Computer-Based Exercises for Learning to Read and Spell by Deaf Children

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There is a surprising lack of systematic research evaluating the effects of reading exercises for young deaf children. Therefore, for this article, two computer-based exercises were developed and learning effects were determined by posttests. One (spelling oriented) exercise was to select the correct word among three orthographically similar alternatives that corresponds to a drawing or a sign (digital video). The other (meaning oriented) exercise was to select the correct sign or picture among three alternatives that corresponds to a written word. Eleven deaf Dutch children with a mean age of 7 years 10 months participated in the study. A first question was whether in single-word exercises the meaning or the spelling of a word should be emphasized. A second question was whether there was any effect of using drawings or signs to refer to the meaning of the word. The results reveal that emphasizing the word spelling is most effective for learning to read for deaf children and the findings also suggest that drawings are more efficient in the current exercises.

Because most hearing people do not know the sign language, one way of deaf persons to communicate with them is to use written language. Also, given the overwhelming necessity of being able to read and write in order to function well in modern society, deaf people may want to learn to use written language. Various studies, however, have shown that the reading skills of deaf children are generally low (cf., Musselman, 2000; Wauters, van Bon, & Tellings, 2006). Typically, the teaching of reading (actually, written language) has not been very successful for many deaf individuals.

Computer-based exercises might be very important in instruction and practice of reading and spelling. A major advantage seems to be the flexible presentation of signs (either stills or dynamic video clips), pictures, photos, etc., and printed words. The aim of this article therefore was to explore the effects of two different computer-based exercises for learning the associations between printed words and meanings. More specifically, a first research question was whether it is important with regard to effectiveness in single-word learning to emphasize either the orthographic or the semantic characteristics of a word. Secondly, because in such exercises a reference to the word meaning has to be included, a research question was whether the word meaning is best represented by still drawings or by showing a video clip dynamically displaying the corresponding sign.

Literacy appears the strongest predictor for success in the education of deaf children (Barker, 2003). Unfortunately, time and again it has been demonstrated that on average the reading comprehension skill of deaf children is relatively low (e.g., Conrad, 1979; Musselman, 2000; Paul, 1997; Pintner & Patterson, 1916; Traxler, 2000; Trybus & Karchmer, 1977; Wauters et al., 2006). In a recent Dutch study, the averaged reading comprehension score of almost 464 deaf students between 6 and 20 years of age appeared to be at a level equivalent to a hearing child in the first grade (Wauters et al., 2006). The overriding conclusion is that reading performance of deaf children is on average much delayed compared to hearing children. There are some obvious reasons for this difference. Deaf children evidently do not have a fluent command

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of the spoken language of which the written language is a counterpart, and they do not have easy access to the phonological code which is very helpful or even essential to learn an alphabetic orthography.

For profoundly deaf children that are born to deaf parents, sign language is very likely their first language. This language is probably acquired as easily as hearing children learn their spoken language. The difficulty is that there is no direct structural relationship between sign language and spoken language. In contrast, the deaf children born to hearing parents are not exposed to sign language from birth on. The linguistic input they receive is variable (e.g., intensive oral training, signed versions of the spoken language, lipreading, fingerspelling, and supplementary sign language), both in quality and intensity. Although some children succeed in becoming relatively fluent users of the spoken language, it is more likely that most do not. When confronted with the written representation of the spoken language, most deaf children have rather limited knowledge of the vocabulary and grammar that print represents and therefore it is more difficult to predict and infer meaning.

When a hearing beginning reader is asked to identify a single written word, he likely would use the alphabetic principle that graphemes represent the phonological structure of a word (Perfetti & Sandak, 2000). By associating the corresponding sounds to letters and using blending procedures, the written word can be transformed into a spoken word that he most often is familiar with. This spoken form can then be used to directly access the knowledge in the mental lexicon to retrieve the meaning of the word. But if a child was born deaf and spoken language has been barely accessible, this procedure of using phonological recoding does not seem a viable approach (Goldin-Meadow & Mayberry, 2001). Although it appears that the more proficient deaf readers develop some sort of phonological knowledge, most authors agree that optimal phonological recoding is not readily available for most young deaf children (e.g., Beech & Harris, 1997; Leybaert & Alegria, 1995; Schaper & Reitsma, 1993; Transler & Reitsma, 2005). Moreover, phonologically decoding printed words is not very useful when the profoundly deaf child does not know the phonological form of the word and its associated meaning.

For deaf children learning the written language is thus quite a challenge. Profoundly, deaf children need to learn the mapping between the sign language they know and print. Unfortunately, it is unknown how to teach the print-language mapping (Musselman, 2000). Extensive individualized instruction and practice are probably essential in order to acquire fluent skills in identifying printed words and develop written language vocabularies. It is rather surprising that empirical studies are scarce in which different exercises for deaf children have systematically been investigated (see for recent exceptions Trezek & Malmgren, 2005; Trezek & Wang, 2006).

Especially computer-based literacy exercises may play an important role to provide such opportunities for practice. Modern technology would easily allow for varied and dynamic presentations of print together with digitized speech, movies, pictures, etc. Importantly, individualized practice can be continued almost endlessly as long as the pupil enjoys and is interested. Also, feedback in exercises can be given on screen immediately and privately, even a long series of mistakes does not necessarily lead to public embarrassment. Therefore, this article is an attempt to empirically evaluate the effects of computer-based reading exercises for deaf children. Instead of developing and evaluating a whole package of instructional materials and procedures, we began to ask a few simple but basic questions. A first research question in our investigation was whether it is important with regard to effectiveness in single-word learning to emphasize either the orthographic or the semantic characteristics of a word. Second, because in such exercises a reference to the word meaning has to be included, a research question was whether the word meaning is best represented by still drawings or by showing a video clip dynamically displaying the corresponding sign.

A reason to expect beneficial effects of a semantic emphasis in learning the association between a meaning and a printed word is that it most resembles the actual process of reading in daily life. Reading ultimately means translating the written form into meaning. For hearing children, this may involve converting the written word first into its spoken counterpart, but probably in deaf children the meaning is directly addressed although we do not know much of the
details of this process (Musselman, 2000; Perfetti & Sandak, 2000). In order to learn about the association between a printed word and its meaning, exercises with a focus on the meaning, as represented by signs or by pictures, should be most beneficial for learning new (printed) words, as compared to orthographic focused exercises.

There is also reason, however, to expect relatively more positive effects of exercises focusing on the orthographic details of words. Knowledge of word spellings is indispensable for identifying words, because only one letter can make a change in the meaning of a word. For instance, the words “trip” and “trap” vary only in one letter, but the meaning differs completely. Because deaf children cannot rely on sounding out separate letters as hearing children, it is not surprising that often their word identification skills are found worse than those of their hearing peers (Beech & Harris, 1997; Harris & Beech, 1998; Merrils, Underwood & Wood, 1994). Whereas hearing children receive feedback as they sound out the word that they have read, deaf children cannot rely on this, and as a consequence, no feedback is given to the child if the word is read—and thus identified—incorrectly. Detailed knowledge about the words’ spelling is indispensable for deaf children as they have to be able to recognize the word correctly in order to retrieve the corresponding word meaning from memory. Therefore, the hypothesis could also be that the exercise which emphasizes the orthographic characteristics of a word will be most effective for learning to read new words. Another argument for this hypothesis is that the correct word spelling will be more difficult to memorize than pictures or signs. Encouraging the child to look closely to the spelling of a word will prevent the child of only glancing at the whole word. Only by paying attention to the complete string of letters can accurate orthographic knowledge be established.

There are various ways to refer to word meanings in computer-based exercises, for instance, by an illustration of the meaning, such as a photo or drawing, or by a sign. An advantage of the first option is that drawings are independent of sign language development. A picture enables a child to understand the meaning of the word even as he does not know the sign for the construct. A disadvantage, however, is that not all words can easily be illustrated in this way, for instance, abstract words like “friendship” or “underneath.” Obviously, this problem does not exist with the use of signs. Formerly, signs could only be displayed as drawings which were rather difficult to understand. A line drawing of a sign is not a very precise translation of the sign into print, it only displays the way the sign should be executed with various symbols for specific movements. Nowadays, as computer technology has increased, a digital video of sign with all movements can be shown. A video clip of the sign is likely much easier to comprehend than a static drawing of the sign.

A prominent distinction between pictures and signs is that pictures display an abstract image of the item and signs refer to the child’s preferred or in some cases the first language. Studies conducted with second language hearing participants indicate that learning to translate L2 to L1 words (Italian–Dutch) is easier than learning to associate the L2 words to pictures (Lotto & De Groot, 1998; but see Snodgrass, 1993). However, it is unclear whether such findings can be generalized to the condition in which sign language is the L1. Research findings with deaf children revealed that words which are part of the signed vocabulary, but not part of the reading vocabulary, are identified better if the drawing of the sign had been added to the instruction (Stoefen-Fisher & Ae Lee, 2001). In a study of Gentry, Chinn, and Moulton (2004/2005), stories presented by print and drawings were compared to stories presented through print plus sign language. The results indicated that the level of comprehension was highest for stories presented by print and drawings. Therefore, it is interesting to determine the effects of using drawings as compared to digital videos of signs in word identification exercises as described before. The words being used in this article were already part of the signed vocabulary of the participating deaf children but not yet of their written language vocabulary. The hypothesis is that using signs can help to build an association between the words and concepts they represent because signs directly draw upon the knowledge a child has already developed and therefore may provide a tie to the internal language system of the child (Stoefen-Fisher & Ae Lee, 2001).
Summarizing, this article investigates whether in word learning exercises for deaf children the orthography or semantics of a word needs to be emphasized in order to obtain the highest learning effect. A second research question is whether it is more effective in these exercises to use a picture or to use a digital video of a sign to refer to the word meaning. The expectation is that exercises which emphasize the orthography and use signs to refer to the word meaning will be most effective.

Method

Participants

Eleven children participated (six boys and five girls). They were recruited from four classes in two specialized primary schools in the west of the Netherlands. In these schools, instruction is given by Dutch sign language, Dutch with signs, and whatever means are available to inform children and communicate with them. The average age was 7;10 years (min = 6;8, max = 9;7). All children were profoundly deaf; the hearing loss ranged between 90 and 120 dB with a median of 103 dB. Ten children used external hearing aids, the hearing gains ranged between 15 and 45 dB. As reported by their teachers, the IQ scores of the deaf children, measured with a nonverbal standardized test by the school, varied from 77 to 98. Of four children, the teachers reported secondary deficits, for one child neurological and for three slight motor problems. These children did not perform differently than the others in the experimental training and testing though. One child had two deaf parents who were also native sign language users. Among the group of deaf children with hearing parents, nine had at least one native Dutch-speaking parent and one child had two non-Dutch-speaking parents.

The children had been for 2–5 years at the schools specialized in teaching children that are hard of hearing or deaf, but instruction in written language only began 1 or 2 years before this study was done. No formal or standardized reading test was available to establish the student’s actual reading levels at the beginning of the study, simply because no such test appropriate for children with deafness had been developed at the time this study was conducted. Because they were very well informed about their pupils’ academic skills, their teachers were confident that they could not read any more words than the ones that had been taught so far during 1 or 2 years classroom instruction (on average about 35 words, except perhaps a few additional ones, including their own and their friends names, for instance). The teachers also made a judgment about the expressive and receptive sign language skills of the children on an arbitrary scale from 0 to 3, ranging from “not able to communicate with signs” (0) to very good use of sign language (3). Each child was rated by two teachers, and consistency was near perfect. According to the teachers, two children had moderate signing skills, four were reported as fairly good signers, and five were very good signers. Irrespective of these judgments, we verified whether the participating children knew the signs of the words to be practiced. They all did.

Materials and Design

For this study, it was crucial that the words were part of the signed vocabulary of the children but not (yet) of their written language vocabulary. To select words that could be signed by all children, but not read, two pretests were administered. In the reading test, words were shown on paper and the children were asked to produce the corresponding sign. In the sign test, drawings were presented and the children had to show the corresponding sign. All words used for the pretest originated from the reading method for deaf children being used at the school, but the selected words had not yet been taught to these children and would not be included in regular reading lessons in the next few weeks while this study was carried out. Further requirements for the words were that by changing one or two letters, two other words would appear for which a drawing and a digital video of the sign was available. The videos used in this study were obtained from the Dutch Sign Center. Finally, also two words semantically related to the target had to be available, both with a drawing and digital video of sign. Knowledge of these orthographic and semantic distracters was also tested. All tests were preceded by a short explanation and a few examples. The target words and corresponding distracters finally selected were
all familiar in sign language, but unknown in print, as indicated by the results of the pretests (see the Appendix for the words used in this study).

Two different types of computer-based exercises for learning the mapping between single printed words and corresponding signs were compared. In one type, a word meaning by way of a picture or a sign was presented on screen, and the child is asked to select the correct word spelling from three alternative printed words. In the other form, a printed word is presented, and the child is invited to select the correct word meaning as represented by pictures or signs. Whatever selection the children made, appropriate feedback was given immediately, and in case an error was made, the correct answer was explicitly shown. In both conditions, the distracters were selected to resemble the target word, either orthographically or semantically. Whereas the goal for both types is to establish an association between the printed word and the word meaning, there is a difference in emphasis of the exercises which is related to the basis of selection. Because the distracters were quite similar to the correct answer, the child has to look very closely to the options in order to differentiate between them. When a selection has to be made from among three orthographically similar words, the emphasis of the exercise is assumed to be on the spelling of the word. Similarly, semantic emphasis is the result of having meaning related options for an answer.

A within-subject design was used. All children participated in all conditions. There were four different schemes of presentation: orthographic selection, with drawings or with sign, and semantic selection, drawings or with signs (see Table 1). Twenty words were assigned to conditions according to these schemes. To avoid that children had to learn too many words at a time, two practice periods were scheduled. In each period, 10 words were practiced. All children practiced the same words, but the mode of presentation differed. During the first period, six children received the words by orthographic selection and five by semantic selection. For five children, the word meanings of the even-numbered words were presented by signs and the odd-numbered words by drawings; for the other six children it was the other way around. In the second training period with 10 new words, the children who practiced orthographic selection were administered semantic selection and the children who practiced semantic selection first now received orthographic selection.

Procedure

A multimedia program installed on a laptop was used to present the exercises. During the practice periods, an experimenter was always present. In the exercises with orthographic selection, a drawing or sign was shown on top of the screen (see Figure 1; note that it is unfortunately impossible to show a dynamic video on paper). Underneath three words were presented, the correct alternative, for instance blad (leaf), and two orthographically alike spelled words, for example, klad (stain) and glad (smooth). In the semantic exercises, the written word was shown on top of the screen, and the representation of its meaning, by either a drawing or a sign, was shown underneath among semantically or conceptually related distracters (see Figure 2). For instance, for jurk (dress), the distracters were drawings or signs of trousers and sock. In the exercises with digital videos of signs, the movies started each time the cursor went over it.

The children selected an option by clicking on it. Immediately after making a choice, the child received

<table>
<thead>
<tr>
<th>Scheme of presentation</th>
<th>Training period 1</th>
<th>Training period 2</th>
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<tr>
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<td>Words 1, 3, 5, 7, 9</td>
<td>Words 2, 4, 6, 8, 10</td>
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<tr>
<td>Orthographic selection</td>
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<td>signs drawings signs drawings signs drawings</td>
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<td>Semantic selection</td>
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Table 1 The balancing of words across conditions
feedback. If correct, a happy face on a green background was shown in the middle of the screen and the answer turned green. If incorrect, a sad face on a red background was shown, the answer turned red and the correct alternative turned green. During training, the answers were saved by the computer program. Prior to the first training period, an instruction and practice session was scheduled. Each training period lasted three weeks in which the children practiced six times, twice a week. Per session, all words were presented three times, so in total all words were shown 18 times. On average, one session lasted about 10–15 min.

A few days after each training period, three posttests were administered: a reading test, a spelling test, and a word identification test. In the reading test, the practiced words were shown on paper and the children were asked to read the words and make the corresponding sign. In the spelling test, the experimenter presented the sign and the children had to write down the corresponding word. In the word identification test, the experimenter made the sign and the children had to select the correct word among four printed alternatives. The three distracters were orthographically alike pseudowords; for each alternative, the first, the last, or middle letter (or letter cluster) was changed. All tests were preceded by a short explanation and simple examples. For the reading test and the word identification test, one point was given for each answer. In the spelling test, two points were given for a correct word spelling and one point for each word of which half or more of the letters was spelled correctly.

Results

First, analyses were carried out on the data with respect to the performance during practice. The results are presented in Figure 3 as the percentage correct as a function of consecutive session and conditions of practice. The means per session are shown for a better overview although each session actually consists of three trials. It should be noted that because there always were three alternatives to choose among, chance level is already 33% correct. The data clearly show that in general the proportion correct is well above chance level. Second, the results clearly show that the orthographic selection is more difficult than the semantic selection exercises. Overall, the percentage correct is much higher in the exercises with semantic emphasis. Finally, the children steadily improved during training for the words practiced in the orthographic selection condition. No such increase was found for the words practiced in the semantic selection condition, although the scores during the first three trials in the first session were a little variable. But even the first trial, performance was on average about 80%. Also, as is evident from Figure 3, a ceiling effect for semantic selections is apparent in the later sessions.

The scores were subjected to multivariate analyses of variance (MANOVAs) with repeated measures in which type of exercise and mode of meaning reference were entered as within-subject factors. There was no statistically significant difference between the usage of drawings or signs during practice. The semantic

Figure 1 Example of an exercise with an orthographic emphasis; a leaf is shown and the first word (blad) is the correct choice. Note that instead of a picture also a movie of a sign could have been shown.

Figure 2 Example of an exercise with a semantic emphasis; the word jurk (dress) is shown and the alternatives show a jacket and a sock.
Selection exercises were significantly easier than the exercises that used orthographic selection; analysis of the accuracy rates that were registered during practice showed that there was a main effect for type of selection, $F(1, 10) = 569.88, p < .001, \eta^2_p = .98$. Also, a significant interaction effect for type of selection with session, $F(5, 6) = 6.89, p = .02, \eta^2_p = .85$, demonstrated that the difference decreases over sessions.

Before training, the children could not read any of the words used in this training experiment as evidenced by their performance on the pretests. The results of the posttest showed that after the training period, on average, 56% of the words were read correctly, whereas 26% of the words were spelled correctly. The results of the word recognition test showed that 78% of the words were correctly identified by the subjects. Note that, for this latter test, the chance level of correct word identification is already 25% but that the scores are well above guessing rate. The average percentage correct of the children on the posttests as a function of condition of practice is presented in Figure 4. As can be seen in this Figure, the reading scores show a substantial difference between orthographic and semantic selection, and the other tests show differences in the same direction. Also, the difference between practice using signs versus drawings is relatively small but quite consistent. In all conditions, higher posttest scores were obtained when words were practiced with drawings as a means to refer to meaning.

The scores on the three posttests were subjected to MANOVAs for repeated measures with type of exercise and mode of meaning representation as within-subjects factors. Higher scores were obtained for words that were practiced in the orthographic selection condition. The overall MANOVA revealed a significant effect of practice condition, $F(1, 10) = 16.06, p < .01, \eta^2_p = .62$, and a significant interaction effect between condition and type of posttest, $F(2, 9) = 11.23, p < .01, \eta^2_p = .71$. The latter interaction indicates that the effect is more pronounced for the reading test in comparison to the other tests. Planned comparisons for each type of posttest showed that scores after the orthographic selection exercises were significantly higher than after semantic exercises, $p$'s < .04. When word meaning was indicated by a drawing during training, higher scores were obtained.
in the posttests than when words were represented by signs, but the overall difference between the usage of drawings and signs was not statistically significant. Planned contrasts for each posttest separately showed that only for the spelling test a significant effect for mode of meaning representation appeared, \( F(1, 10) = 4.81, p = .05 \), effect size \( \eta^2_p = .33 \). No relationships or interactions with facility in using sign language as indicated by teachers’ judgments were found.

Finally, an analysis was made of the conditional probability of reading and spelling a word correctly in the posttest. The data show that of the words correctly read in the posttest, 48% is spelled correctly. At the other hand, if a word is spelled correctly then 84% of these words are also read correctly.

**Discussion**

Because reading skills of deaf children are generally quite low, extensive individualized instruction and practice are essential in order to increase word identification skills and written language vocabularies. This article evaluated computer-based reading exercises in order to determine the effects of emphasizing either the orthographic or the semantic characteristics of a word. In the exercises, the options involved either presenting the word meaning, by a drawing or a sign, and asking the child to select the correct word spelling or to present the word spelling and inviting the child to select the correct word meaning as represented by drawings or signs. Distracters resembled the target word, either orthographically or semantically. Because of the very process of selecting the correct answer, the exercises are considered to have an orthographic or semantic emphasis, respectively. The second research question was whether in such exercises the word meaning is best represented by drawings or by signs.

The findings of the posttest demonstrate that it is very well possible for deaf children to learn new printed words by using computer-based exercises. On average, the children have learned to read correctly about 12 words out of 20, whereas they could not read a single word of these before the training began. The spelling scores in the posttest were considerably lower, about 20% correct. This smaller learning effect is not very surprising because in general spelling is much harder than reading, probably even more so when there is no corresponding pattern of sound segments that can be consulted. The scores on the word identification test were obviously the highest, but it should be noted that for this test 1 out of 4 could already be correct on basis of guessing. Although it is unknown how much guessing actually occurred, the true score is probably lower than 78% and thus approaches the averaged score on the reading test (56% correct).

Overall, the results of this study are quite encouraging with regard to the possibilities of using computer-based exercises in the education of deaf children. Using computer-assisted practice in teaching deaf children to read may appear to be flexible and very efficient, that is, very cost effective in situations where the student-to-teacher ratio is generally low. Although the current experiment was not designed as an intervention study per se, it should be noted that this group of children learned to read only about 35 words in 1 or 2 years in regular classroom. Learning about 12 words on average in a few weeks time suggests that using a computer-based program is quite promising.

With regard to the main research question, the results revealed that in the reading posttest words practiced in the orthographic conditions were recalled better than words of which the word meaning had been practiced. Confirming findings were found for the spelling posttest and for the word identification posttest, as can be seen in Figure 4. Although this small scale study did not reveal spectacular effects, the findings are quite consistent over the three posttests. One reason that the effect is not so impressive might be related to the fact that during training for one target word always the same orthographically similar alternatives were presented. The children may easily also have learned about which words were not the targets using a rather limited set of discriminating cues. For example, the words in Figure 1 can be discriminated on basis of the first letter only. A correct answer can be given after inspecting just this first letter and ignoring the other letters. However, as is clear from the list of words in the Appendix, the example in Figure 1 is in fact representative of only three cases where letter alternatives are restricted to one position. The other words and corresponding alternatives are dissimilar in at least two positions for the
same target. A simple strategy to focus on fixed positions would thus not be very helpful overall. Still, the children might have developed a strategy to select per item the letters that were crucial to differentiate and pay increasingly less attention to the other letters. Therefore, one possible way to boost the training effects might be to present various alternatives with dissimilarities in all positions throughout, so that complete inspection of words is necessary before the correct word can be selected.

The finding of consistent higher effects with orthographic emphasis during printed word training suggests that confronting a deaf child with alternative spellings stimulates the knowledge of the word specific and unique pattern of letters. This knowledge is apparently functional in that it can be used in later reading and maybe in spelling when more practice is provided. The results thus do support the hypothesis that exercises that emphasize the orthographic characteristics of a word will be most effective for learning to read new words. The format of the exercise seems to successfully counter the often observed tendency of deaf children to only globally look at printed words. Instead, the procedure encouraged them to closely attend to the letter structure. Knowledge about the complete letter pattern is necessary both for accurate reading and for spelling. The posttest results indicate that an exercise with an emphasis on the meaning of the word is less effective with regard to learning the orthographic details.

One could argue that the relatively lower learning effects of the semantic condition are a consequence of the high proportion of correct responses during practice. The results of the training sessions show that the scores quickly approached ceiling, even taking into account the guessing rate. Apparently, the children found it quite easy to choose the correct picture or sign (from a choice of three) that matched a printed word. Although semantically related pictures or signs were used (e.g., dress, trousers, sock), the children were fairly confident in selecting the picture or sign corresponding to the word. These findings demonstrate that deaf children in this situation had no problem in distinguishing among related semantic references and readily learn to associate the printed word with the corresponding picture or sign. However, they were able to establish this association without fully attending to the orthographic details of the printed word. It should be noted that in the current experiment the target words did not share many orthographic patterns and were quite dissimilar. The children could therefore rely on a quick look and only use partial cues of the printed word to discriminate between the small set of associations to be practiced. This type of practice does apparently generate less accurate knowledge of the printed word than the orthographic exercises in which a more detailed discrimination of printed words is required. The knowledge acquired in the semantic condition is therefore less adequate for independent and functional use in later posttests.

Another object of this article was to investigate the usage of drawings and signs as a way for referring to word meanings during practice. The results indicate that words which were accompanied by drawings in the training tend to have higher scores in the posttests than words of which the word meanings were presented by signs. This finding was consistent for the various posttests but statistically significant only for the spelling test. This result contradicts the hypothesis that sign would facilitate reading more than drawings. However, they seem to square with the study conducted by Gentry et al. (2004/2005). They found that the level of comprehension was significantly higher for stories presented by print and drawings than for stories presented through print plus sign language. Gentry et al. argued that their findings could be explained because teachers of deaf children traditionally make heavy use of pictures when teaching reading. This is true for the present group of deaf children too. In the reading, education pictures are used abundantly and children might therefore be accustomed to associate printed words to pictures. Another explanation of the fact that more words were learned when pictures were used to refer to the meaning might be that drawings have an advantage over videos of signs in terms of attentional resources. Drawings can be perceived at a single glance during the exercises, whereas a sign takes time to completely see the movements. Therefore, it may be possible that for storing information about new written words, glancing quickly at a drawing is more efficient than looking at a sign. Of course,
there are many words that cannot easily be represented by a simple picture. For abstract words, signs are needed. Also, using signs may be more natural because it directly relates to the first language of most profoundly deaf children. But the present results suggest that signs should be used judiciously in exercises for beginning reading. A picture can be worth a thousand words or signs for that matter.

Limitations and Further Studies

In this article, only 11 profoundly deaf children participated. Although this small number of participants is not unusual in research with deaf children, a larger number is clearly necessary in order to determine the effects of these exercises more robustly. Also, a larger group is required when issues with respect to individual differences in learning are investigated. In this article, we did not find an effect of differences in the facility of using sign language, but it would be interesting to see in a larger study whether there are differential effects in the extent to which children do profit from these exercises and which factors would contribute to such differences.

Another limitation of this article is the relatively brief period of training and the limited number of words that were presented. It is obvious that for an ultimate evaluation of the relative effects of the different exercises, a longer period of training and many different words should be planned. Such an extended period of using the computer-based exercises would also be interesting for the education of the deaf because it would bear a resemblance to actually using it on an almost daily basis in the schools. Related to this, it would be important to find out whether children can and will use the exercises independently. In this article, the research assistant was present all sessions in order to observe the process, and if needed, to respond to questions. The program is, however, designed to allow children to practice independently at any time that is convenient for them or would fit classroom activities. Although the children in this article reported to enjoy the exercises throughout, an relevant question would be whether they remain motivated and interested when they work independently for many weeks or months.

With respect to the differences obtained between the use of signs and the use of drawings, it should be noted that the words that were selected were all concrete because of the planned research contrast. Of course, there are many words and concepts that are difficult to capture in a picture or drawing. Therefore, the use of dynamic signs will surely be an essential ingredient of further computer-based exercises. We now presented a printed word either with a drawing or with a sign. But one could hypothesize that a combination of the two is even better, if available. Still, the use of pictures or drawings and video clip of a sign are relatively old-fashioned approaches. There is no reason not to explore the possibilities of using digitized photos and video clips of actual events to illustrate the meaning. Further research should be done to find out what the optimal ways are to refer to the meaning of words.

Finally, the results suggest that a strong focus on the letter pattern of the words is most profitable in learning new words. However, in the present exercises, the focus was relatively indirect. The basic idea was that the children were required to inspect the letter pattern more closely when orthographically similar words were presented. One may wonder though whether a stronger focus would be even more beneficial. One way to attain such concentration on the pattern of letters is obviously to help the deaf child to learn to spell the word. In the process of spelling a word, all the letters should be attended to. In a computer-based exercise, one could, for example, start with copying a word letter by letter and gradually move to attempts to spell by heart. Because spelling requires knowledge about the full pattern of letters, it would be interesting therefore to see how reading accuracy improves by guided practice in trying to spell the word.

Conclusion and Implications

First of all, the findings of this study have successfully demonstrated that computer-based exercises can contribute to learning to read in profoundly deaf children. Second, encouraging children to carefully inspect the letter by letter pattern of words do lead to higher scores in reading than emphasizing the
correspondence between printed word and meaning. Because deaf children cannot readily use phonological decoding modes to identify words, detailed knowledge of word spelling is quite important. Therefore, exercises should be used that promotes the knowledge of the orthographic pattern of words. The rather simple way of using orthographically similar distracters in this article already showed to improve learning scores.

It is clear that for developing a considerable vocabulary with fully specified orthographic representations, much practice and guidance is needed. Computer-based literacy exercises may play an important role to provide such opportunities for practice.

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Appendix: Target words and orthographic and semantic distracters per training period

<table>
<thead>
<tr>
<th></th>
<th>Orthographic</th>
<th>Semantic</th>
</tr>
</thead>
<tbody>
<tr>
<td>First training period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bril (glasses)</td>
<td>Tril</td>
<td>Hearing aid</td>
</tr>
<tr>
<td>Snoep (candy)</td>
<td>Snoer</td>
<td>Ice cream</td>
</tr>
<tr>
<td>Kopje (cup)</td>
<td>Dopje</td>
<td>Mug</td>
</tr>
<tr>
<td>Lepel (spoon)</td>
<td>Klepel</td>
<td>Knife</td>
</tr>
<tr>
<td>Spin (spider)</td>
<td>Spil</td>
<td>Fly</td>
</tr>
<tr>
<td>Trein (train)</td>
<td>Troon</td>
<td>Bus</td>
</tr>
<tr>
<td>Rug (back)</td>
<td>Rug</td>
<td>Stomach</td>
</tr>
<tr>
<td>Jurk (dress)</td>
<td>Kurk</td>
<td>Trouser</td>
</tr>
<tr>
<td>Blad (leaf)</td>
<td>Klad</td>
<td>Plant</td>
</tr>
<tr>
<td>Bank (couch)</td>
<td>Tânk</td>
<td>Chair</td>
</tr>
<tr>
<td>Second training period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan (pan)</td>
<td>Pin</td>
<td>Scissors</td>
</tr>
<tr>
<td>Jongen (boy)</td>
<td>Jongen</td>
<td>Girl</td>
</tr>
<tr>
<td>Bord (plate)</td>
<td>Borg</td>
<td>Knife</td>
</tr>
<tr>
<td>Toren (tower)</td>
<td>Turen</td>
<td>House</td>
</tr>
<tr>
<td>Ring (ring)</td>
<td>Ving</td>
<td>Cap</td>
</tr>
<tr>
<td>Wolk (cloud)</td>
<td>Wolk</td>
<td>Sun</td>
</tr>
<tr>
<td>Tand (tooth)</td>
<td>Tang</td>
<td>Hair</td>
</tr>
<tr>
<td>Taart (pastry)</td>
<td>Kaart</td>
<td>Cake</td>
</tr>
<tr>
<td>Keel (throat)</td>
<td>Meel</td>
<td>Belly</td>
</tr>
<tr>
<td>Muis (mouse)</td>
<td>Muïs</td>
<td>Frog</td>
</tr>
</tbody>
</table>

Note. Some distracters are used in the first as well as the second training period. However, because the children practiced only in one training period with semantic emphasis, they never saw the words twice.

References


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