What the Processing of Real Words and Pseudohomophones Can Tell Us about the Development of Orthographic Knowledge in Prelingually Deafened Individuals

Paul Miller
University of Haifa

This study represents an attempt to determine the nature and efficiency of the strategies used by prelingually deafened individuals for the recognition of written words with reference to an orthographic self-teaching concept (D. L. Share, 1995). A research paradigm asking the participants to make categorical judgments for real words and pseudohomophones of the real words was used for gathering the data. Participants were prelingually deafened, native signers ($n = 11$, age $= 14.18$) and a hearing control group ($n = 25$, age $= 15.00$). In general, findings suggest that, although the participants with deafness were very impaired in their phonological decoding abilities, their efficiency in recognizing and categorizing written words was similar to that of their hearing counterparts. This suggests that they must have developed strategies for the acquisition of orthographic knowledge that do not rely on phonology.

The ultimate goal of reading is comprehension. However, to achieve this goal the novice reader first has to learn to efficiently recognize the building blocks of a sentence, the words. According to current theory, there are at least two strategies readers of alphabetic orthographies use for the recognition of written words (Jackson & Coltheart, 2001). The first of these strategies converts the graphemes of written words into corresponding phonemes and assembles them into phonological entities that serve as the basis for their identification in the reader’s phonological lexicon. The second strategy connects letter strings of written words with mental, orthographic representations that mediate the recognition of their meaning.

Whereas both these routes principally provide gateways to word meaning, proficient reading has been claimed to rely mainly on the direct, orthographic route (see for example Frith, 1986), along which the identification of written words is significantly faster (e.g., Paap & Noel, 1991). Such enhancement in identification may prove particularly beneficial for the comprehension of complex sentences which—due to extensive structural processing—make heavy demands on Working Memory resources.

In view of the crucial role assigned to orthographic knowledge in proficient reading, the conditions underlying its development have recently become the subject of particularly vivid dispute (e.g., Rastle & Coltheart, 1999; Shankweiler, 1999). At the core of this disagreement are questions concerned with the role played by phonology in the development of permanent orthographic representations for written words, on the one hand, and the way such representations mediate meaning, on the other hand (Frost, 1998; Jackson & Coltheart, 2001).

A theory that has gained wide attention in this respect is the self-teaching concept of Share (1995), according to which nearly all printed word learning takes place when children independently identify unfamiliar letter strings they encounter in the course of everyday reading. From a self-teaching perspective, for the formation of well-specified orthographic representations visual exposure to written words is not
sufficient (Share, 2004). This position is in line with findings suggesting that neither direct instruction nor contextual guessing constitutes a viable means for the identification of specific lexical identities in written words as the basis for orthographic learning (e.g., Share, 1995). As there is no evidence linking the formation of orthographic representation for written words to their visual processing, Share argues that the formation of well-specified orthographic representations is the result of the exhaustive letter-by-letter decoding (en route to a correct pronunciation) that draws the attention of the reader to the order and identity of letters within the read letter string (Share, 2004). In other words, it is the phonological decoding of the novel letter string that initially attunes the attention of the reader to the orthographic information of the word (the letter graphemes) and connects it with meaning.

The position that assigns phonological decoding a central role in the formation of orthographic knowledge as the basis for proficient reading is in line with an abundant body of evidence that links delay in the acquisition of reading skills, as well as persistent reading disorders in individuals with intact hearing, to deficiencies in their phonological abilities (e.g., Ehri, Nunes, Stahl, & Willows, 2001; Report of the National Reading Panel, 2000; Troia, 2004; Vellutino, Fletcher, Snowling, & Scanlon, 2004, for reviews). In particular, phonemic awareness—the basis for the mapping of orthographic units to their phonological counterparts—and pseudoword reading—as an indication of letter-by-letter decoding—have in recent years become true forerunners in the prediction of reading development and the diagnosis of reading disorders. Findings in this respect actually suggest that being weak in these domains puts individuals at risk for reading failure (e.g., Stanovich, 2000; Troia, 2004; Vellutino et al., 2004).

According to the self-teaching concept (Share, 1995, 2004), inefficient phonological decoding skills affect reading comprehension via their impact on the processing of words at the lexical level (e.g., Vellutino et al., 2004). On the one hand, deficient phonological skills are assumed to manifest in a slow and likely imprecise reading of written words by means of a grapheme-to-phoneme conversion routine. As a consequence, the proper functioning of higher order processes operating on the words of a sentence for determining its meaning is not guaranteed, which may lead to comprehension breakdown. On the other hand, the slow and imprecise phonological decoding of written words is assumed also to result in the development of impaired orthographic representations that fail to efficiently mediate their meaning based upon their orthographic properties.

Going by this line of argumentation, severe phonological deficits are expected to undermine word-reading fluency, whether the reader accesses meaning via the assembled phonology of words (indirect route) or via their association with orthographic representations (direct route). Yet, several findings obtained from studies conducted with readers with prelingually acquired deafness suggest that the validity of this hypothesis in its strong sense may not be tenable (Harris & Beech, 1998; Harris & Moreno, 2004; Izzo, 2002; Kelly, 2003; Miller, 1997, 2000, 2001, 2002a, 2002b, 2004a, 2004b, 2005, in press-a, in press-b; Walters & Doehring, 1990).

Permanent, profound hearing impairments from early childhood undoubtedly have detrimental consequences for ability of an individual to develop phonological memories. This is clearly indicated by evidence that shows that the awareness of such individuals to the phonological building blocks of spoken words is drastically reduced (Charlier & Leybaert, 2000; Dyer, MacSweeney, Szczerbinski, & Campbell, 2003; Hanson & Fowler, 1987; Hanson & McGarr, 1989; Miller, 1997; Sutcliffe, Dowker, & Campbell, 1999; Transler, Leybaert, & Gombert, 1999; for a review on this subject see Nielsen & Leutke-Stahlman, 2002). In a sense, one can hardly avoid the impression that their impoverished perception of speech often prevents individuals with prelingual deafness from establishing sufficiently specified phonological representations, representations that—according to the self-teaching notion—are claimed to be at the core of the ability of readers to decode written words phonologically, and of their success to build up proper orthographic knowledge.

It is however noteworthy that such failure in acquiring proper phonological knowledge may not be a necessary consequence of prelingual deafness.
This has been convincingly demonstrated in a line of research (Charlier & Leybaert, 2000; LaSasso, Crain, & Leybaert, 2003; Leybaert & Lechat, 2001) examining the phonological skills of individuals from a background where oral communication is sustained by cued speech ([CS] Cornett, 1994), a system that visually (manually) conveys phonemic information that the severely hearing impaired can no longer perceive unambiguously from speech reading, either because of where the articulation in the vocal tract takes place (gutturals) or because it coincides with other phonemic information that is identical in visual appearance on the speakers lips (e.g., voiced d/t). Findings from such research actually show that—particularly when provided from early childhood—consistent exposure to CS sustained communication fosters phonological skills in prelingually deafened individuals who are comparable to those of their hearing counterparts.

At first glance, the fact that, as a group, the reading comprehension skills of individuals with severe, prelingual hearing impairments have been found to lag far behind those of regular readers (Miller, 2000, 2005, in press-b; see Marschark & Harris, 1996; Musselman, 2000; Paul, 2001, for reviews) seems to be consistent with a standpoint that their impoverished reading skills reflect, at least partly, the impact of their phonological deficits upon the processing of written words (Padden & Hanson, 2000; Perfetti & Sandak, 2000). This conclusion is directly suggested by findings showing that differences in the phonological abilities of readers with prelingual deafness (phonemic awareness, phonological decoding) are indicative of their reading levels (Campbell & Wright, 1988; Dyer et al., 2003; Hanson, Libermann, & Shankweiler, 1984; Harris & Beech, 1998). However, several recent findings suggest that this conclusion warrants reconsideration.

First, Izzo (2002) convincingly demonstrates that the reading comprehension level of individuals who are deaf is not associated with their phonemic awareness (see also Miller, 1997). Second, individuals with prelingual deafness were consistently found to show hearing-comparable word-processing skills (Miller, 2002a, 2004a, 2004b, 2004c, 2005, in press-a, in press-b), this in contrast to task-matched dyslectic readers whose ability to process written words proved to be significantly impaired (Miller, in press-a). Third, there is some evidence that pinpoints decoding automaticity—rather than phonological coding per se—as the factor determining reading comprehension in individuals who are deaf (Kelly, 2003).

Evidence from the investigation of readers with deafness seems to argue against the condition sine qua non status assigned to phonological decoding in the explanation of reading failure, in general, and reading failure in prelingually deafened readers, in particular (Izzo, 2002; Miller, 2002a, 2004a, 2004b, 2005, in press-a, in press-b; Olson & Caramazza, 2004; see also Swanson, Trainin, Necoechea, & Hammill, 2003 reaching a similar conclusion based on findings obtained from experiments conducted with hearing readers). However, it has not been demonstrated directly, so far, that the knowledge used by individuals who are deaf for mediating the meaning of written words did not evolve from their phonological abilities, nor has it been shown that such individuals are capable of efficiently processing written words that they may not be able to decode phonologically.

This article represents an attempt to shed light on these issues by contrasting the word-processing skills of prelingually deafened readers and a control group of hearing readers with their abilities to process pseudohomophonic nonsense letter strings. All research hypotheses tested were based on the assumption that phonological decoding underlies the proper functioning of the orthographic self-teaching mechanism (self-teaching notion, Share, 1995). Therefore, we predicted that individuals able to recognize the meaning of a written real word would also be capable of recognizing the same word when presented as a pseudohomophonic nonsense letter string—by means of its phonological decoding.

For the processing of pseudohomophones—because they are not represented in orthographic memory—the reader necessarily has to resort to a grapheme-to-phoneme conversion procedure. We therefore predicted that their processing would prove to be significantly slower in comparison to processing of the paralleling real words. Finally, we hypothesized that individuals with prelingual deafness—due to their impoverished phonological skills—would be disadvantaged relative to their hearing counterparts. We expected this to be true whether they would be asked
to process real words or pseudohomophonic nonsense letter strings.

Method

Participants

Eleven native signing students with prelingual deafness and a control group of 25 hearing students participated in the experiment. According to their personal files, the intelligence of all participants was within the range accepted as normal for age. Moreover, all of them had intact or corrected-to-intact vision. None of them was diagnosed as having a specific learning disability, and all of them had Hebrew as their first spoken language.

Deaf participants. Deaf participants were selected according to five criteria. (a) Their unaided pure tone hearing in the better ear at the frequencies 0.5, 1.0, and 2.0 kHz was 85 dBHL or higher (American National Standards Institute, 1989). (b) Their deafness was hereditary. This criterion was set because—in contrast to acquired deafness that often is accompanied by additional cognitive malfunctioning—the impact of hereditary deafness is normally limited to the auditory domain. (c) Both their parents were deaf. (d) Their primary language was Israeli Sign Language (ISL). This criterion was set to ascertain that the participants who were deaf were in possession of a fully fledged language that served them as a vehicle for cognition and communication. (e) Their first spoken language was Hebrew.

Five of the participants with deafness were boys and six were girls. Due to the low prevalence of hereditary deafness, the students included in the deaf group were selected from different schools and from several grade levels. Four of them were seventh graders, three were eighth graders, two were ninth graders, and two were tenth graders. According to their personal files none of them had been obliged to repeat a class. The average grade level of the deaf group was 8.18 (1.17) with a mean chronological age of 168 months (range 148–198 months).

One of the seventh graders and the two tenth graders were fully integrated into regular hearing classes. The remaining nine participants visited deaf classes where the simultaneous use of spoken language in conjunction with Signed Hebrew is used for instructional purposes. They were, however, all partly mainstreamed into hearing classes during activities such as arts and sport. Some of them were also mainstreamed in mathematics.

The phonemic awareness of the participants was examined in a parallel experiment based on a test developed especially for the assessment of phonemic awareness in individuals who are deaf (Miller, 1997). This test assesses two particular domains, namely sensitivity to the initial phoneme or to the final phoneme of picture names. Each domain was tested by means of 12 four-picture series, with two pictures in each series whose names had a particular phonological feature in common. An average score calculated for the two assessed domains shows that the phonemic awareness of participants with deafness proved to be very poor, both relative to the test scale (5.73 [2.19] on a 12-point scale) and to the phonemic awareness of the participants from the hearing control group (5.73 [2.19] vs. 11.60 [0.71]). Moreover, according to teacher ratings the vast majority of them had reading comprehension skills well below those of age-matched hearing students.

Hearing participants. The participants in the hearing control group—7 eighth graders, 11 ninth graders, and 7 tenth graders—were selected from classes paralleling those of the individuals in the deaf group. Thirteen of them were boys and 12 were girls. For all of them, Spoken Hebrew was the mother tongue. Only individuals with intact reading skills were included. The average grade level of the participants in the control group was 9.00 (0.76) with a mean chronological age of 179 months (range 162–197 months).

Initially, it was planned to test four signing individuals from grade levels paralleling those of the individuals included in the control group. Regrettably, due to the low prevalence of native signing individuals fitting the research criteria, the number of such individuals we succeeded in identifying in Northern Israel was much smaller (eight). To achieve a reasonable sample size of native signing individuals, it was therefore decided to include in the signer group four individuals from grade level seven who fit the selection criteria.
cited above. This explains why, in the average, the grade level of the hearing control group was somewhat higher in comparison to that of the signer group.

Stimuli

In Hebrew, a significant part of phonetic (in particular vowel) information is not represented by letter graphemes interlaced into the consonantal letters, but by means of a set of small diacritical marks (dashes and points) normally placed separately and clearly below the consonantal letter string. This method of vowelization is called pointing.

In recent years, Hebrew orthography has been shown to be particularly fruitful ground for the investigation of the reading process (see Shimron, 1993, 1999, for a review of this line of research). This suitability arises from some of its orthographic features, which allow the manipulation of written Hebrew words’ graphemic and phonological levels in a straightforward manner. One of these features is the phenomenon that several letter graphemes and some vowel diacritics (pointing) of the Hebrew alphabet, although historically standing for different phonemes, have ceased to carry phonetically distinguishable information for the Modern Hebrew reader. As a result, some of the phonemes comprising Hebrew have become codable by more than one grapheme.5

Another feature of Hebrew orthography is manifested in the fact that the phonetic values represented by its letter graphemes and vowel diacritics are highly predictable. This makes pointed Hebrew a shallow orthography that permits the phonology of written words to be efficiently assembled by means of a grapheme-to-phoneme conversion routine. The diversity of homophony between different letter graphemes or between different vowel diacritics, on the one hand, and the high predictability of their phonetic values, on the other hand, has been extensively used by researchers for the manipulation of the phonological and graphemic levels of Hebrew words, manipulations designed to elucidate particularities regarding the reading process in Hebrew. The method used for testing the research hypotheses of this article is based on an experimental categorical decision paradigm developed by Share and Raviv (2002) that extensively utilized the possibilities arising from the unique grapheme-phoneme relationship in pointed Hebrew for preparing the stimulus materials.

The paradigm includes two experimental conditions: a real-word reading condition and a pseudohomophone reading condition (see Appendix). The real-word reading condition presents participants with a list of 100 fully pointed (fully vowelized) Hebrew letter strings, arranged in four columns on an A4 sheet. All the letter strings represent Hebrew nouns of various lengths and frequency. Among the letter strings, randomly distributed over the four rows, are 31 nouns referencing concepts of food. The task is to circle as quickly as possible all the food concepts, starting with the first letter string at the top of the first column, and advancing in a top-down, right-to-left manner, column by column, through to the last letter string. A separate sheet comprising an additional six letter strings presented in one column—some of them food concepts—is used for task explanation and practice.

The pseudohomophone reading condition is identical with the real-word reading condition except in three regards: (a) The letter strings used for stimulation are pseudohomophones of the nouns of the real words used in the real-word reading condition, (b) the pseudohomophonic letter strings presented in the four columns are distributed differently, and (c) there are also some differences regarding the instructions given during task explanation (see Procedure section below).

The pseudohomophones (PH) used for stimulation are nonsense letter strings created by exchanging some of the letter graphemes of the real words (RW) used in the real-word version by different, homophonic letter graphemes (e.g., RW = יִזְרֵאֵל [piteria] vs. PH = מִזְרֵאֵל [piteria] = mushroom). In some instances, phoneme substitution also includes the replacement of letter graphemes by diacritics of identical phonetic value and vice versa (e.g., RW = רֹטֶב [rotev] vs. PH = דָּשֶּן [rotev] = dressing/sausage). Yet, no matter what substitutions formed the basis for creating the pseudohomophones, their orthography—as that of their paralleling real words—remains shallow (see Appendix), allowing their straightforward phonological decoding based on a simple set of grapheme-to-phoneme conversion rules (see details regarding the characteristics of pointed Hebrew...
above). Thus, we assumed that the execution of the paradigm by the two participant groups should be adequate for elucidating evidence regarding the efficiency of their reading strategies as well as whether the development of these strategies is rooted in the phonological abilities of the participants.

Procedure

The experiment was conducted in a quiet room. All participants were tested individually. For participants with deafness, explanations and instructions were given both in spoken Hebrew (by the experimenter) and in ISL (by a professional ISL/Hebrew translator). The real-word condition was always tested first.

The participants were asked to sit in front of a table with the experimenter sitting to their right. The experimenter informed the participants that they would have to circle the words in a word list representing things human beings eat. He then placed the practice sheet in front of them and demonstrated the task by circling the first food concept in the practice list. After the demonstration, he told the participants to circle the remaining food concepts in the practice list. After the experimenter was confident that the participants understood the task requirements, he moved on to administer the real-word test sheet.

The experimenter placed the real-word reading test sheet in front of the participants, covered by a cardboard. He informed the participants that, on the covered test sheet were four columns of words, some of which designate some kind of food. He instructed them that they should read the words silently from the top of the farthest right column in a top–down, right-to-left manner and to circle those representing things people eat, as practiced before. He told them to raise a hand or to say “finished,” when they reach the end of the list.

The experimenter informed the participants that he is going to measure time and that therefore they should mark the words representing food concepts as quickly as possible, still reading them carefully to prevent mistakes. The moment the participants indicated their readiness, they were told to concentrate on the right upper corner of the cover cardboard and to hold the pencil prepared for marking. The experimenter then removed the cardboard at once and started the stopwatch. Timing was stopped the moment the participants indicated that they finished reading the last word. Both time and the adequacy of the markings of the participants were recorded for subsequent analyses.

The pseudohomophone reading condition was tested after a 2-min relaxation break. The experimenter told the participants that they would now see a list of letter strings that sound like familiar words when they are read, although their spelling is not correct. He then presented the practice sheet to the participants, voiced out the first two pseudohomophonic letter strings, and demonstrated that both sound like words and that one of them sounds like a food concept. He then asked the participants to indicate among the remaining letter strings on the practice sheet those that sound like something that is eaten. None of the hearing participants had particular problems in understanding the task.

For some of the participants who were deaf, some practice was required until their performance indicated that they understood the task requirements. Such practice, if necessary, included the repeated, random identification of the pseudohomophones presented on the practice sheet based on their overt voicing. In any case, the experimenter administered the pseudohomophone reading test to the participants only after their ability to identify the pseudohomophones used for practice demonstrated unequivocally that they understood the idea of pseudohomophony. The procedure used for the administration of the pseudohomophone reading test was identical with the one used for administering the real-word reading test.

Results

The findings presented in this section were obtained from the analyses of five aspects of the two tests used to examine the word-decoding skills of the two participant groups, namely (a) findings related to differences in the groups’ abilities to categorize real words as opposed to pseudohomophones, (b) findings concerning the rates of misidentified real words and pseudohomophones, (c) findings concerning the speed of processing of the two stimuli categories, (d) findings regarding
relevant correlations between the two experimental conditions as well as between the different processing dimensions of each of these conditions, and (e) findings related to developmental aspects of the participants’ performance. Subsequently, the findings are reported in the above order.

Dealing with a population with a very low prevalence within the general population, the sample size of the signer group turned out to be relatively small and very different in size to that of the hearing control. It was therefore decided to execute all analyses in both parametric and nonparametric statistics. We expected that using both a parametric and nonparametric approach would strengthen the validity of the findings. However, within the Result section, the findings reported by default were obtained based on parametric statistics. It was decided to report results yielded by nonparametric statistics only in instances where they contradict with the findings from parametric analyses or for emphasizing the validity of a particular finding.

The first series of analyses compared the quantity of the correctly categorized (identified) food concepts by the two participant groups in relation to differences in stimulus type. In a first step, a comparison based on a multivariate analysis of variance (MANOVA) was executed. In this comparison, we computed stimulus type (real word, pseudohomophone) as the within-subject factor and group (signer, hearing) as the between-subject factor. Averages for correctly categorized real words and pseudohomophones are presented in Table 1.

A statistically significant effect of stimulus type was yielded, $F(1, 34) = 220.90, p < .001$, suggesting that, overall, the participants correctly identified and categorized more letter strings in the real-word reading condition than in the pseudohomophone reading condition. The group effect was statistically significant, $F(1, 34) = 73.94, p < .001$, suggesting that, in comparison to the signer group, the hearing control group was more successful in identifying letter strings referencing food concepts.

A significant interaction between the two main effects, $F(1, 34) = 112.87, p < .001$, indicated, however, that this performance gap between the two participant groups was not uniform in the two reading conditions. Indeed, a post hoc analysis conducted with one-way analysis of variance (ANOVA) comparing the participant groups’ rates of correctly identified food concepts in the real-word reading condition and the pseudohomophone reading condition separately revealed no statistically significant evidence that the individuals from the signer group were inferior to their hearing counterparts when required to indicate food concepts from among real words. Yet, in doing the same with pseudohomophones, the participants from the signer group were found to be markedly disadvantaged.

The second series of analyses compared the quantity of incorrectly categorized (identified) food concepts by the two participant groups with respect to the two stimulus categories. Averages for incorrectly categorized real words and pseudohomophones are presented in Table 2.

Although error rates were generally very small, a comparison analysis based on MANOVA was executed with stimulus type (real word, pseudohomophone) computed as the within-subject factor and group (signer, hearing) as the between-subject factor. A statistically significant effect of stimulus type was yielded,

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean number of correctly categorized real words and pseudohomophones for the prelingually deaf, control, and combined groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td>Number of correctly categorized items$^a$</td>
</tr>
<tr>
<td>groups</td>
<td>Real words</td>
</tr>
<tr>
<td>Deaf</td>
<td>27.82 (5.04)</td>
</tr>
<tr>
<td>Hearing</td>
<td>30.08 (2.06)</td>
</tr>
<tr>
<td>All participants</td>
<td>29.39 (3.36)</td>
</tr>
</tbody>
</table>

$^a$Maximum per item type = 31.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Mean number of incorrectly categorized real words and pseudohomophones for the prelingually deaf, control, and combined groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td>Number of correctly categorized items$^a$</td>
</tr>
<tr>
<td>groups</td>
<td>Real words</td>
</tr>
<tr>
<td>Deaf</td>
<td>0.73 (1.27)</td>
</tr>
<tr>
<td>Hearing</td>
<td>0.12 (0.44)</td>
</tr>
<tr>
<td>All participants</td>
<td>0.31 (0.82)</td>
</tr>
</tbody>
</table>

$^a$Maximum per item type = 69.
interaction between the two main effects was statistically not significant, suggesting that the impact of stimulus type upon the two participant groups was uniform.

Although not warranted by the lack of group effect obtained in the MANOVA analysis because of rather large standard deviations observed in relation to the group means, it was decided to also conduct a post hoc analysis comparing the groups’ processing speed for real words and pseudohomophones separately using a one-way ANOVA. Findings obtained from this comparison revealed that, relative to their hearing counterparts, the native signers processed letter strings that were real words slower, $F(1, 34) = 13.15, p > .01$. No such evidence was found in relation to the processing of the pseudohomophonic letter strings.

For uncovering differences regarding the processing of real words as opposed to pseudohomophones, a comparison analysis based on a MANOVA procedure was executed. In this analysis, stimulus type (real word, pseudohomophone) was computed as the within-subject factor and group (signer, hearing) as the between-subject factor. The effect of stimulus type was found to be statistically significant, $F(1, 34) = 72.03, p > .001$, suggesting that, overall, the participants required more time to process the pseudohomophonic letter strings than the letter strings that were real words. The group effect was statistically not significant, suggesting that, overall, the stimulus-processing-speed of the two participant groups was comparable. The interaction between the two main effects was statistically not significant, suggesting that the impact of stimulus type upon the two participant groups was uniform.

Table 3  Mean execution times for real word and pseudohomophone lists for the prelingually deaf, control, and combined groups

<table>
<thead>
<tr>
<th>Participant groups</th>
<th>Execution time</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Real words</td>
<td>Pseudohomophones</td>
<td></td>
</tr>
<tr>
<td>Deaf</td>
<td>67.64 (16.18)</td>
<td>118.45 (52.79)</td>
<td></td>
</tr>
<tr>
<td>Hearing</td>
<td>52.76 (8.54)</td>
<td>122.92 (29.99)</td>
<td></td>
</tr>
<tr>
<td>All participants</td>
<td>57.31 (13.16)</td>
<td>121.56 (37.65)</td>
<td></td>
</tr>
</tbody>
</table>

Note. Standard deviations for the respective means are shown in parentheses.
between these two dimensions was statistically significant \((r = -0.53, p < 0.05, n = 11)\), suggesting that decrease in execution time was associated with an increase in the number of correctly identified food concepts. Calculating the same correlation for the hearing control group revealed a probability of borderline significance only \((p = 0.06)\). For none of the groups was the amount of correctly identified pseudohomophones related to the time taken for their indication.

A further aspect investigated by correlation analyses was the way the performance of the participant groups related to their level of formal schooling (grade). It was assumed that the nature and strength of the association between these two variables in some way would be indicative of the contribution of formal schooling to the functioning of the participants in the two assessed domains. Correlation analyses focusing on the processing time dimension revealed that, for the signer group, task completion time under real-word reading conditions was strongly, negatively correlated with grade level \((r = -0.80, p < 0.01, n = 11)\). A similar, significant grade-level-related association was also found with respect to the number of correctly identified real words \((r = 0.57, p < 0.05, n = 11)\). There was, however, no statistical evidence that either of these two task dimensions correlated with grade level when considering the performance of the signing individuals in the pseudohomophone reading condition.

With regard to the hearing control group, the number of correctly identified food concepts in the pseudohomophone reading condition was found to be somehow developmentally determined. An interesting finding was that, however, the direction of this correlation turned out to be counterintuitive to expectations \((r = -0.35, p < 0.05, n = 25)\). There was no evidence that, for the hearing participants, other aspects of task execution were developmentally biased.

Initial comparison analyses suggested that the signer group—although comparable to the hearing control group with respect to the number of correctly identified food concepts from the real-word list—was somewhat slower in processing the real words (see above). In view of the strong association between grade level and quantitative dimension related to the categorization of the real words, it was suspected that such group differences reflect a developmental trend rather than true differences between the performances of the two groups in the real-word reading condition.

To test for this possibility, it was decided to conduct a post hoc group comparison after excluding the four seventh graders from the signer sample because the hearing control group contained no individuals from this grade level. After this exclusion, the mean grade levels were 8.86 for the signer group \((n = 7)\) and 9.00 for the hearing control group \((n = 25)\).

A post hoc comparison of the performance of the two groups (signers vs. hearing) on the different quantitative dimensions (number of identified food concepts, performance time) on the real-word reading test after this exclusion failed to reveal significant group differences. This was true whether the comparison was conducted with parametric statistics (one-way) or with nonparametric statistics (Mann-Whitney). In fact, the average number of identified food concepts showed a notable rise (from 27.82 [5.03] to 30.00 [1.41], correctly identified items) and proved ex post to be virtually the same for both groups (30.00 [1.41] for the signers; 30.08 [2.06] for the hearing control). With regard to the ability to correctly identify pseudohomophones, excluding the participants from the lowest grade level scarcely changed the group mean (8.82 [7.13] to 9.43 [4.12]).

To provide a broader basis for the explanation of the performance of the participants in the present experiment, their success in processing real words and pseudohomophones was also correlated with their overall phonemic awareness assessed in a parallel experiment.\(^7\) For the hearing participants a statistically significant association between their level of phonemic awareness and their ability to categorize pseudohomophones was revealed \((r = 0.59, p = 0.001, n = 25)\). There was however no evidence that phonemic awareness was related to their processing of real words \((r = 0.08, n = 25)\). For the participants with prelingual deafness, phonemic awareness was not found to be indicative of the processing of either of these two stimulus categories.

A crosstab analysis cross-associating participants according to hearing status (deaf, hearing) and class type (regular, special) with level of phonemic awareness and looking at their success in categorizing
real words as opposed to pseudohomophones yielded further that all three individuals with deafness who were fully mainstreamed identified all real words perfectly. On the other hand, their score on the phonemic awareness test was notably below that of all the hearing participants and some of the participants educated in classes for the hearing impaired. Except for one of them, this was also true with regard to the pseudohomophone categorization. It is noteworthy that among the two fully mainstream tenth graders one was found to score worst from all the participants tested on the phonemic awareness test (3 on a 12-point scale). The same individual also demonstrated a drastically reduced ability to categorize pseudohomophones (9 out of 31 in contrast to 21, the lowest core obtained by a hearing participant).

Discussion

This study is an additional attempt to shed light on the roots of the reading failure of prelingually deafened individuals. In line with the assumption that the ability to phonologically decode written words is a prerequisite for the development of proper word-reading strategies, we hypothesized that individuals capable of recognizing the meaning of written real words would also be capable of recognizing the same words when presented as pseudohomophonic nonsense letter strings. This hypothesis, however, was not supported by evidence from this study.

Although findings show that hearing individuals were definitely capable of identifying pseudohomophones almost perfectly, the same was far from true for the prelingually deafened signer group. In fact, the prelingually deafened participants failed to identify the meaning of a very substantial portion of words when presented as pseudohomophonic letter strings, which they were perfectly capable of recognizing when presented as real-word letter strings (see Table 1). This actually indicates that they must have succeeded in developing an effective word-reading strategy despite their apparently seriously limited phonological decoding skills (for a similar conclusion see also Miller, 2002a, 2004a, 2004b, 2005, in press-a). This conclusion is also suggested by a notably small and not significantly different number of false identifications made by the two groups. Both these findings actually challenge the validity of the determining character of the phonological component within theories of word reading, in general (see Ehri et al., 2001; Frost, 1998; Report of the National Reading Panel, 2000; Snow et al., 1998; Vellutino et al., 2004), and within the self-teaching concept, in particular (Share, 1995, 1999, 2004).

Pseudohomophones have no entries in orthographic memory. Therefore, to determine the word meaning they reference via their phonology, the reader is forced to resort to a grapheme-to-phoneme conversion strategy that is relatively laborious in comparison to the recognition of paralleling real words on the basis of their orthographic representations in orthographic memory. We therefore predicted that the processing of the pseudohomophones would take notably longer relative to the paralleling real words. This hypothesis was fully confirmed. As Table 3 shows, for both groups, categorizing pseudohomophonic letter strings was markedly more (about doubly) time consuming than categorizing real-word letter strings. This was found to be the case even though the two letter string types were equally shallow from an orthographic point of view, a finding that indicates that the groups used different strategies for the processing of the two stimuli types. This conclusion is particularly warrantable in view of the finding that the success of the signer group in identifying pseudohomophones as food concepts—notwithstanding a notable increase in processing time—remained strikingly poor. This actually implies that—unlike for their hearing counterparts—for the participants with deafness, the intensified processing of the pseudohomophonic stimuli was not traded off by real success.

The conclusion that the participants processed the two stimulus types differently is, however, also plausible when considering the performance of the participants from the hearing control group. That is if for the processing of the two stimuli categories they had used one and the same strategy, it then would necessarily entail that they had processed the stimuli based on a phonological assembling routine. Assuming that such a routine operates at a prelexical stage (see Frost, 1998), the time taken for the processing of the real words and pseudohomophones should have been much more...
similar, i.e., less biased by their lexical status. Yet, the conclusion that hearing participants conducted the processing of the two stimulus categories based on different knowledge is also maintainable in view of the finding that their level of phonemic awareness only predicted success with regard to the categorization of pseudohomophones, but not of real words. This actually suggests that phonological sensitivity was mainly important for the processing of written stimuli for which no orthographic representations are available.

Undoubtedly, relative to the hearing participants tested in the present study, the phonemic awareness of the prelingually deafened signing individuals was drastically reduced. Going by the communally widely held theory that phonemic awareness provides the basis of the ability of an individual to decode written words phonologically (Report of the National Reading Panel, 2000; Snow et al., 1998; Vellutino et al., 2004, for reviews), we forecasted that the individuals with prelingual deafness tested in this study, due to their impoverished phonological skills, would be disadvantaged relative to their hearing counterparts. We predicted this to be the case with regard to both the processing of written real words as well as the processing of pseudohomophonic nonsense letter strings.

This hypothesis was only partly supported by evidence obtained from the comparison of the two participant groups on the two categorization tasks. Although findings related to the processing of the pseudohomophones clearly reflected the phonological deficits of the prelingually hearing impaired participants, there was no clear-cut evidence that such deficits are transferred to their processing of written real words. In fact, fine-tuned post hoc analyses suggested that the ability of such individuals to recognize the written words used for stimulation in this study was surprisingly similar to that of their hearing counterparts.

These findings contradict the position that the development of effective word-reading strategies is contingent on phonological abilities of the individual (Frost, 1998; Report of the National Reading Panel, 2000; see also Padden & Hanson, 2000; Perfetti & Sandak, 2000). Otherwise, the participants with deafness tested in this study would have been disfavored in both test conditions. The finding that for neither the hearing participants nor for the participants with deafness phonemic awareness was correlated significantly with the processing of real words further corroborates that the phonological abilities of the reader may not be a conditio sine qua non for the development of effective word-reading strategies. This conclusion is in line with some recent evidence that suggests that what prevents individuals with prelingual deafness from becoming proficient readers is not a deficit in the processing of written words at the lexical level (see Miller, 2002a, 2002b, 2004a, 2004b, 2004c, 2005, in press-a, in press-b) and that phonology per se may not be a central factor in determining the reading level of such individuals (Izzo, 2001; Miller, 1997; but see also Dyer et al., 2003). The conclusion that the development of orthographic knowledge may not require reliance on the mechanisms of speech perception or production has also been suggested from the analyses of spelling errors made by prelingually deafened individuals as opposed to individuals with intact hearing (Olson & Caramazza, 2004). Evidence obtained from these analyses actually suggests that notwithstanding their ignorance of phonological constraints, individuals who are deaf rarely produced orthographically illegal spellings. Such findings—obtained by means of different methodologies—demonstrate that prelingually deafened readers eventually internalize adequate knowledge for the processing of written words. This seems to be the case regardless of their communication background (signing vs. oral), their functional hearing level, or their actual reading comprehension skills (Miller, 2002a, 2005, in press-b). In fact, a straightforward comparison between readers with diagnosed dyslexia and prelingually deafened readers has shown that, despite their impoverished phonological skills, only the word-reading skills of the latter deviated significantly from those of a task-matched hearing control (Miller, in press-a).

The remarkably poor ability of the signer group to identify food concepts based on pseudohomophones seems to highlight their weak phonological processing skills. Some critics, however, may argue that such failure could also reflect a misunderstanding of the task per se. It may be, for example, that rather than trying to base the identification of the food concepts in the pseudohomophone list on the phonological processing
of their graphemes, they indicated such letter strings based upon guessing. Yet there are at least two aspects of the pattern of success of the signer group that seem to argue against such a guessing hypothesis. First of all, the number of pseudohomophonic letter strings erroneously identified as food concepts is definitely too small relative to the portion of correctly identified letter strings (see Tables 1 and 2). If the processing strategy of the signing participants would have been based on a guessing strategy, this proportion should logically have been approximately reflected in the proportion of correctly and erroneously marked pseudohomophones. This was, however, not the case. Second, the total number of marked letter strings was definitely too small to reflect sheer guessing. This conclusion seems reasonable given that the pseudohomophone list was always administered after the real-word list. In other words, the signing participants must have been aware that there were more pseudohomophonic letter strings that referenced food concepts, but apparently were unable to identify them based on their impoverished phonological decoding skills.

Taking into consideration the hearing-group-comparable categorization of real words by the signer participants, on the one hand, and their rather drastically impoverished ability to figure out, based upon their phonology, which among the pseudohomophones referenced food concepts, on the other hand, the conclusion that the strategy they used for processing the real words was somehow rooted in the knowledge of how words are written (orthographic knowledge) rather than how words sound (phonological knowledge) seems warranted. This raises the possibility that the poor performance of the signer group on the pseudohomophone task reflects an attempt to process the pseudohomophones orthographically rather than phonologically (see also Padden, 1993). In other words, partial congruence in the orthographic patterns of a pseudohomophone and its paralleling real word served them as the basis for making a categorical decision.

Although this possibility cannot definitely be ruled out, there are several points that actually suggest that this was not the case. First of all, considering the orthographic properties of the real words and their paralleling pseudohomophones (see Appendix), it becomes apparent that there were substantial differences in the way each of these stimulus types was spelled. Moreover, as in guessing, due to such orthographic disparity, the use of an orthographically based reading strategy for the processing of the pseudohomophones should have led to a proportionally higher rate of erroneous categorization. This in particular because, in some instances, pseudohomophones representing nonfood distracters were orthographically more similar to real words representing food concepts than were the pseudohomophones paralleling real words (e.g., ידוע = real word, ידועות = paralleling pseudohomophone, ידוע = pseudohomophone distracter).

Going by the above argument, assuming that the poor pseudoword decoding of the signing participants reflects the use of a grapheme-to-phoneme conversion procedure implemented based on insufficiently developed phonological knowledge (phonemic awareness) makes sense. It is noteworthy in this regard that, for individuals with prelingual deafness, the number of correctly identified pseudohomophones was positively correlated with the number of correctly indicated real words. Taking into account that the orthographic knowledge the signer group manifested in this study notably exceeded its phonological skills, this significant correlation seems to imply that effective orthographic skills somehow foster the development of phonological decoding skills. If this is indeed the case, it would explain why, in some studies conducted with prelingually deafened students, better readers were also found to be more effective phonological coders (e.g., Conrad, 1979; Hanson & Lichtenstein, 1990; Hanson et al., 1984; for reviews see Padden & Hanson, 2000; Paul, 2001; Perfetti & Sandak, 2000).8

For the hearing participants, probably due to a near to perfect performance in both stimulus conditions, the identification of real words representing food concepts was not found to be associated with their ability to recognize the same concepts when presented as pseudohomophones. On the other hand, their performance showed a significant relationship with regard to the speed of processing of these two stimulus categories. Regrettably, the final significance of this relationship is not sufficiently
clear. However, it seems possible that it reveals a processing component beneath strategic aspects related to the processing of a particular stimulus type—such as the individual pace processing of the participants.

One would expect such a component to be pinpointed as a significant correlation between two tasks, as long as it is not obscured by a particular skill deficit that interferes with the execution of either of them. The finding that task execution time correlated only for the hearing participants may therefore indicate that they were equipped with adequate skills for the processing of both real words and their pseudohomophones. With regard to the latter, this was certainly not the case for the signing participants, which may explain why for them the execution of the two tasks was not correlated.

The dissociation between orthographic and phonological skills of prelingually hearing impaired individuals becomes strikingly real when considering findings concerning their functioning in these domains from a developmental perspective. Such findings actually suggest that the phonological abilities of such individuals—reflected in their success in processing pseudohomophones—remain desperately static over the years (grade levels). This is in sheer contrast to their orthographic knowledge, which, as suggested by robust correlations, seems to become not only richer over the course of time—permitting them to recognize more written words—but which they also seem to be able to apply more rapidly in mediating the recognition of the meaning of written words. The fact that such development occurred without a notable, parallel development in their phonological skills is strong evidence that the prelingually deafened individuals tested in this study must have found a gateway to orthographic knowledge that is not contingent on their impaired phonological knowledge. Moreover, the finding that, when matched more closely by grade level, the performance of the deaf signing participants on the real-word version was found to be statistically indistinguishable from that of their hearing counterparts, implies that this gateway may be as efficient as the one potentially offered by a self-teaching mechanism relying on the phonological decoding of written words.

In summary, the findings obtained from this study—although partly in discord with some of the currently accepted theories of word reading—are by and large encouraging in nature. They actually highlight that individuals with prelingual deafness are capable of developing effective word-reading strategies even if their phonological abilities, due to permanent auditory deprivation, remain drastically impoverished. It should be emphasized that whereas findings from this study convincingly demonstrate that the development of orthographic knowledge underlying this strategy occurs despite a persistent deficit in the phonological abilities of prelingually deafened individuals, future research will have to determine whether this development keeps pace with that of individuals with proper hearing or individuals with deafness who have access to phonetically fully specified language input (Charlier & Leybaert, 2000; LaSasso et al., 2003; Leybaert & Lechat, 2001). However, the fact that the findings presented from this study were obtained with a vocabulary that comprised many low-frequency words (see Appendix) suggests that, given adequate conditions, the development of such knowledge may be rather rapid.

Regrettably, findings from this study are not very telling with regard to the conditions that foster such development, and further research is needed to clarify this important issue. Nevertheless, because they clearly indicate that such development is largely independent of the phonological abilities of the prelingually deafened reader (see also Miller, 2004a, 2004b, 2004c; Olson & Caramazza, 2004), the realm of possibilities to investigate is already somewhat narrowed down.

According to teacher ratings, most of the prelingually deafened signers participating in this study had reading comprehension skills well below the norm, which explains why the vast majority of them were not fully mainstreamed into hearing classes but visited special classes for the hearing impaired. Knowing, as suggested by the findings of this and other studies (see Miller, 2002a, 2004a, 2004b, 2004c, 2005, in press-a, in press-b), that such impoverished understanding is not due to some processing deficit at the word level is important because it directs remedial efforts to potential deficits in higher order
processing, deficits prelingually deafened readers may not be able to cope with as effectively on their own as they apparently do when required to process written words at the lexical level (e.g., Miller, 2000, 2005, in press-b).

Having found evidence for the development of orthographic knowledge in individuals who seem to lack the phonological skills that—according to a phonologically based self-teaching notion—are the prerequisite for the development of orthography representation (Share, 1995) does not necessarily imply that the average hearing reader does not accumulate orthographic knowledge based on the phonological decoding of written words nor does it imply that individuals with deafness raised by means of a language system that reliably and fully depicts the phonological structure of spoken words may not do so either. Yet, what the findings regarding the performance of the prelingually deafened individuals in this study suggest is that the self-teaching concept should be extended to include additional acquisition mechanisms that—in the absence of an adequate phonological knowledge—continue to guarantee the eventual acquisition of orthographic representations as the basis for the efficient identification of written words. Whereas such a mechanism may not play a central role in the achievement of reading proficiency in regular readers, for other readers it may be the cornerstone of progress. In any case, without postulating the existence of such an alternative, not phonologically based acquisition mechanism, an explanation of the intact word-processing skills demonstrated by prelingually deafened individuals in the present and other studies (see Miller, 2002a, 2004a, 2004b, 2005, in press-a, in press-b) seems rather problematic.

It may of course be that even if individuals with prelingual deafness develop orthographic knowledge in the absence of adequate phonological skills, their inability to decode written words phonologically may still turn out to be detrimental with regard to their reading comprehension. Indeed, Stanovich (1994) argues that phonological encoding may function, not directly in lexical access, but as an efficient way of holding strings of words in short-term memory while higher-level processors operate upon them. This position is in accordance with findings demonstrating that proficient readers, aside from substantial orthographic knowledge, also possess adequate skills for the phonological processing of the written words (Report of the National Reading Panel, 2000). Therefore, the finding that the participants with deafness tested in the present experiment had drastically impoverished abilities to process written stimuli phonologically may be a sufficient cause for failing them in making sense of written text.

Findings from this study indicate that efficient word-recognition skills may not be contingent on the existence of well-developed phonological skills. The same evidence, however, is insufficient for definitely determining whether or not a failure to decode written words phonologically indeed impacts negatively their postlexical processing. It is the goal of future research to resolve this important issue. It is nevertheless noteworthy that in this study all the prelingually deafened participants who were fully mainstreamed manifested markedly reduced phonemic awareness and that among them one came out lowest in this regard (see also Izzo, 2001). Assuming that for keeping up with hearing individuals in a regular classroom, individuals with prelingual deafness must possess adequate reading skills, the fact that some of the tested participants indeed succeeded in doing so their impoverished phonological skills notwithstanding cannot be simply ignored. It actually portends that proficient reading skills eventually develop even within a phonological vacuum.

In this study, the prelingually deafened individuals examined were all native signers. In other words, their primary language was ISL and not spoken language. Regrettably, the paradigm used in this study does not allow drawing conclusions as to what extent their competence in this manual language determined the way they processed the real words and the pseudohomophones. Yet, the possibility of such an influence cannot be ruled out. Moreover, even if sign language per se may not function as a direct mediator in the processing of written words (Kyle, 1989; Miller, 2004a), finger-spelling proficiency, which normally accompanies sign language competence, may well provide the basis of a decoding mechanism.
that fosters the internalization of orthographic knowledge—a decoding mechanism that could substitute for deficient phonological decoding (see Padden & Ramsey, 1998).

Because finger spellings reference letters rather than phonemes, the effectiveness of such a finger-spelling-based decoding mechanism for the processing of pseudohomophones would necessarily be limited. As already stated, whether these scenarios are indeed real cannot be answered by evidence obtained in this study, and their, at the moment, speculative nature will have to be proved true in future research. Yet what the findings from this study tell quite clearly is that having a sign language as a primary code is not detrimental for the development of orthographic knowledge. Otherwise, the signing individuals would have underscored their hearing counterparts in the categorization of the real words as well.

Finally, the study reported here was conducted in an orthography—pointed Hebrew—that may create particular reading conditions. Therefore, for substantiating their generality, the findings obtained from this study will have to be replicated in other orthographies (French, English, etc.) based on comparable methodologies.

## Appendix

The real word (RW) and pseudohomophone (PH) lists

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RW</td>
<td>PH</td>
<td>RW</td>
<td>PH</td>
</tr>
<tr>
<td>1</td>
<td>שְׁמוֹן</td>
<td>שַׁמֶּחַ</td>
<td>פָּרָתָה</td>
</tr>
<tr>
<td>2</td>
<td>וּדֵי</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
</tr>
<tr>
<td>3</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>4</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>5</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>6</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>7</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>8</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>9</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>10</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>11</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>12</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>13</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>14</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>15</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>16</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>17</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>18</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
<tr>
<td>19</td>
<td>שְׁמוֹנָה</td>
<td>פָּרָתָה</td>
<td>שְׁמוֹנָה</td>
</tr>
</tbody>
</table>
Appendix Continued

<table>
<thead>
<tr>
<th></th>
<th>RW</th>
<th>PH</th>
<th>RW</th>
<th>PH</th>
<th>RW</th>
<th>PH</th>
<th>RW</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>14a</td>
<td>הקור</td>
<td>קור</td>
<td>מתק</td>
<td>מק</td>
<td>20a</td>
<td>מתכ</td>
<td>מתכ</td>
</tr>
<tr>
<td>21</td>
<td>מות</td>
<td>נמק</td>
<td>לנמד</td>
<td>ומק</td>
<td>נמק</td>
<td>נמק</td>
<td>נמק</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>17a</td>
<td>מתק</td>
<td>מק</td>
<td>מתק</td>
<td>מק</td>
<td>23a</td>
<td>מתק</td>
<td>מתק</td>
</tr>
<tr>
<td>23</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>48a</td>
<td>טא</td>
<td>טא</td>
<td>טא</td>
<td>טא</td>
<td>טא</td>
<td>טא</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td>מק</td>
<td></td>
</tr>
</tbody>
</table>

Notes

1. ISL is the signed language used by the deaf community in Israel. As in American Sign Language, its vocabulary is built systematically according to limited sets of formational parameters such as hand shape, hand movement, and place of articulation.

2. In Israel, children start primary school at about age six.

3. Signed Hebrew and spoken Hebrew are similar in a limited sense, reflected in a rough matching of the sign order to the word order in Hebrew. In most other linguistic aspects, there are essential incompatibilities between the two systems, such as an almost complete lack of devices in Signed Hebrew to represent the rich morphological structure of spoken Hebrew.

4. Because in Israel there are no standardized reading comprehension tests available, the actual reading level of the participants with deafness could not be determined. Estimations in this regard are based on teacher ratings that, although subjective, show broad interteacher agreement.

5. For example, the letter graphemes "ה" (taf) and "ו" (tet) are both read as the phoneme /t/ and the letter graphemes "נ" and "נ" both can assimilate the phonemes /a/, /a/ and /a/ depending on how they are pointed. The same phenomenon exists also with regard to vowel diacritics. For example, the vowel diacritics "א" (kamatz) and "א" (Patah) both represent the phoneme /a/, whereas the vowel diacritics "א" (segol) and "א" (Tsere) stand both for the phoneme /e/.

6. All significant results reported from post hoc analyses are significant at a probability level of \( p \leq 0.05 \).

7. A full report of findings from this experiment and their implication in relation to the phonological and orthographic abilities of prelingually deafened and hearing individuals is in preparation.

8. It should be emphasized that the causal relationship drawn based on such findings was usually interpreted to be in the opposite direction, with phonological coding leading to more effective reading skills.

References


Received November 5, 2004; revisions received April 11, 2005; accepted April 13, 2005.