READING COMPREHENSION AND ITS RELATION TO THE QUALITY OF FUNCTIONAL HEARING: EVIDENCE FROM READERS WITH DIFFERENT FUNCTIONAL HEARING ABILITIES

THREE GROUPS OF STUDENTS—19 hard of hearing, 20 deaf, and a control group of 36 typically developing hearing readers—were compared on their ability to process written words at the lexical level and on their comprehension of words within the structure of a sentence. Findings generally suggested that severe prelingual hearing loss does not prevent the development of word processing strategies adequate for efficient processing of written words at the lexical level, although such hearing loss seems to put individuals at risk of failure in internalizing syntactic knowledge crucial for proper processing of words at the sentence level. Evidence further indicated that neither the amount of functional hearing (deaf vs. hard of hearing), the hearing status of their parents (hearing impaired vs. hearing), nor the use of sign language as a primary communication mode was a direct cause in this regard.

Factors considered central for explaining the reading process in hearing readers—such as phonemic awareness and phonological coding—have also been targeted in attempts to illuminate the origins of the impoverished reading skills of people with severe prelingual hearing loss (Charlier & Leybaert, 2000; Dyer, MacSweeney, Szczepanski, & Campbell, 2003; Hanson & Fowler, 1987; Hanson & McGarr, 1989; Miller, 1997; Sutcliffe, Dowker, & Campbell, 1999; Transler, Leybaert, & Gombert, 1999; for a review, see Nielsen & Leutke-Stahlman, 2002). Indeed, findings of deficits in this regard have often been interpreted as causal evidence of the obstacles such readers face in their struggle to make sense of written texts (e.g., Hanson & Lichtenstein, 1990; Padden & Hanson, 2000; Perfetti & Sandak, 2000). The validity of the hypothesis that deficiencies associated with reading failure in hearing readers are also directly relevant to reading difficulties in people with prelingual hearing loss, however, has recently been questioned (Izzo, 2002; Musselman, 2000). The present study is an attempt to further specify the causes preventing many individuals with prelingual hearing loss from becoming fluent readers.

During the past three decades, research into the reading processes of typically and atypically developing hearing readers has pinpointed the ability to recruit phonology for the mediation of...
written words as the most salient factor determining reading success (e.g., Ehri, 1999; Ehri, Nunes, Stahl, & Willows, 2001; Frost, 1998; National Reading Panel, 2000; Share 1995; Snow, Burns, & Griffin, 1998). The most persuasive evidence for this hypothesis has been the finding that dyslectic readers consistently show significant impairments in phonemic awareness—that is, their ability to manipulate the phonemic structure of words—or in their ability to rapidly retrieve the phonological labels of verballizable, visual stimuli (see National Reading Panel, 2000, for a review of this subject). Yet the corroboration of the contribution of phonology to reading success has also come from findings that link reading progress in novice readers with these readers’ awareness of the phonemic structure of words (e.g., Byrne & Fielding-Barnsley, 1989; Chapman & Tunmer, 2003; Kjeldsen, Niemi, & Olofsson, 2003). Findings of notable phonological deficits typical of dyslectic readers (Stanovich & Siegel, 1994) have their clear parallel in readers with severe prelingual hearing loss, a population well known for its rather drastically impoverished reading skills (for a review, see King & Quigley, 1985; Miller, 2000; Paul, 2001).

In the presence of a strong phonological theory of reading (Ehri, 1999; Frost, 1998; Share, 1995) that postulates inefficient phonological coding as being at the core of reading failure in hearing readers, it is tempting to trace the impoverished reading skills of individuals with prelingual hearing loss back to their phonological impairment (Hanson & Lichtenstein, 1990; Padden & Hanson, 2000; Perfetti & Sandak, 2000). This temptation is particularly strong in view of findings that show that, among prelingually deafened students, individuals found to decode written words phonologically prove to be better readers (Conrad, 1979; Hanson, 1982, 1991; Hanson, Liberman, & Shankweiler, 1984; Hanson & Lichtenstein, 1990; Lichtenstein, 1998; Lillo-Martin, Hanson, & Smith, 1992). However, inferences of a causal association from these two coinciding findings should be made with caution. Findings from some recent studies indeed suggest that the role assigned to phonology within the reading process of individuals with severe prelingual hearing loss may have been overstated (see, e.g., Izzo, 2002; Miller, 1997, 2002b, 2004c; Swanson, Trainin, Necoechea, & Hammill, 2003), and that the functioning of such individuals at the lexical level—the level phonological coding has been claimed to affect directly—is not notably different from that of their typically developing hearing counterparts (Miller, 2001, 2002a, 2004a, 2004b).

Phonological representations, the subject of phonemic awareness, are thought to evolve from auditory experience. If this assumption is correct, the ability to establish phonological representation is contingent on an individual’s quality of hearing. In other words, better hearing should provide a firmer basis for the internalization of phonological representations of words upon which the reader can rely for the mediation of written words. Therefore, assuming that phonological coding enhances the processing of written words at the lexical level (National Reading Panel, 2000), hard of hearing individuals—although probably disfavored relative to hearing individuals—should show an advantage over individuals with prelingual deafness in tasks requiring the processing of written stimuli. This is because people who are hard of hearing, unlike the deaf, are assumed to experience some functional hearing of the language spoken in their surroundings (Paul, 2001), which may sustain them in internalizing phonological knowledge.

**Objectives of the Study**

The first objective of the present study was to shed light on the relative contribution of the quality of functional hearing to the processing efficiency of written words. For this purpose, hard of hearing students, prelingually deaf students, and a group of typically developing hearing students were asked to perform two word processing tasks. The purpose of one task was to assess the students’ perceptual word processing skills; the purpose of the other was to assess their conceptual word processing skills. It was hypothesized that if variation in functional hearing—because it leads to qualitative differences in the phonological representations of words—affected the processing of written words, group differences would be found in relation to the conceptual processing of written words where phonology was assumed to fulfill a mediating function. However, no such differences would be expected to occur on the other tasks for which access to conceptual knowledge was not a prerequisite for performance.

One reason for the failure of individuals with severe prelingual hearing loss to understand written information may be their inefficient recognition of written words in the absence of effective phonological coding (Hanson & Lichtenstein, 1990; Padden & Hanson, 2000; Perfetti & Sandak, 2000), an inefficiency that is transferred to higher-order processes responsible for determining the final meaning of written words at a supra-lexical level (Baddeley, 1986, 1990), such as their significance within the context of a sentence.

The second objective of the present study was to substantiate the relevance of such transfer to the explanation of
reading comprehension differences attributable to variation in the quality of functional hearing. Therefore, in addition to performing the word processing tasks, participants were asked to demonstrate their understanding of the content of a series of sentences requiring a multiple-choice response. It was hypothesized that if the recognition of written words were biased by quality of functional hearing, such a bias would be transferred to higher-order processes and would therefore also be a determining factor in relation to the comprehension of the test sentences. In other words, better hearing would be associated with better word processing abilities as well as with superior sentence comprehension, and vice versa.

A growing body of evidence suggests that phonology may not play a crucial role within the reading processes of individuals with severe prelingual hearing loss (see, e.g., Izzo, 2002; Miller, 1997, 2002b, 2004c; Swanson et al., 2005), and that the efficiency of the strategy or strategies used by such individuals may prove as effective for the processing of written words at the lexical level as the strategies used by their hearing counterparts (Miller, 2001, 2002a, 2004a, 2004b). Yet the fact that individuals with severe prelingual hearing loss may have adequate skills for the processing of written texts at the lexical level, while encouraging, does not necessarily turn such individuals into good readers. On the contrary, as I have already stated, the ability of such readers to understand written information often remains remarkably limited (Miller, in press; for a review, see Paul, 2001).

One possible reason for the persistence of the reading deficits of individuals with severe prelingual hearing loss is a dearth of knowledge of the world; another is insufficient development of metacognitive skills (e.g., the ability to infer information that is not explicitly stated in a text or the ability to understand figurative language). Both are crucial for elucidation of the final message conveyed in a sentence or paragraph (Marschark & Everhart, 1997; for a review, see King & Quigley, 1985; Paul, 2001). However, the fact that individuals with severe prelingual hearing loss have been found to misinterpret sentence meaning even in instances in which content knowledge was controlled for and the inferring of information was not required (Hatcher & Robbins, 1978; Miller, 2000; Quigley, Power, & Steinkamp, 1977) suggests that deficits in world knowledge and in metacognitive skills, although contributing to such individuals’ reading failure, may not be, per se, its fundamental cause.

Deficiency in another area, syntactic knowledge, may more likely be to blame. Syntactic knowledge reflects an understanding of how the meaning of single words is specified by their temporal structuring within a sentence. The acquisition of such structural knowledge is assumed to result from repeated exposure to a speech act uttered in relation to a concrete, experienced action or event. For hearing individuals, such opportunities become available from early childhood, promoting the gradual internalization of syntactic knowledge regarding the spoken language of their surroundings. In the presence of severe prelingual hearing loss, the conditions underlying speech perception are, however, essentially altered, with the perception of speech being predominantly transferred to the visual track. Yet in contrast to the act of listening to a spoken message, in speechreading the visual distinction of words is rather limited, because the representations of the composing phonemes of words on the lips of a speaker are either partly absent or partly indistinguishable, and the task of recognizing words often obligates the speechreader to do a massive top-down processing of the words in order to disambiguate their identity. Such top-down processing is likely to allot mental resources to the word recognition process that, in individuals with intact hearing, may be available for the extraction of structural knowledge (syntactic rules) that determines the final meaning of words within a sentence.

There is an impressive body of research indicating that insufficiently developed syntactic knowledge may be a central cause of the poor reading comprehension of individuals with severe prelingual hearing loss (Deal & Thornton, 1985; Jones & Quigley, 1979; Wilbur et al., 1977; Quigley, Smith, & Wilbur, 1974; Webster, 1986; Wilbur & Quigley, 1975). However, the exact nature of such a syntactic deficit is not entirely clear. Some findings suggest that the problem may be merely quantitative; that is, individuals with severe prelingual hearing loss rely on a limited set of syntactic rules in trying to make sense of a text (Hatcher & Robbins, 1978; Quigley, 1982; Wood, 1984). Because such rules are also applied to texts for which they are not adequate, continuous misinterpretations are unavoidable.

A second hypothesis mentioned in the literature is that the rule-based knowledge acquired by individuals with severe prelingual hearing loss is of a different nature (Cumming & Rodda, 1985; Ivimey, 1976; Quigley et al., 1977; Webster, 1986). This is because the predominantly visual orientation of such individuals causes their attention to focus on the spatial characteristics of the text instead of the temporal ordering of the words. However, in view of other findings (Gormley & Franzen 1978; Ewoldt,
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1981; Miller, 2000; Yurkowski & Ewoldt, 1986), another potential cause of the reading difficulties of individuals with severe prelingual hearing loss has arisen: the possibility that such individuals may not use rule-based, bottom-up processing (syntactic processing) as a strategy for making sense of texts (Ewoldt, 1981; Gormley & Franzen, 1978; Miller, 2000; Yurkowski & Ewoldt, 1986). Rather, these readers seem to skip the processing of sentence structure as a source of significance, trying instead to recreate the meaning of a sentence simply by applying their prior knowledge and experience in interpreting its content words.

A third objective of the present study was to expand understanding of the strategies used by individuals with severe prelingual hearing loss to recreate sentence meaning. Because the ability to hear is claimed to be crucial to the spontaneous acquisition of syntactic knowledge (Paul, 2001), the question of the degree to which the quality of functional hearing determines the nature of the reading strategy someone adopts for making sense of a sentence is of particular interest. In the present study, for the purpose of elucidating evidence regarding the nature of the predominant reading strategy used by participants, the sentences used to test reading comprehension were manipulated with regard to their semantic plausibility (semantically plausible vs. semantically implausible). It was hypothesized that, for readers with adequate syntactic knowledge, variation in semantic plausibility would not significantly affect reading comprehension. However, it was predicted that the use of insufficient or deviant syntactic knowledge in sentence processing would be manifested in poor understanding in both semantic plausibility categories. Participants who deduced sentence meaning by interpreting the content words with reference to their prior knowledge and experience were predicted to demonstrate relatively intact understanding of semantically plausible test sentences—this in contrast to their comprehension of semantically implausible sentences, which, it was hypothesized, would be markedly impoverished. It was further assumed that better functional hearing would promote the internalization of syntactic knowledge. It was therefore anticipated that hard of hearing participants would outperform their deaf counterparts. This advantage was expected to be particularly notable with regard to the comprehension of semantically implausible sentences for which topdown processing cannot compensate for deficient syntactic processing.

Method
Participants
Twenty deaf students, 19 hard of hearing students, and a control group consisting of 36 hearing students participated in the experiment. All participants were middle school or high school students from a public school in northern Israel that provided classes for students with normal hearing and for students with hearing loss on the same campus. A Total Communication approach was used in classes for the students with hearing loss, with communication for instruction based on the simultaneous use of spoken Hebrew and Signed Hebrew. In hearing classes, the principle language of instruction was Hebrew.

Because of the low prevalence level of individuals with severe prelingual hearing loss within the general population, the study participants had to be chosen from classes in the 7th to 11th grades: a broad range. Nonetheless, the three participant groups were, overall, fairly well matched with respect to average grade level and average chronological age. Moreover, they were found to have comparable general information-processing abilities in a pilot study assessing fine-motor skills and ability to process digits.

According to their personal files, all students selected for participation in the present study had intelligence within the normal range. Furthermore, they all had normal or corrected-to-normal vision. None were diagnosed with a particular learning or motor disability; hence, learning deficits in the two participant groups with hearing loss could be assumed to be the result of their hearing status. The first spoken language in the homes of all participants was Hebrew.

Hard of Hearing Participants
Four criteria guided the selection of the students who made up the hard of hearing group:

1. Their unaided pure tone averages (0.5, 1.0, and 2.0 kHz) in the better ear were in the range of 60 to 80 dBHL (American National Standards Institute, 1989). Such individuals are assumed to have some functional hearing for speech sounds when properly fitted with hearing aids.
2. Their hearing loss was diagnosed prior to age 2 years, that is, before they acquired the spoken language of their surroundings.
3. All attested that they used hearing aids consistently in and out of school.
4. When asked, all affirmed that they had some functional hearing that made them aware of the teacher talking in the classroom, although they normally could not understand the teacher’s words solely by listening.

For most academic subjects, the participants in the hard of hearing group (n = 19) were taught in special
classes for the hearing impaired, together with other students who were deaf. They were, however, partly mainstreamed into hearing classes during art lessons and sports. Several of them were also mainstreamed in mathematics. Two of the hard of hearing participants had parents who were hard of hearing themselves; in one of these cases, only the father had impaired hearing. The parents of the remaining 17 hard of hearing participants had normal hearing. All hard of hearing participants claimed that their parents communicated with them in spoken Hebrew, which they seemed to sustain by manual signs. It could not be ascertained, however, if this manual system was compatible with standard Signed Hebrew. (Because there are no available tools for assessing competency in Signed Hebrew, no objective information could be obtained regarding the level of competency of the participants, the participants’ parents, and the participants’ teachers in this communication mode.)

The average grade level of the hard of hearing group was 8.9 (range: 7th to 11th grade). Average chronological age was 186 months (SD = 24 months). Average hearing loss was 73 dBHL (range: 60 to 80 dB).

Deaf Participants

Deaf participants (n = 20) were selected on the basis of five criteria:

1. Unaided pure tone averages (0.5, 1.0, and 2.0 kHz) in the better ear were 85 dBHL or higher.
2. Onset of hearing loss had been prelingual (i.e., occurring prior to age 2 years).
3. They attested to having a clear preference for Israeli Sign Language (ISL) over spoken Hebrew.
4. All attested that they wore hearing aids most of the time and that, per school policy, they wore them at all times in the classroom.
5. When asked, all declared that they were not aware that the teacher was talking in class without looking in his or her direction. However, most of them also stated that they could occasionally hear very loud sounds, such as the teacher clapping hands to get the attention of students.

Six of the deaf participants had parents who were deaf themselves. The parents of the remaining 14 were both hearing. Like the hard of hearing participants, the parents from the deaf group were taught in special classes for the hearing impaired for most academic subjects. They were mainstreamed into hearing classes during art lessons and sports, and some of them also for mathematics. All six deaf participants with deaf parents claimed to communicate with their parents in ISL. According to the reports of the 14 deaf participants with hearing parents, their communication mode at home was a combination of spoken and manual language. What exactly the nature of this manual language was and how competent the parents were in using it was, regrettably, not obvious from the reports of the participants.

In all, despite their clear preference for ISL, all participants in the deaf group definitely had some level of proficiency in spoken Hebrew, deriving from systematic speech lessons, from daily exposure to a speaking environment in and out of school, and from activities such as reading and writing. Their average grade level was 8.9 (range: 7th to 11th grade); average chronological age was 183 months (SD = 18 months). Average hearing loss was 89 dBHL (range: 85 to 110 dB).

Hearing Participants

The students in the hearing control group—five to six individuals per grade level—were randomly chosen from classes paralleling the classes for students with hearing loss from which the participants who were deaf or hard of hearing were selected. The mean grade level of the hearing control group was 8.9 (range: 7th to 11th grade); average chronological age was 179 months (SD = 18 months).

Stimuli

The present study was designed to obtain data on hard of hearing, deaf, and hearing individuals in two domains: (a) their word processing skills and (b) their ability to comprehend written texts.

Assessment of the Three Groups’ Word Processing Skills

The word processing skills of the participant groups were examined in relation to two levels of processing: perceptual and conceptual. For assessment of their abilities in processing written words’ perceptual properties, the participants were presented with 40 word pairs—half of them consisting of two identical words (e.g., כל לכל [dog dog]) and the remainder consisting of two different words (e.g., כל נע [shoe dog])—within 40 rectangular fields, ordered in five rows on a standard A4 sheet. The participants were asked to rapidly mark perceptual and conceptual. For assessment of their abilities in processing written words’ perceptual properties, the participants were presented with 40 word pairs—half of them consisting of two identical words (e.g., כל לכל [dog dog]) and the remainder consisting of two different words (e.g., כל נע [shoe dog])—within 40 rectangular fields, ordered in five rows on a standard A4 sheet. The participants were asked to rapidly mark pairs containing two identical words with the symbol ‘✓’ and pairs composed of two different words with the symbol ‘X’ in a right-to-left, top-down fashion. (The right-to-left working direction reflects the direction of reading in Hebrew.) Both performance time and performance accuracy were recorded for subsequent analysis. A practice sheet containing two rows of word pairs presented within rectangular fields...
was prepared for task explanation and practice.

All word pairs were built from words that, according to the expertise of three independent teachers of the deaf, should be within the realm of the active vocabulary of prelingually deafened fifth graders. Because, in this task, the words in identical word pairs were physically identical (PI), the participants could make their identically judgments based on the physical (perceptual) properties of the words, that is, without processing the words conceptually via their phonology. Therefore, it was assumed that the performance of the participants on this word processing task would be helpful in specifying the impact of a severe prelingual hearing loss on the perceptual processing of written words.

As in the first word processing task, the second word processing task required the participants to determine as quickly as possible between-word identicalness in 40 word pairs presented within 40 rectangular fields, with half of the word pairs consisting of two identical words and the remainder consisting of two different words. Both execution time and decision accuracy were recorded. A practice sheet containing two rows of word pairs presented within rectangular fields was prepared for task explanation and practice.

The second word processing task differed from the first in two aspects. First, the vocabulary used for stimulations was different, although it was chosen according to the same familiarity criterion. Second, the two words making up a word pair were always presented in two different typescripts, one in print and the other in handwriting. As a result, identical words were not physically (perceptually) identical, but merely conventionally identical (CI), for example, נסיך פאר [PARTY] (The term conventional identicalness refers to an identity between two words that cannot be determined on a mere perceptual basis, but that must be mediated by some form of knowledge.)

It was assumed that, in order to discern word pairs consisting of the same word twice from word pairs consisting of two different words (e.g., נלעע פאר [ACTION thought]), participants would have to retrieve some form of conventionalized representations for the words or for the letters of the words, such as their phonology. If this line of reasoning were correct, the CI word processing task should be an adequate method for elucidating word processing differences originating from differences in the quality of the functional hearing of individuals.

Assessment of the Three Groups’ Comprehension of Written Text
Twenty-four short, unrelated sentences were used to clarify differences in the reading strategies and the reading comprehension levels of the groups, because of the variation in the quality of their functional hearing. The participants’ understanding of the test sentences was assessed by means of a multiple-choice model (see Appendix), using one question and two optional answers (chance level performance = 50%). All the sentences depicted very simple and concrete situations or actions that were assumed to be comprehensible to children much younger than those tested in the present study; some sentences depicted both situations and actions. This simplicity was important for neutralizing the impact on the comprehension of the test sentences of deficits in world knowledge and experience resulting from permanent auditory understimulation. Moreover, the words used in composing the test sentences were very basic. No figurative language was used.

The test sentences included two sentence categories (see Appendix). The first category comprised 12 semantically plausible sentences (SP), and the second category 12 semantically implausible sentences (SI). The syntactic structures of sentences from the SP category and the SI category were matched, with each SP sentence having a syntactically corresponding SI sentence. Although the vocabulary used for the composition of the two sentences was different, it was comparable with respect to difficulty.

All SP sentences could be correctly understood by the mapping of their content words to prior world knowledge. It was therefore assumed that their syntactic bottom-up processing would be less crucial for their comprehension and, consequently, should less disfavor participants ignoring the information conveyed by word order. For all SI sentences, processing the syntactic structure of the sentences was a prerequisite for proper understanding, because these sentences depicted situations that contradict everyday experience (see Appendix). In fact, skipping such processing was expected to lead to consistent misinterpretations of sentence meaning.

The 24 test sentences were presented to the participants in random order. Four additional sentences were prepared for task explanation and for ascertaining the understanding of the test procedure by the participants.

Procedure
All participants were tested individually. For participants from the two groups with hearing loss, explanations and instructions were provided both in spoken Hebrew (by the experimenter) and in Signed Hebrew (by a professional interpreter). The two parts of the experiment were administered to
the participants in a fixed order, with testing of their word processing skills being followed by examination of their comprehension of written sentences.

Assessment of the Three Groups’ Word Processing Skills
The two word processing tasks were administered in rotated order. The experimenter explained to the participants that they should indicate two identical words with ‘✓’ and two different words with ‘X’. He demonstrated the procedure by correctly marking the first four word pairs on the practice sheet. He then asked the participants to continue marking the remaining word pairs. The word processing task that was administered first was given to the participants only after their practice demonstrated their understanding of the task. The word processing task administered second followed immediately after the participants completed the first task.

The experimenter instructed the participants that they should execute the task as quickly as possible in a top-down, right-to-left manner. The participants were asked not to correct themselves if they made a mistake. Both performance time and accuracy of the identicalness judgments were recorded for subsequent analyses. None of the participants demonstrated problems in understanding and performing the two word processing tasks.

Assessment of the Three Groups’ Comprehension of Written Text
The first page of the reading test contained the sentences prepared for task explanation and practice. The experimenter told the participants that the test was not an examination and would not be forwarded to their teachers. He instructed the participants to read each sentence with its corresponding question carefully and to indicate an answer only after they were confident that it was correct. He provided an example by reading the first two practice sentences, indicating their correct answers. He then asked the participants to read the remaining two practice sentences and to indicate their correct answers. The participants were permitted to continue working on the test sentences only after their performance on the practice sheet demonstrated that they understood the task procedure.

The moment the participants were ready to work on the test sentences, the experimenter informed them that time was not restricted and reminded them to read the sentences and questions thoroughly before indicating their answers. He also encouraged them to ask for help in case they should encounter an unfamiliar word in one of the test sentences. None of the participants showed difficulties understanding the test requirements.

Results
Findings from three different lines of analysis are reported: findings regarding the word processing skills of the participants (as shown by the two word processing tasks), findings from analysis of their reading comprehension skills, and findings concerning the way the functioning of the groups in these two skill domains was correlated. A further line of analysis of a descriptive nature is presented with a view to expanding knowledge regarding the nature of the reading strategies of the three participant groups, these strategies’ efficiency, and the way the strategies were linked to the quality of the functional hearing of the participants.

Analysis of the Three Groups’ Word Processing Skills
The performance time means and error rates of the groups for the two word processing tasks are presented in Table 1. Two general linear model (GLM) analyses of variance—one analyzing speed of processing and another analyzing processing accuracy—were executed. (GLM repeated measures analyze groups of related dependent variables that represent different measurements of the same attribute.) In both analyses, task type (PI word pairs, CI word pairs) was computed as a within-subject factor and group (hard of hearing, deaf, hearing) as the between-subject factor. The analysis of the performance times of the participants reveals a statistically significant task type effect ($F[1, 72] = 122.41, p > .001$), suggesting that words were

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance time (sec)</th>
<th>Error rate (maximum = 40.00)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Perceptual processing of words</td>
<td>Conceptual processing of words</td>
</tr>
<tr>
<td>Hard of hearing</td>
<td>23.47 (2.79)</td>
<td>32.52 (4.80)</td>
</tr>
<tr>
<td>Deaf</td>
<td>22.87 (3.89)</td>
<td>32.03 (6.15)</td>
</tr>
<tr>
<td>Hearing</td>
<td>24.52 (4.00)</td>
<td>31.36 (5.23)</td>
</tr>
<tr>
<td>All participants</td>
<td>23.81 (3.72)</td>
<td>31.83 (5.34)</td>
</tr>
</tbody>
</table>

Note. Standard deviations for the respective mean values are provided in parentheses. *The perceptual processing accuracy of the participants who were hard of hearing was found to be somewhat less than that of the other groups. However, because the error rate in this condition was well below 1% for all groups, the significance of this decrease in accuracy seems negligible.
reading comprehension

processed significantly faster under PI conditions than under CI conditions. The group effect was not found to be significant. There was also no evidence of a significant interaction between the two main effects.

The analysis of the error rates disclosed a statistically significant task type effect \( (F[1, 72] = 49.29, p > .001) \), indicating that the processing of CI word pairs was notably less accurate than the processing of PI word pairs. Neither the group effect nor the interaction of the group effect with the task type effect was of statistical significance. However, findings obtained from a post hoc analysis of the error rates in a multivariate model indicated that the perceptual processing of words (PI word pairs) by hard of hearing individuals was significantly less accurate than the perceptual processing of words by participants who were deaf or by participants who were hearing. (The probability level of all findings reported from post hoc analyses is \( p > .05 \)).

Developmental trends in the basic word processing skills of the groups were examined in a series of correlation analyses. (Unless specified differently, correlations were calculated using a Pearson product-moment procedure.)

For the hard of hearing and deaf groups, the perceptual and conceptual processing of written words was not found to be associated with either of the two developmental variables. In contrast, for the hearing control group, speed of processing for both word processing tasks correlated negatively with grade level (for PI word pairs \( r = -.52, p = .001 \); for CI word pairs \( r = -.38, p > .05 \) \( n = 36 \)), suggesting that formal schooling contributes to the word processing skill of hearing individuals. The processing of PI word pairs by the hearing participants was also found to be significantly associated with their chronological age \( r = -.36, p > .05 \) \( n = 36 \), indicating an acceleration in the perceptual processing of written words, due to maturation.

Analysis of the Three Groups’ Sentence Comprehension

The sentence comprehension scores (SCS) of the three participant groups—overall and for SP and SI sentences separately—are presented in Table 2. Sentence comprehension was analyzed in a GLM procedure computed as a repeated measure model with semantic plausibility (SP, SI) being defined as the within-subject factor and group (hard of hearing, deaf, hearing) as the between-subject factor. The effect of semantic plausibility on sentence comprehension was statistically significant \( (F[1, 72] = 83.12, p > .001) \), indicating that, overall, understanding of SP sentences was superior to understanding of SI sentences. Furthermore, a statistically significant group effect suggested that the three participant groups varied notably in their understanding of the test sentences \( (F[1, 72] = 16.36, p > .001) \). Moreover, a significant interaction between the two main effects provided evidence that the semantic plausibility effect was not uniform for the three groups \( (F[2, 72] = 11.23, p > .001) \).

A series of post hoc analyses was conducted to clarify the final significance of the main effects as well as the final significance of the way they interacted. In a first step, a Scheffe procedure revealed that the overall SCS of both groups with hearing loss was noticeably below that of the hearing control group. When performance in the two sentence categories was considered separately, a more complex group performance profile was yielded. On SI sentences, the comprehension of the hearing control group was superior to that of the other groups. However, with regard to the comprehension of SP sentences, the hearing control group outperformed the participants who were hard of hearing but not those who were deaf. The sentence comprehension of participants who were deaf and participants who were hard of hearing was not found to differ significantly. This was found to be true regardless of whether their overall SCS or their SCS for the two sentence categories was considered.

In a second step, post hoc analyses focused on the semantic plausibility effect and the way it interacted with the group effect. A series of paired \( t \)-test comparisons was used to compare performance on SP sentences with performance on SI sentences for each group separately. For the hearing

Table 2

<table>
<thead>
<tr>
<th>Group</th>
<th>Semantically plausible sentences</th>
<th>Semantically implausible sentences</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard of hearing</td>
<td>88.16 (18.28)</td>
<td>67.54 (25.29)</td>
<td>77.85 (18.89)</td>
</tr>
<tr>
<td>Deaf</td>
<td>90.42 (10.57)</td>
<td>77.08 (19.84)</td>
<td>83.75 (13.44)</td>
</tr>
<tr>
<td>Hearing</td>
<td>96.53 (5.02)</td>
<td>95.83 (6.45)</td>
<td>96.18 (3.91)</td>
</tr>
<tr>
<td>All participants</td>
<td>92.78 (11.65)</td>
<td>83.66 (20.66)</td>
<td>88.22 (14.29)</td>
</tr>
</tbody>
</table>

Note. Standard deviations for the respective mean values are shown in parentheses.

* Sentence comprehension is sustained by prior knowledge.

Proper sentences comprehension obliges syntactic processing.
control group, the effect of semantic plausibility on comprehension was not notable, a finding that suggested that the hearing participants’ syntactic skills were intact. In contrast, both groups with hearing loss demonstrated a markedly better understanding of SP sentences in comparison to SI sentences: for the hard of hearing group, \( t(18) = 3.94, p > .001 \); for the deaf group, \( t(19) = 3.51; p > .001 \; \text{one-tailed} \).

The size of the semantic plausibility effect—calculated by abstracting SCS of SI sentences from SCS of SI sentences—was examined by means of a one-way analysis of variance. No evidence was obtained that the size of the semantic plausibility effect was different for the group with prelingual deafness and the group that was hard of hearing. However, relative to that for the hearing control group, the size of the semantic plausibility effect found for the two groups with hearing loss was significantly larger.

Overall, comprehension for the two sentence categories was significantly, positively correlated: \( r = .53, p > .001 \; (n = 75) \). However, as expected, at the group level, correlations between the two sentence categories were only found for the hard of hearing and deaf groups: \( r = .49, p > .05 \; (n = 19) \); \( r = .52, p > .05 \; (n = 20) \), respectively. The absence of a significant correlation between these two sentence categories for the hearing control group probably reflects a ceiling effect. After all, the control group’s comprehension was close to perfect for both sentence categories.

A series of correlation analyses was conducted to pinpoint developmental trends in the performance of the participant groups on the sentence comprehension test. For the hard of hearing participants, neither their overall SCS nor their SCS for the two sentence categories, separately, correlated with their grade levels. However, a significant positive correlation was yielded between comprehension of SI sentences and chronological age: SI \( r = -.40, p > .05 \; (n = 19) \).

For participants with prelingual deafness, the correlation pattern obtained for developmental trends in their understanding of written text was more complex. Overall, SCS correlated negatively with chronological age (\( r = -.41, p > .05 \; (n = 20) \)), suggesting that older individuals did not perform as well as younger ones. SCS was, however, not found to be significantly associated with grade level. Comprehension for both sentence categories was negatively correlated with chronological age: SP \( r = -.40, p > .05 \); SI \( r = -.34, p > .08 \; \text{ns} \; (n = 20) \). In addition, a positive correlation between the comprehension of SP sentences and schooling level was pinpointed: SL \( r = .46, p > .05 \). No such evidence, however, was found with regard to the comprehension of SI sentences. For the hearing control group, no evidence of developmental trends related to their understanding of the test sentences was found.

### The Relation Between Word Processing Skills and Sentence Comprehension

A series of correlation analyses was conducted to clarify how the word processing skills of the participant groups related to their performance on the sentence comprehension test. In general, considering speed of processing, both the perceptual (PI) and conceptual (CI) processing of written words was found to significantly, negatively correlate with the overall SCS of the participants: \( r = -.23, p > .05 \); \( r = -.24, p > .05 \; (n = 75) \). When these correlations were considered with reference to the two sentence categories (SP and SI sentences), significant correlations were found only between the perceptual and conceptual processing of words, and the understanding of SP sentences (\( r = -.29, p > .01 \; (n = 75) \); \( r = -.27, p > .01 \); respectively \( n = 75 \)), but not for the comprehension of SI sentences.

Analyses of the same association at the group level reveal that, for participants who were hard of hearing, the conceptual processing of word pairs (CI) was significantly, negatively related to their overall SCS: \( r = -.44, p > .05 \; (n = 19) \). The same correlation calculated for perceptual word processing was only of borderline significance: \( r = -.38, p > .06 \; (n = 19) \). However, correlation analyses focusing on the SCS for the two sentence categories revealed that, for the hard of hearing group, perceptual and conceptual word processing speed were both associated only with the comprehension of SP sentences (\( r = -.52, p > .05 \); \( r = -.56, p > .01 \); respectively \( n = 19 \)), but not with the comprehension of SI sentences. For neither the prelingually deafened participants nor the hearing participants was word processing speed related to understanding of the test sentences.

There was evidence of a significant negative correlation between the conceptual word processing accuracy of the hearing participants and their understanding of the test sentences. The correlation was yielded with regard to their overall SCS (\( r = -.53, p > .001 \; (n = 36) \)), as well as their SCS for SP sentences (\( r = -.30, p > .05 \; (n = 36) \)) and SCS for SI sentences (\( r = -.42, p > .01 \; (n = 36) \)). Word processing accuracy was not found to correlate with understanding of the test sentences for any of the other groups.

### Regrouping the Participants Into Performance Clusters

In the analyses reported so far, the performance of the participants was...
analyzed using quality of functional hearing (deaf, hard of hearing, hearing) as a grouping criterion. However, considering the huge standard deviations found for the participants who were deaf or hard of hearing with regard to their sentence comprehension in general, and their comprehension of the SP and SI sentences in particular, one can hardly avoid the impression that hearing status may not be an optimal grouping criterion for adequately representing the reading skills of such individuals. In other words, there is reason to believe that at least the two groups with hearing loss represented subgroups of readers with very different reading skills.

To test for this possibility, it was decided to ignore the hearing status of the participants in the subsequent post hoc analyses and to regroup them—based on their comprehension of SP and SI sentences—into performance clusters. A quick cluster procedure (K-means), computing SP and SI scores as grouping factors, was used for this purpose. An optimal clustering of the participants yielded three performance clusters, with a maximum distance between cluster centers reached after four iterations. Sentence comprehension means for the three performance clusters are presented in Table 3.

As can be seen from Table 3, participants assigned to the first performance cluster showed comprehension approaching chance level for both SP and SI sentences, a performance pattern expected for readers who rely on atypical structural knowledge for reading. Thus, in the following, Cluster 1 is referred to as the atypical reader profile or the atypical reader group.

The second performance cluster scored high on SP sentences but low on SI sentences, a performance pattern expected for readers who use a semantic, top-down reading strategy for making sense of texts. Therefore, in the following, Cluster 2 is referred to as the semantic reader profile or the semantic reader group.

The third performance cluster was characterized by near-perfect to perfect performance on both SP and SI sentences, a pattern expected for readers who rely on adequate syntactic knowledge for making sense of text. Cluster 3 is therefore referred to in the following as the syntactic reader profile or the syntactic reader group.

For the purpose of obtaining insight into the distribution of the original participant groups with respect to the three reader profiles, the participants assigned to a particular profile were identified by means of a cross-tabs procedure with reference to their original hearing status (hard of hearing, deaf, hearing) as well as to the hearing status of their parents (hard of hearing, impaired, hearing). A summary of the participant distribution is provided in Table 4.

### Table 3
Sentence Comprehension Profile for the Three Performance Clusters, and Performance Scores (Percentile) by Sentence Type

<table>
<thead>
<tr>
<th>Performance cluster</th>
<th>Semantically plausible sentencesa</th>
<th>Semantically implausible sentencesa</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1: atypical readers (n = 5)</td>
<td>60.00 (13.69)</td>
<td>63.33 (13.94)</td>
<td>61.67 (12.98)</td>
</tr>
<tr>
<td>Cluster 2: semantic readers (n = 14)</td>
<td>88.69 (9.59)</td>
<td>49.45 (15.14)</td>
<td>69.04 (10.93)</td>
</tr>
<tr>
<td>Cluster 3: syntactic readers (n = 56)</td>
<td>96.73 (5.43)</td>
<td>94.05 (7.74)</td>
<td>95.34 (4.94)</td>
</tr>
</tbody>
</table>

Note. Standard deviations for the respective mean values are shown in parentheses.

a Proper sentence comprehension obliges syntactic processing.

### Table 4
Participants’ Distribution Within the Three Performance Clusters With Reference to Their Hearing Status and Their Parents’ Hearing Status

<table>
<thead>
<tr>
<th>Hearing status of participant</th>
<th>Hearing status of parent</th>
<th>Atypical readers</th>
<th>Semantic readers</th>
<th>Syntactic readers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard of hearing</td>
<td>Hearing impaired</td>
<td>1</td>
<td>—</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hearing</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>Deaf</td>
<td>Hearing impaired</td>
<td>—</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Hearing</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Hearing</td>
<td>Hearing impaired</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Hearing</td>
<td>—</td>
<td>—</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5</td>
<td>14</td>
<td>56</td>
<td>75</td>
</tr>
</tbody>
</table>
Among the eight participants with hearing loss (two hard of hearing and six deaf) whose parents had hearing loss themselves, five were identified as fitting the syntactic reader profile, two the semantic reader profile, and only one the atypical reader profile (see Table 4). In fact, among the five participants with hearing loss who were assigned to the atypical reader profile, four were children of hearing parents. Moreover, 12 of the participants with hearing loss (7 hard of hearing and 5 deaf) who had hearing parents were found to have a semantic reader profile, whereas 15 (8 hard of hearing and 7 deaf) exhibited a performance profile that identified them as syntactic readers.

Because the three reader profile groups were unequal in size and two of them were rather small, it was decided to use nonparametric statistics for their further examination. The first examination focused on differences among the three reader profile groups with regard to the processing of written words (see Table 5). A series of Mann-Whitney tests (groups paired) comparing performance on the two word processing tasks failed to reveal statistically significant evidence that the three reader profile groups differed in their word processing skills. This was found to be true when speed of processing or processing accuracy was considered, and despite the fact that participants with an atypical reader profile were, on average, notably slower in their processing of PI and CI word pairs.

A series of Mann-Whitney tests (groups paired) was executed to compare the comprehension of SP and SI sentences by the three reader profile groups (see Table 5). Evidence from these analyses shows that participants with an atypical reader profile underperformed syntactic readers in both sentence categories: \( Z = -4.25, p > .001; Z = -3.89, p > .001 \), respectively. In addition, syntactic readers were found to understand the two sentence categories notably better than participants with semantic reader profiles: \( Z = -5.54, p > .001; Z = -6.05, p > .001 \), respectively. It is noteworthy, however, that in a parametric comparison analysis (one-way analysis of variance) where variance rather than ranks were used to calculate group differences, the comprehension of SP sentences was found to be comparable for semantic and syntactic readers.

An examination of the semantic plausibility effect (SP-SI) using nonparametric statistics (Wilcoxon signed-ranks test) revealed no evidence that—for participants with an atypical reader profile—comprehension in the two sentence categories was significantly different. For semantic readers, however, the impact of semantic plausibility was large (\( z = -3.32, p > .001 \); one-tailed). Although notably smaller, the effect of semantic plausibility on comprehension was also significant for the syntactic readers (\( z = -2.13, p > .05 \); one-tailed). A comparison based on a Mann-Whitney test further suggested that the size of the semantic plausibility effect was significantly more prominent for participants with a semantic reader profile, in comparison to atypical readers and to syntactic readers (\( z = -3.28, p > .001; z = -5.88, p > .001 \); respectively). There was, however, no evidence that the size of the semantic plausibility effect was notably different for participants who were atypical readers and participants who were syntactic readers.

A series of correlation analyses (Spearman) was conducted to clarify how the word processing skills of the three reader profile groups related to the groups’ comprehension of P and SI sentences. For participants in the syntactic reader group, statistically significant negative correlations related to processing speed were found between their perceptual (PI) and conceptual (CI) processing of written words, and their comprehension of SI sentences: \( rs = -2.7, p > .05; rs = -3.33, p > .01 \), one-tailed; respectively \( n = 56 \). A similar association was also yielded when the same correlations were calculated with their overall SCS: \( rs = -2.9, p > .05; rs = -2.6, p > .01 \), one-tailed; respectively \( n = 56 \).

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Word Processing Times and Age Profiles for the Three Performance Clusters, and Performance Time and Error Rate Means for the Processing of Physically Identical and Conventionally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Error rate</td>
</tr>
<tr>
<td>Cluster</td>
<td>Pairs</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Atypical</td>
<td>42.23</td>
</tr>
<tr>
<td></td>
<td>(13.87)</td>
</tr>
<tr>
<td>Semantic</td>
<td>37.39</td>
</tr>
<tr>
<td></td>
<td>(6.55)</td>
</tr>
<tr>
<td>Syntactic</td>
<td>37.27</td>
</tr>
<tr>
<td></td>
<td>(5.00)</td>
</tr>
</tbody>
</table>

Note. Standard deviations for the respective mean values are shown in parentheses.
was, however, no evidence linking word processing speed to comprehension of SP sentences. Moreover, for syntactic readers, increased accuracy in the processing of CI word pairs was found to correlate with their SCS overall \((rs = -0.30, p > .05\); one-tailed \((n = 56)\) and with their SCS for each of the semantic plausibility categories: SP sentences \(rs = -0.30, p > .05\); SI sentences \(rs = -0.41, p > .01\); one-tailed \((n = 56)\). Execution of the same correlation analyses with the other two reader profile groups revealed no significant evidence of an association between their processing of PI and CI pairs and their understanding of the test sentences.

An additional series of correlation analyses was conducted to disclose possible developmental trends in the comprehension of SP and SI sentences by readers in the three reading profile groups. Findings from these analyses show that grade level was not significantly correlated with performance on the sentence comprehension test for any of the three reader types. This was found to be true whether the correlation analyses focused on the comprehension of SP or SI sentences. However, for semantic readers, increase in chronological age was found to be positively associated with an improved understanding of SI sentences: \(rs = .49, p > .05\) one-tailed \((n = 14)\). No other significant correlations were pinpointed by analyses computing chronological age as the developmental variable.

**Discussion**

The present study represents an attempt to further specify the roots of the impoverished reading skills of individuals with prelingual hearing loss. More specifically, the study focused on the relative contribution of the quality of hearing of individuals to their functioning in two areas: the processing of written words at a lexical level and the comprehension of words within the structure of a sentence.

The basic assumption was that reduced functional hearing has a detrimental influence on the ability of an individual to establish proper phonological representations for words. Because such phonological representation are claimed to mediate the conceptual processing of written words (Ehri, 1999; Ehri et al., 2001; Frost, 1998; National Reading Panel, 2000; Share, 1995; Snow et al., 1998), word processing efficiency was expected to decrease with a decrease in functional hearing. In other words, it was predicted that hearing individuals would be more effective word processors than individuals with hearing loss, and that hard of hearing individuals, because they have some functional hearing, would prove more proficient than deaf individuals.

This hypothesis, however, was not confirmed by the findings of the present study. In fact, the word processing efficiency of individuals with prelingually acquired hearing loss was found to be strikingly similar to that of individuals with intact hearing. This equality was apparent both at a perceptual (PI) and a conceptual (CI) word processing level, and regardless of whether quantitative (time) or qualitative (error rate) processing aspects were considered. Of particular interest in this regard is the finding that even those among the participants with hearing loss who were identified by the quick cluster analysis as having obvious difficulties in comprehending the test sentences—the participants with atypical reader profiles or with semantic reader profiles—were never found to be statistically distinguishable at the lexical level from participants with intact sentence comprehension skills.

Findings regarding the functioning of the hard of hearing and deaf groups on the two word processing tasks strongly suggest that permanent auditory deprivation from early childhood, although certainly resulting in seriously reduced phonological knowledge (Nielsen & Leutke-Stahlman, 2002), does not prevent the development of word processing strategies adequate for the efficient processing of written words. This is in line with findings from other studies (Miller, 2002a, 2004a, 2004b) that indicate that the cause of the failure of individuals with severe prelingual hearing loss to comprehend what they read is not a phonological deficit that undermines the processing of written words at the lexical level. The fact that in these studies, as in the present study, the conceptual processing of written words by prelingually deafened individuals was not found to be inferior to that of their hearing counterparts is particularly noteworthy in this regard. It actually suggests that hypotheses linking the poor reading comprehension of severely prelingually hearing impaired individuals directly and causally to their impoverished phonological abilities (Hanson & Lichtenstein, 1990; Padden & Hanson, 2000; Perfetti & Sandak, 2000) may not be tenable.

A second hypothesis tested in the present study was that the quality of the functional hearing of individuals affects reading comprehension via its effect on their word processing skills. In other words, better hearing—because it facilitates the development of phonological knowledge—promotes enhanced strategies for the recognition of written words, which in turn positively affect higher-order processes underlying reading comprehension. Findings from the present study fail to confirm that the reading comprehension of the participants indeed reflected such a causal transfer.

Considering the comparable per-
formances of the three participant groups on the word processing tasks on the one hand, and their divergent abilities to understand the test sentences on the other hand, a conclusion is warranted that the cause of impoverished reading comprehension of individuals with prelingual hearing loss is some malfunctioning in the processing of written words at a supralexical, probably syntactic, level. Moreover, it appears that such deficiency may not be related to functional hearing in a straightforward manner. This is suggested by the fact that, even though they had better functional hearing, the hard of hearing participants as a group never outperformed the participants with prelingual deafness. The same conclusion is also reasonable in view of the finding that only about half of the individuals who were hard of hearing or deaf manifested a deficit at the sentence level (see Table 4).

In light of findings from the present study, there is no doubt that severe hearing loss from early childhood places individuals at risk of developing reading problems. This is obvious from the finding that all participants identified as deviant readers were either hard of hearing or deaf. It is noteworthy, however, that not all individuals with hearing loss manifested a deficient understanding of the test sentences, and that those who did were evenly represented by participants from both the hard of hearing and the deaf groups (see Table 4). This implies that beyond a certain level of severity, quality of functional hearing per se may not be very indicative with regard to the quality of an individual’s reading skills. Findings from the present study indeed suggest that focusing on reading strategies of individuals with hearing loss may be a more fruitful approach to understanding the underlying causes of their reading problems.

There is definitely more to reading comprehension than the processing of the structural information in written text. However, because in oral language the way words are structured within the word sequence of a sentence affects their final meaning, processing of the structure of a sentence must be considered a cornerstone of proper reading comprehension. It was therefore hypothesized that, for readers with adequate syntactic knowledge, variation in the semantic plausibility of a sentence would not significantly affect its comprehension. This is because, for such readers, the bottom-up processing of a sentence overrides the straightforward interpretation of word meaning based on prior knowledge and experience.

In the present study, the only group for which the existence of adequate syntactic knowledge for the processing of the test sentences could be assumed was the hearing control group. Their close-to-perfect understanding of the two types of test sentences indeed suggests that, as hypothesized, readers with adequate syntactic knowledge would have no problem understanding texts whether they were semantically plausible or not. On the other hand, the significantly impoverished understanding of the test sentences by the hard of hearing and deaf participants, overall, particularly of SI sentences, indicates that, as groups, people who are deaf or people who are hard of hearing may be deprived of knowledge that is essential for a proper understanding of written texts.

As already stated in the present study, not all of the participants who were hard of hearing or deaf evidenced a deficit related to the processing of the test sentences according to structural rule-based knowledge. On the contrary, cluster analyses suggest that among these participants a substantial portion (about half) processed the test sentences based on adequate syntactic knowledge (see Table 4), a finding reflected in their hearing-group-comparable performance in both sentence categories. The finding that a notable number of such individuals—their severe hearing loss notwithstanding—had adequate structural (syntactic) knowledge for comprehending the test sentences is encouraging. Regrettably, however, the findings also suggest that, despite years of formal schooling, too many of the participants who were hard of hearing or deaf seemingly comprehended the test sentences without having the adequate structural knowledge to do so successfully.

Detailed analyses of the data conducted in order to illuminate the factors underlying the impoverished reading comprehension of individuals with prelingual hearing loss suggest that the predominant reason for this performance anomaly was that these readers apparently did not process syntactic information conveyed by the sentence structure (word order). Instead, they seem to generate sentence meaning by interpreting the content words of the sentences with reference to prior knowledge and experience. The use of such a reading strategy by individuals with severe prelingual hearing loss has also been suggested elsewhere (Ewoldt, 1981; Gormley & Franzen, 1978; Miller, 2000, in press; Yurkowski & Ewoldt, 1986). As findings from the present study show, such a semantic reading strategy sustains the comprehension of the content of written messages quite effectively, as long as the message is in line with the world knowledge and experience of the reader. However, in instances in which prior knowledge and experience are lacking, reliance on such a reading strategy unavoidably leads to serious pitfalls in reading comprehension, a fact reflected in the rather drastically
impaired comprehension of SI sentences by the participants with hearing loss, who, in the present study, exhibited a semantic reader profile.

Although the majority of the participants from the hard of hearing or deaf groups who did not manifest a syntactic reader profile seemed to rely on a semantic reading strategy for making sense of the test sentences, the reading strategy used by some of them was apparently not semantic in nature (see Table 3). This finding is manifested in their markedly impoverished comprehension of sentences from both sentence categories. On the one hand, such concomitant, uniform reading deficits indicate that these participants relied on rule-based knowledge for the processing of the test sentences from the two plausibility categories. On the other hand, however, their notably impaired understanding of these sentences strongly suggests that the knowledge they used was either incomplete or inappropriate for the proper processing of the test sentences. Other researchers have pointed to the possibility that the poor reading comprehension of readers with severe prelingual hearing loss may originate in reliance on a limited set of syntactic rules (Hatcher & Robbins, 1978; Quigley, 1982; Wood, 1984) or the processing of written texts by means of rules that do not correspond to verbal syntax (Cumming & Rodda, 1985; Ivimey, 1976; Quigley et al., 1977; Webster, 1986). The performance pattern on the sentence comprehension test found for the atypical reader group seems to confirm that the knowledge they used was either incomplete or inappropriate for the proper processing of the test sentences.

To understand the final implication for reading comprehension of the use of atypical structural knowledge, it is worthwhile to contrast this form of sentence understanding in the present study with that of the participants who seemed to rely on a semantic reading strategy. In general, one cannot avoid the impression that the consequences of using inadequate structural knowledge for the processing of texts are more detrimental than those accompanying the use of a semantic reading strategy. It actually appears that individuals with an atypical reader profile ignore prior knowledge and experience as a potential source of information while trying to determine the meaning of a sentence. Instead, they seemed to focus for this purpose on bottom-up processes that—implemented on the basis of partly inadequate knowledge—generated markedly poor reading comprehension.

It is noteworthy that the chronological ages of the five participants with hearing loss who demonstrated an atypical reader profile were remarkably high for their average grade level (see Table 5) as well as relative to the chronological ages of the two other reader profile groups, who themselves were strikingly similar in this regard. This actually suggests that in the course of their formal education these five participants with hearing loss may not always have been able to keep pace with class requirements. Whether their lagging was directly, causally linked to their inefficient reading strategy cannot be definitely determined based on data collected for the present study; although such a conclusion seems warranted.

Findings from the present study suggest that—in contrast to hearing individuals, who all seemed to use the same reading strategy for making sense of the test sentences—different individuals from the hard of hearing and deaf groups seemed to use reading strategies that were not homogeneous in nature. Because these reading strategies were found to differ drastically with regard to their effectiveness, it would be worthwhile to try to disclose the conditions that underlie their development.

One hypothesis tested in this regard was that the development of an adequate reading strategy—one that properly interprets sentences from both the SP and the SI sentence categories—would depend on the quality of an individual's functional hearing. Findings from the present study support this hypothesis, but in a restricted sense. On the one hand, considering the performance of the hearing participants, it is obvious that the ability to hear is a sufficient condition for building up substantial structural knowledge regarding a spoken language, knowledge that for such individuals will eventually become the basis for the understanding of connected written texts. On the other hand, the finding that the hard of hearing participants were not found to acquire structural knowledge more readily than their prelingually deafened counterparts indicates that—beyond a certain hearing-loss level—auditory stimulation may not be sufficient for guaranteeing the spontaneous internalization of rule-based knowledge concerning the language spoken in an individual's surroundings. If this line of reasoning is correct, then the finding that—among both the hard of hearing and deaf groups—some of the participants obviously used a reading strategy that referenced syntactic knowledge warrants looking for other factors that explain why this was not the case for all of them.

Parental hearing status is one factor that may be helpful in clarifying why some of the participants who were hard of hearing or deaf seemed to use a deviant reading strategy to process the test sentences from the two semantic plausibility categories. Among the parents of the participants from the two groups with hearing loss,
there were eight who themselves were hearing impaired (see Table 4). There are at least two reasons why having parents with hearing loss could create less favorable conditions for similarly situated children in their struggle to acquire structural knowledge regarding spoken language. First, parents with hearing loss often lack adequate syntactic knowledge of spoken language themselves; that is, their ability to serve as effective language models for their children with hearing loss may be restricted. Second, such parents tend to communicate with their children by means of sign language, which has unique syntactic principles. Such language experience not only quantitatively reduces exposure to spoken code as a basis for the abstraction of its syntactic rules but, alternately, may lead to the internalization of the formational principles of sign language that, if applied to spoken language, interfere with comprehension.

If one follows these lines of reasoning, then among the participants with hearing loss, those who had parents with hearing loss would be expected to be either semantic readers or readers with an atypical reader profile, whereas those with hearing parents would be more likely to be identified together with the hearing participants as syntactic readers. Yet, as can be seen from Table 4, these hypotheses were completely contradicted by findings of the present study.

First of all, the performance profile in the two sentence categories of the participants who had parents with hearing loss proved that most of these participants relied on a syntactic reading strategy. Actually, such individuals were proportionally more common among the syntactic readers (63%) than participants with hearing loss who had hearing parents (48%). This suggests that linguistic advantages or disadvantages that could arise from the hearing status of these individuals’ parents were not transferred straightforwardly, parent to child. This is most clearly demonstrated by the finding that, among the five participants who manifested an atypical reader profile, four were children with hearing loss who had hearing parents. It is particularly noteworthy in this regard that none of the six deaf participants with parents who were themselves deaf were found to be atypical readers, even though they reported that they relied on sign language for communication with their parents. This absence of atypicality—in conjunction with the finding that the majority of the prelingually deafened individuals with deaf parents proved to have adequate syntactic knowledge for properly understanding the SI sentences—is convincing evidence that the use of sign language, per se, does not impede the acquisition of rule-based knowledge as the basis for reading, but may even foster it. This later conclusion is consistent with findings showing that, among prelingually deafened individuals, those who are native signers tend to have better reading skills (Conrad, 1979; Kampfe & Turecheck, 1987; Weisel, 1984; Zwiebel, 1987; for a review, see Paul, 2001).

Another factor that may affect the acquisition of syntactic rules is formal schooling (grade level). This was found to be true whether this relation was examined with reference to the hearing status of the participants (hearing, hard of hearing, deaf) or with reference to their reader profiles (atypical, semantic, syntactic). Because the application of syntactic knowledge was a prerequisite for the understanding of the SI sentences, the finding that these sentences’ comprehension was not significantly correlated with grade level is noteworthy. It actually suggests that formal education may not be very effective in fostering the capacity of individuals with severe prelingual hearing loss to build up an understanding of the rules governing spoken code.

In sum, findings from the present study show that the seriously impoverished reading skills that characterize individuals with severe prelingual hearing loss as a group reflect the reliance on reading strategies that are based on insufficient or deviant structural knowledge regarding the spoken code, rather than a failure to efficiently process written words at the lexical level. This is, of course, not to say that such individuals may not eventually have deficits in their word knowledge, deficits that impede their understanding of written text. Yet, from findings of the present study and others (Miller, 2002b, 2004a, 2004b), it seems reasonable to assume that once written words are familiar to such individuals, they recognize them—despite a profound phonological weakness—with great efficiency.

Findings from the present study show convincingly that the existence of proper hearing, in conjunction with exposure to a speaking environment, provides a sufficient basis for the spontaneous acquisition of rule-based, structural knowledge that sustains the
**Reading Comprehension**

...
use of Total Communication with its students with hearing loss. Regrettably, this is still not the favored educational approach of many hearing parents of deaf children in Israel.

4. The test sentences were prepared from words taken from a word pool I used for the preparation of sentences in a previous experiment (Miller, 2000). According to two teachers of the deaf and a speech therapist—all of them working closely with deaf children at the initial primary-school levels—all words included in this pool should be within the realm of deaf second graders’ vocabulary.

References


Appendix A
Examples of Sentences Used to Assess Study Participants’ Reading Comprehension

Semantically Plausible Sentence
S: HA-YALDA SHE-SHAMRA AL HA-TINOKET KAR’AH.
   (The girl who looked after the baby was reading.)
Q: MI KARA? (Who was reading?)
A1: HA-BAHURA. (The girl.)
A2: HA-TINOKET. (The baby.)

Semantically Implausible Sentence
S: HA-IMA SHE-TILA IM HA-TINOKET BACHTA.
   (The mother who took the baby for a walk was crying.)
Q: MI BACHTA? (Who was crying?)
A1: HA-IMA. (The mother.)
A2: HA-TINOKET. (The baby.)
In Paul Miller’s article “Reading Comprehension and Its Relation to the Quality of Functional Hearing: Evidence From Readers With Different Functional Hearing Abilities,” (pp. 305–22) in volume 150 (3), summer issue, an error occurred in the results section (pp. 311–16). In every instance the incorrect text “p >” should be replaced with “p <”, except on page 313, second column, where the phrase “p > .08 ns (n = 20)” is correct. There is an additional error on page 314, right column below Table 3, in the sentence beginning with “Seven of the hard of hearing . . .” The word “Seven” should be “Nine”.

The American Annals of the Deaf regrets any inconvenience or confusion these errors may have caused our readers.