wordlist 1 and 2 +</td>
<td>List 1 in Condition B</td>
<td>Wordlist 1 and 2 +</td>
</tr>
<tr>
<td></td>
<td>Nontrained list 1</td>
<td>List 2 in Condition A</td>
<td>Nontrained list 1</td>
</tr>
<tr>
<td>4</td>
<td>Wordlist 1 and 2 +</td>
<td>List 1 in Condition B</td>
<td>Wordlist 1 and 2 +</td>
</tr>
<tr>
<td></td>
<td>Nontrained list 1</td>
<td>List 2 in Condition A</td>
<td>Nontrained list 1</td>
</tr>
</tbody>
</table>

Because it was impossible to create different matched experimental groups, each participant was trained in both the speech only condition (A) and the speech plus signing condition (B). Training in word recognition was repeated twice with four different word lists. The lists and conditions were offered in a different order to the different groups; Table 1 shows the order for each group.

Independent and Dependent Variables. The independent variable was the condition in which the words were trained. The dependent variables were accuracy and speed. Accuracy was measured by the number of items answered correctly. Speed was measured in seconds needed to answer to an item. Time started running on appearance of the picture on the screen and was stopped when the participant had pushed a key.

Data Analysis. Two participants were excluded from analyses because they did not manage to learn the testing procedure. All analyses were conducted with data from the remaining 14 participants. Speed and accuracy data were analyzed using nonparametric tests because the dependent variables did not show a normal distribution. One-tailed tests were used because we expected that accuracy and speed would increase after training. Error analysis was done using t tests.

Results

Preliminary Kruskall-Wallis analyses showed that accuracy and speed of responding in the pre- and posttest were not influenced by age, IQ, sex, amount of hearing loss, age of onset of deafness, or ethnicity (Dutch or non-Dutch). To rule out differences in difficulty between the six different lists of words, these lists were studied in preliminary analyses. The number of correct responses and the speed of responding in all pretests were compared for the three training periods. A Kruskall-Wallis test showed no statistically significant difference in accuracy. Speed of responding differed among the

TABLE 2. Reaction Times in Seconds in Pretest

<table>
<thead>
<tr>
<th>Period</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest training 1</td>
<td>14</td>
<td>6.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Pretest training 2</td>
<td>14</td>
<td>4.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Pretest training 3</td>
<td>14</td>
<td>4.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

TABLE 3. Mean Number of Correct Responses

<table>
<thead>
<tr>
<th>Period</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy pretest training 1</td>
<td>14</td>
<td>17.36</td>
<td>7.25</td>
</tr>
<tr>
<td>Accuracy posttest training 1</td>
<td>14</td>
<td>19.71</td>
<td>6.49</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>2.35</td>
<td></td>
</tr>
<tr>
<td>Accuracy pretest training 2</td>
<td>14</td>
<td>16.29</td>
<td>5.70</td>
</tr>
<tr>
<td>Accuracy posttest training 2</td>
<td>14</td>
<td>18.21</td>
<td>6.55</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>1.92</td>
<td></td>
</tr>
<tr>
<td>Accuracy pretest training 3</td>
<td>14</td>
<td>17.71</td>
<td>5.84</td>
</tr>
<tr>
<td>Accuracy posttest training 3</td>
<td>14</td>
<td>18.50</td>
<td>6.27</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>0.79</td>
<td></td>
</tr>
</tbody>
</table>
three training periods, $\chi^2 (5, N = 42) = 34.9, p < .001$. A post hoc Mann-Whitney test showed that the speed of responding in the pretest differed between Training Periods 1 and 2, $Z = -3.79, p < .001$, and 1 and 3, $Z = -2.82, p < .001$. Training Periods 2 and 3 did not differ from each other (see also Table 2).

Wilcoxon signed ranks analyses of accuracy, irrespective of training period, training condition, and list of words, showed a significant increase, $Z = -2.07, p < .05$, in accuracy between pre- and posttest. On average, five words more were identified in the posttest than in the pretest. Table 3 shows the results for the separate training periods. Pre- and posttests differed significantly in Training Period 1 and 2, $Z = -1.76, p < .05$ and $Z = -2.07, p < .05$, respectively.

The pooled training sessions were also analyzed for effects on speed of responding. The participants responded 1.1 seconds faster in the posttest than in the pretest. This difference was statistically significant, $Z = -2.79, p < .01$. The pre- and posttests differed significantly in the first and third training periods, $Z = -3.11, p = .001$ and $Z = -1.85, p < .05$, respectively. The response times in the posttest were shorter than in the pretest (see Table 4).

So far, effects for general training have been reported irrespective of training condition. The training periods had an overall significant positive effect on word recognition, both with respect to accuracy and speed. If we look at the three training periods separately, the accuracy of word recognition increased significantly in Training Periods 1 and 2, whereas the speed improved significantly in Training Periods 1 and 3.

Next, we studied the effect of the training condition—speech only, speech and signing, and no training—on word recognition. Table 5 shows these results. Only the number of words learned by speech and signing showed a significant increase between the pre- and posttest, $Z = -2.59, p < .01$. Analysis of the three training periods separately showed an increase for the speech plus signing condition in the first period, $Z = -2.04, p < .05$, and the second period, $Z = -3.03, p < .01$. In Training Period 3, none of the training conditions led to an increase in correct responses.

Analyses of the speed of responding in the three training conditions showed that in all three conditions speed of responding improved. In the speech only condition, the 14 children responded on average 1.5 seconds faster in the posttest than in the pretest, $Z = -2.86, p < .01$. In the speech plus signing condition the speed improved .9 seconds from pre- to posttest, $Z = -2.41, p < .01$. Additionally, for the untrained words the speed of responding improved 1.0 second, $Z = -2.71, p < .01$. Speed of responding improved significantly for all three conditions in the first training period but not in the second period. In the third period, speed of responding improved only for the speech only condition, $Z = -2.61, p < .01$.

Summarizing, we found that under the speech plus signing condition, improvement in accuracy and speed was significant; by contrast, in the speech only condition, only speed of responding improved significantly. The significant effect of the speech plus signing condition on accuracy was found over all pooled training periods and in the Periods 1 and 2. Training did not generalize to untrained words, al-

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**TABLE 4. Reaction Times (RT) in Seconds**

<table>
<thead>
<tr>
<th>Period</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT pretest training 1</td>
<td>14</td>
<td>5.9</td>
<td>2.1</td>
</tr>
<tr>
<td>RT posttest training 1</td>
<td>14</td>
<td>4.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Difference</td>
<td>-1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT pretest training 2</td>
<td>14</td>
<td>4.3</td>
<td>2.6</td>
</tr>
<tr>
<td>RT posttest training 2</td>
<td>14</td>
<td>4.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Difference</td>
<td>-0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT pretest training 3</td>
<td>14</td>
<td>4.6</td>
<td>1.8</td>
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<td>2.2</td>
</tr>
<tr>
<td>Difference</td>
<td>-1.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**TABLE 5. Mean Number of Correct Responses per Condition**

<table>
<thead>
<tr>
<th>Period</th>
<th>n</th>
<th>M</th>
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<tr>
<td>Accuracy pretest condition A</td>
<td>14</td>
<td>17.93</td>
<td>6.12</td>
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<tr>
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<td>Difference</td>
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<tr>
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<td>6.19</td>
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<tr>
<td>Difference</td>
<td></td>
<td>0.5</td>
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though the speed of responding also improved for these words.

Results thusfar refer to the average group results; however, we also studied the individual responses of the 14 children. Analysis of the individual achievements showed that the number of individual children scoring higher in accuracy in the posttest in the speech only condition was 6, 6, and 5 for the respective three training periods, whereas the numbers in the speech plus sign condition were 8, 11, and 9, respectively. Looking at the speed, we found that 12, 7, and 10 children, respectively, performed faster in the posttest than in the pretest for the speech only condition, and 13, 3, and 8 children, respectively, in the speech plus signing condition. These results show that, first, not all 14 children profited from the training. Second, more children in the speech plus signing condition than in the speech only condition were responsible for the significant average improvement in accuracy. Third, the significant improvement in speed of responding, irrespective of training condition, was reflected in the approximately even numbers of children in the speech only and speech plus signing condition who improved in speed of responding between pre- and posttest.

The kinds of errors made by the children was studied last. The respective mean numbers of semantic errors, phonological errors, and nonsense errors were 3.9 (SD = 2.6), 3.0 (SD = 2.2), and 3.1 (SD = 2.7). Post hoc multiple comparisons with Bonferroni correction for capitalization on chance revealed no significant differences. Only the difference between semantic and phonological errors approached the corrected significance level of one third of 5%, t (41) = 2.47, p = .018.

Discussion

The main purpose of this study was to investigate the effect of signs from SLN, in conjunction with speech, on word recognition by deaf children. To this end we trained 16 deaf or hearing-impaired students in matching written words with corresponding pictures. In pre- and posttest, we measured the influence of the independent variable condition on the dependent variables, speed and accuracy of word recognition.

Findings showed a general significant effect of training on accuracy of word recognition. The accuracy improved significantly in Training Periods 1 and 2. Speed increased significantly in Training Periods 1 and 3. In Training Period 1, speed did increase due to the training, yet a simultaneous increase in the recognition of untrained words took place as well. The improvement in speed might be due to habituation to computer use.

Looking at the training conditions, we did find a significant increase in accuracy, but only in the speech plus signing condition. Speed improved in both conditions. These findings suggest that the addition of signs to speech facilitates word recognition by deaf children.

These results are in line with findings of previous research. In Pijfers's (1989) study, participants recognized words more accurately as real words when they knew the corresponding sign than when they only knew the pronunciation of the word. In the recall tasks from Bonvillian (1983), Conlin and Paivio (1975), and Odom et al. (1970), words with a sign equivalent were remembered more accurately than words without a sign equivalent.

In the present study we investigated not word recall but, rather, word recognition. Recalling words better when a sign equivalent is available does not necessarily mean one can also learn to recognize words better by using signs. No direct connection exists between word recognition and word recall, which means evidence about word recall does not tell us how children recognize words.

Furthermore, we trained word recognition instead of merely assessing it. We did not investigate in which way deaf children recognize words, but rather tried to find a way to teach deaf children word recognition. The training was given in a classroom setting with four children in each group. This means training can be easily implemented in deaf education. In this study we found an effective way to teach word recognition to deaf children, in which signs play a prominent role.

According to the connectionist model of Van Orden and Goldinger (1994), a strong connection exists between the orthographic and phonological features; other connections are less strong. In this study we compared this model with a model in which the weaker connections have been made stronger (see Figure 2).

In the speech only condition, a strong connection exists between the orthographic and phonological features. By adding the signing in the speech plus signing condition, the
Results showed that this model is the more effective of the two for word recognition by deaf children because accuracy improves in the speech plus signing condition. Results of this study also showed that phonological mediation, a central aspect in Van Orden’s (1987) recurrent network model, also plays an important part in deaf children’s word recognition. Word recognition improves when signs are used in addition to this phonological mediation. Through the sign, a connection is made between the word and its meaning, in addition to the phonological information.

Findings should have implications for the reading instruction of the deaf. First, training deaf children in recognizing written words improves the accuracy of word recognition. Thus, reading instruction should partially concentrate on teaching deaf children how to recognize written words. Second, using signs in addition to speech in training word recognition is more effective than using speech only. This does not mean, however, that speech is of no importance whatsoever in the word recognition process of deaf children. The significance of our findings should be seen against the background of reading instruction for deaf children in general and in the Netherlands more specifically. Until recently, reading instruction for deaf children in our country took place in a rather unmethodical way with little emphasis on word recognition. Instead, reading instruction was seen as the written counterpart of language development. The actual real-world experiences of children were taken as the context in which language and reading instruction had to take place, and formal teaching of reading was not emphasized. Moreover, global attachment of meaning to text was given priority at the expense of training in word recognition. Current research on reading clearly stresses the importance of both fast and accurate word recognition and methodical educational approaches. Our research shows that through systematic training using speech and signs, accuracy and speed of written word recognition of deaf children may be improved significantly. We did not examine whether certain reading methods are more effective than others or whether word recognition improves reading skills. Rather, we examined whether training improves speed and accuracy of word recognition. We found that it is worthwhile to train word recognition, independent of what method of reading instruction is used. Furthermore, the training format we used is applicable to a variety of educational contexts. The program itself is adaptable, and the fact that it is computer based makes it applicable to classrooms in which individual and independent classroom work is emphasized. This emphasis is growing, given the fact that individual variation in learning profiles and competencies of deaf children is increasing and that, at least in the Netherlands, education for deaf children in bigger groups than the traditional ratio of 6 pupils to 1 teacher is advocated, mainly because of social reasons.

Of course, our research has its limitations as well. First, the research group was small and heterogeneous due to the small number of deaf children available in the desired age range at the institute at which the research was carried out. This also explains the use of the age range (6–10 years). Therefore, it would be interesting to replicate the study with a larger group representative of the deaf population. Participants should range in age from 6 to 8 years old because in the Netherlands, hearing children start reading instruction at that age. Second, participants knew the words used in the study, as well as the corresponding signs. Additional research should apply training with unknown words to see whether words taught in Condition B are better recognized than words taught in Condition A. In this case, longer training would be necessary because participants would have to be taught the meaning of the words.

**AUTHORS’ NOTE**

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