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Reading by Children with Low Vision

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Abstract: This study of the reading of text found that despite their lower reading speed on a reading-comprehension task, the children with low vision comprehended texts at least as well as did the sighted children. Children with low vision need more time to read and comprehend a text, but they seem to use this time with enough efficiency to process the semantic, as well as the syntactic, information.

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Children with low vision read isolated words more slowly than do sighted children (Bullimore & Bailey, 1995; Gompel, Janssen, van Bon, & Schreuder, 2003;

Gompel, van Bon, Schreuder, & Adriaansen, 2002; van Bon, Adriaansen, Gompel, & Kouwenberg, 2000). As Koenen, Bosman, and Gompel (2001) proposed, the difference in the reading speeds of children with low vision and sighted children may even be greater in text reading than in word reading because, besides pattern recognition, reading texts requires additional visual processes such as the control of eye movements, which may be more difficult for some children with low vision. It is possible, however, that readers with low vision compensate for this disadvantage with a greater reliance on contextual information. By *context*, we mean the sentence or text in which a word is embedded.

Several studies of sighted children and adults showed that a meaningful context facilitates the reading process (Nation & Snowling, 1998; Perfetti, Goldman, & Hogaboam, 1979; Stanovich, West, & Feeman, 1981; West & Stanovich, 1978). Furthermore, these studies found that these contextual effects are larger for less-skilled readers. Less-skilled readers are likely to rely on such additional sources of information as context to compensate for less-efficient word-identification skills (Nation & Snowling, 1998; Stanovich et al., 1981).

Several studies have also shown that contextual effects are larger, even for skilled readers, when the visual input is degraded (Becker & Killion, 1977; Massaro, Jones, Lipscomb, & Scholz, 1978; Sanford, Garrod, &

Boyle, 1977; Sperber, McCauley, Ragain, & Weil, 1979; Stanovich & West, 1979, 1981). If a degraded visual input causes sighted readers to rely more on context, then people with low vision should have larger context effects than do sighted people because, for them, visual input is always degraded. Nevertheless, research on this issue has not been consistent. Fine and Peli (1996) found that there was no difference in the gains from context between participants with central field loss (CFL) and sighted readers, whereas Bullimore and Bailey (1995) found relatively larger gains for readers with CFL than for sighted readers. We did not find any studies that compared the use of context by children with low vision with that of sighted children.

On the basis of the literature just discussed, one may expect that children with low vision may depend on context more because it lessens their need to decode every single word. On the other hand, children with low vision may make less use of the context because the task of decoding already puts a burden on their processing capacities.

Another disadvantage for children with low vision in reading text may be related to their processing capacity and working memory. If children with low vision need more time and effort to decode words, they have less processing capacity and working memory left for syntactic and semantic analysis. Reading comprehension and syntactic processing (the processing of information about the structure of sentences), in particular, are partly governed by the amount of working memory that is available (Baddely & Wilson, 1988; King & Just, 1991). Consequently, it can be expected that the reading comprehension of children with low vision is hampered by a lower reading speed and less remaining processing capacities.

In an earlier study (Gompel et al., 2002), however, we found that children with low vision who had no additional disabilities (for example, learning disabilities, impaired cognitive abilities, or hearing impairments) are at least as good as are sighted children in comprehending texts. In that study, reading comprehension was measured by the number of correct answers on questions about texts that the children read. However, in the task, no distinction could be made between semantic processing and syntactic processing. It is possible that children with low vision do have problems with the syntactic processing of sentences. Syntactic processing can be measured using the cloze procedure, in which the deleted words are function words (Abraham & Chapelle, 1992). Cloze tests of reading comprehension consist of texts with words that are omitted at regular or irregular intervals, and the respondents are required to fill in the missing words (Hartley & Trueman, 1986).

To gain a better understanding of the reading of sentences by children with low vision, the following questions need to be answered. First, is the difference in reading time between texts and isolated words different for children with low vision than for sighted children? Second, do children with low vision rely more on contextual information than do sighted children? Because reading is more than just decoding, whether words or sentences are being read, the third question is this: Do the slower reading rates of children with low vision affect the children's semantic and syntactic processing of sentences? The final question that we investigated has to do with possible processing differences within the group of children with low vision. Children with visual field restrictions may have more problems reading sentences than do children with low vision who have intact visual fields, because a visual field defect is a source of inefficient eye movements (Rubin & Turano, 1994). Rubin and Turano also suggested that people with central scotomas read more slowly than do other individuals with low vision because they have to use the peripheral retina to decode the visual pattern, which is far less efficient for this task than is the fovea.

Method

Participants

In this study, the participants were 123 children in the Netherlands—41 with low vision (21 girls and 20 boys), 41 sighted children matched by educational age (25 girls and 16 boys), and 41 sighted children matched by reading level (23 girls and 18 boys). The sighted children were selected from a regular primary school. The educational age in months and the reading scores of all the participants are presented in Table 1.

At the time of the study, all 41 participants with low vision had an educational age of 40 to 60 months. (Five attended a special school for students with visual impairments, one attended a primary school for special education, and the remaining 35 attended a regular primary school but received outreaching support from an institution for students with visual impairments.) In the Netherlands, school placement is not related to the visual characteristics of visually impaired children, but depends on the children's learning capabilities. An analysis of variance (ANOVA), with school placement as a factor, educational age as a covariate, and the score on the word-decoding test—the Drie Minuten Test (Three-Minute Test; hereafter DMT)—as the dependent variable, however, showed that in our sample, the children with low vision in special schools did not score significantly lower on the word-decoding test than did the children with low vision in the regular schools (F (1,38) = 2.5, $p > .05$). All the participants with low vision were able to and were used to reading standard print. Five children were used to reading with magnifiers.

The sighted children in the reading-level control group had a reading level that was equal to that of the children with low vision ($F < 1$), but their educational age was significantly lower than that of the children with low vision (F (1,80) = 84, $p < .05$). The sighted children in the age-level control group were matched on educational age, but had a significantly higher reading level (F (1,80) = 7.6, $p < .05$). All the participants were native Dutch speakers.

The visual fields of all the children with low vision were examined by low vision specialists of the low vision institutions. Their peripheral visual fields were determined with the Goldmann kinetic perimeter or the Tübinger kinetic perimeter. Their central visual fields (central 30 degrees) were determined with the Friedmann II Static Visual Field Analyzer (Extended Program).

Materials

Reading level was determined by means of the second card of the DMT (Verhoeven, 1995). The DMT is a standardized word-decoding test, consisting of three cards. Reading comprehension was determined by means of a cloze test, the text-reading task of the TAK (Taaltoets Alle Kinderen [Language Test All for Children]; Verhoeven & Vermeer, 1993). The text-reading task of the TAK consists of four texts with a mean length of 262.5 words. In all the texts, 18 to 22 words are left out, and children have to choose the missing word from three alternatives. To measure semantic processing, in two texts the missing words are content words. To measure syntactic processing, in the other two texts, the missing words are function words. Content words, which can be nouns, verbs, adjectives, or adverbs, are words that have a semantic meaning. Function words, which can be pronouns, determiners, prepositions, or conjunctions, are words that have a grammatical meaning; they determine the structural relationships between content words, sentences, phrases, or clauses (Finegan, 1999).

The use of context was measured by means of a word-naming task. Stimuli for this task were 60 words (the target words) with a mean length of 6.1 letters (*SD* 2.2). Target words were nouns or verbs. The words were presented within a congruent (meaningful) context, an incongruent (nonsense) context, or a neutral context. To create these contexts, we constructed 60 simple sentences that all ended with one of the target words. Sentences were constructed such that there were 30 pairs of syntactically similar sentences (for example, "I always put sugar in my *coffee*" and "He always wears a hat on his *head*"). In the congruent-context condition, the target word (for example, *head*) was preceded by the original sentence (for example, "He always wears a hat on his . . . ."). In this condition, the sentence and the target word together formed a logical and meaningful sentence. In the incongruent-context condition, the target word (*head*) was preceded by the other sentence of a pair ("I always put sugar in my . . . ."). In the incongruent condition, the sentence and the target formed a grammatically correct, but logically meaningless, sentence. In the neutral-context condition, the target word was preceded by the Dutch equivalent of the sentence: "The next word is . . . .". This condition is thought to provide no context at all. Every participant was presented with 20 words in the congruent condition, 20 words in the incongruent condition, and 20 words in the neutral context condition. The distribution of the 60 target words over the conditions was different for each participant, but was such that every target word appeared the same number of times in every condition.

Procedure

The DMT was administered according to standard procedures; that is, the participants were presented with a card with isolated words and were instructed to read the words as fast and as accurately as possible. The score was the number of correctly read words within a minute.

The TAK was also administered according to standard procedures. The participants had to read a text and choose the correct word to fit in a sentence from three alternatives by drawing a circle around that word. The format of the test was slightly adapted to the needs of children with low vision. In the original test, the three alternatives to be considered are in a separate column, and the missing word is replaced by dots. In the adapted format, all three alternatives are in the text, separated by slashes and recognizable because they are underlined. This adaptation was made to avoid the selection of a wrong set of alternatives because of erroneous eye movements. The print size of the TAK was not changed. If the participants were used to reading with their optical reading devices, they were allowed to use these devices when they completed the test. Time on task was measured in seconds with a stopwatch. The number of correctly chosen alternatives was scored.

The context experiment was a computerized word-naming task. It was executed on an Apple MacIntosh Powerbook computer, with a screen resolution of 1024 x 768 and a screen diameter of 35 centimeters (1.15 feet). The participants were free to adopt the viewing distance that was the most comfortable for them. Words and sentences were displayed in a 40-point font (for example, the letter "o" had a width of 5 mm., 0.016 feet, and a height of 6 mm., 0.02 feet. The font of the presented words was Geneva.

The participants were first presented with a sentence from which the last word was missing and were instructed to read the sentence aloud. Errors were corrected by the experimenter. When a participant had read the sentence, the experimenter pushed a button on the button box to start the presentation of the target word. The participants were told to read the word as quickly and accurately as possible. Naming latencies were registered for the target words but not for the sentences.

Stimulus presentation and response registration were controlled by a computer program that was designed for this study in the computer language C++. Latencies were registered in milliseconds by means of a voice key. Response evaluations by the experimenter were made by means of a button box. Responses could be correct, incorrect, or a voice-key error (if the voice key did not respond or was triggered by a sound other than the onset of the pronunciation of the target).

Results

Reading isolated words versus text reading

Our first question was whether the difference in reading time between texts and isolated words is different for children with low vision than for sighted children. To compare the reading of isolated words with the reading of text, we calculated the words-per-minute read on the TAK. Table 2 shows the mean words per minute per group. A 3-group (low vision versus age matched versus reading matched) by 2-task (DMT versus TAK) ANOVA was performed on the words per minute results. The ANOVA revealed a significant main effect for task (F (1,120) = 55, $p < .05$). All the children read significantly more words per minute on the word-decoding task than on the text-reading task. The main effect for group was also significant (F (2,120) = 14.8, $p < .05$); the age-matched group read significantly more words per minute than did the reading-matched group and the low vision group. The participants in the age-matched group read, on average, over 1.6 times as many words per minute as did those with low vision. The interaction between group and task was also significant (F (1,120) = 8.0, $p < .05$); the difference between words per minute on the DMT and the TAK was larger for the participants with low vision. The participants with low vision read the same number of words per minute on the DMT as did the reading-matched group ($F < 1$), but they read significantly fewer words per minute on the TAK than did the reading-matched group (F (1,80) = 6.3, $p < .05$).

The effect of contextual information

Our second question was whether children with low vision compensate for the extra burden of text reading with a higher reliance on contextual information. To answer this question, we compared the naming latencies on the word-naming task of the three groups of participants.

For one child with low vision, the data for the context experiment were not complete because of a computer error. Thus, the data of this child were discarded from this experiment, as were those of the two matching sighted children. The mean naming latencies of this experiment are summarized in Table 3. An ANOVA with group (the group with low vision versus the age-matched group versus the reading-matched group) as a between-subjects variable and context (congruent versus noncongruent versus neutral) as a within-subjects variable was performed on the median correct response latencies of each participant. The main effect of group was significant (F (2,117) = 14.3, $p < .05$); the participants with low vision were significantly slower than were the age-matched and the reading-matched participants. Further analyses revealed that the participants with low vision had significantly longer naming latencies than did the age-matched participants in all three context conditions (congruent: F (1,78) = 22.2, $p < .05$; noncongruent: F (1,78) = 22.1, $p < .05$; and neutral: F (1,78) = 27.9, $p < .05$), and than the reading-matched participants (congruent: F (1,78) = 8.9, $p < .05$; noncongruent: F (1,78) = 4.8, $p < .05$; and neutral: F (1,78) = 6.8, $p < .05$).

The main effect of context was significant (F (2,117) = 49.7, $p < .05$). In all three groups, words in the congruent context were read significantly faster than were words in the noncongruent context (F (1,117) = 36.4, $p < .05$) or than words in the neutral context (F (1,117) = 79, $p < .05$). The difference between the neutral context and the noncongruent context was also significant (F (2,117) = 17.1, $p < .05$).

The interaction between group and type of context was significant (F (4,234) = 3.8, $p < .05$). The effect of context was larger in the low vision group than in the age-matched group (F (1,78) = 15.5, $p < .05$). No difference was found between the low vision group and the reading-matched group (F (1,78) = 1.5, $p > .05$).

An ANOVA with group as a between-subjects variable and context as a within-subjects variable on the error rates of the participants revealed a significant main effect of context (F (2,117) = 13.7, $p < .05$). More errors were made in the noncongruent condition and in the neutral condition than in the congruent condition. There was no significant difference in error rates between the groups (F (2,117) = 1.7, $p > .05$), nor was there a significant interaction between group and context ($F < 1$).

Reading comprehension

Our third question, whether the lower reading rates of children with low vision affect their reading comprehension negatively, was answered by analyzing the scores on the TAK. Table 4 shows the mean scores on the TAK for all three groups. An ANOVA with group (low vision versus age matched versus reading matched) as a factor and the number of correct responses on the TAK as the dependent variable revealed a significant difference among the groups (F (2,120) = 13.1, $p < .05$). The low vision group had a significantly higher score than did the age-matched group (F (1,80) = 4.1, $p < .05$) and than did the reading-matched group (F (1,80) = 28.2, $p < .05$).

An ANOVA with group (low vision versus age matched versus reading matched) as a between-subjects variable and the type of word (function words versus content words) as the within-subjects variable was performed on the number of correct responses on the TAK. This analysis showed, besides the aforementioned main effect of group, a significant main effect of type of word (F (1,120) = 277.7, $p < .05$). The participants had higher scores on the texts with missing function words than on the texts with missing content words. No significant interaction was found between group and type of word (F (2,120) = 2.3, $p > .05$), indicating that the effect of type of word was the same for all three groups.

An ANOVA with group as a between-subjects variable and type of word as a within-subjects variable that was performed on the time that the participants needed to complete the TAK showed a significant main effect of group (F (2,119) = 13.9, $p < .05$); the low vision group needed more time than did both other groups. There was no significant main effect for type of word ($F < 1$), indicating that the tasks with missing function words required the same amount of time as did the tasks with missing content words. Nor was there a significant interaction of group and time (F (2,119) = 2.15, $p > .05$), which means that the absence of an effect of type of word on time also applied to the participants with low vision.

Effects of visual field restrictions

Our fourth question was whether there are differences between children with low vision who have and do not have visual field restrictions. From the reported diagnoses, it was expected that half the children with low vision had visual field restrictions and that the other half had intact visual fields. The results of the visual field examination, however, revealed that 30 children, that is, three-quarters of the low vision group, had some kind of visual field defect. The diagnoses and visual field specifications are summarized in Table 5.

To examine possible differences between children with different field defects and children without visual field defects, we repeated all the analyses with the following between-groups contrasts: children with visual field defects versus those without visual field defects; children with central field restrictions versus those without central field restrictions; children with peripheral field restrictions versus those without peripheral field restrictions; and children with absolute field defects versus those with relative field defects. None of the ANOVAs revealed any significant main effect for all the group comparisons (all F's < 1). Nor were any significant interactions found (all F's < 1). It was found, however, that the difference between the naming latencies in the congruent-context condition and the neutral-context condition was larger for the participants with low vision who had visual field restrictions than for the other participants with low vision, although the interaction between context (neutral versus congruent) and group (visual field restriction versus no visual field restriction) did not reach significance ($F(1,37) = 3.19$, $p = .09$).

The results show that reading and comprehending texts took relatively more time than did reading isolated words for all the groups of children in this study. This difference in the time between reading text and reading words was larger for the children with low vision. The results of the word-naming experiment indicate that this additional disadvantage of children with low vision in reading sentences is not caused by a less-developed skill in using contextual information. On the contrary, the results show that children with low vision profit more from context than do sighted children of the same age.

Although the children with low vision read significantly slower than did the sighted children, the results indicate that this factor does not lead to lower comprehension. The semantic, as well as the syntactic, processing skills of the children with low vision were comparable to those of the sighted children.

In this study, no differences were found between the children with low vision who had different kinds of visual field restrictions and those with intact visual fields in reading speed and reading-comprehension skills. Although not significant, there was some indication that the children with visual field restrictions relied on contextual information more than did the other children with low vision.

Discussion

The finding that all the children read more words per minute when they read isolated words (on the DMT) than when they read the texts of the TAK is not surprising. Besides decoding, the TAK also requires deciding which word to fill in (and thus comprehension of the text) and drawing a circle around this word. Although children with low vision also have less well-developed motor skills (Bouchard & Tetrault, 2000), the drawing component of TAK is simple and does not require much precision. Therefore, it is not likely that the difference between the sighted children and the children with low vision can be explained by a difference in the time needed for the drawing component of the task. Another possible disadvantage for children with low vision in this task may be the multiple-choice component. Children have to choose between the alternatives, which may require them to reread the words. For children with low vision, rereading the words may involve extra eye movements. In regular text-reading tasks, however, children may also need to reread words when the words or phrases are not clear or are misunderstood. Therefore, this disadvantage may not be specific to this task.

What is interesting, however, is that the children with low vision read the same number of words per minute on the DMT as did those in the reading-matched group, but they read significantly fewer words per minute on the TAK. There are two differences between the tasks: The DMT requires only the decoding and identification of the words, whereas the TAK also requires comprehension of the text. The second difference is that in the DMT, words are presented in columns, whereas in the TAK, words are presented in lines, which requires more eye movements. The different results on the DMT and the TAK indicate that reading and comprehending texts cause an additional problem for children with low vision above the decoding of the isolated words in a text. Whether this problem is the result of the need for more eye movements, as Koenen et al. (2000) proposed, or is the result of the extra processing time needed to process the syntactic information would be an interesting topic for further research. Nevertheless, children with low vision seem to use this extra time with enough efficiency to process the semantic, as well as the syntactic, information.

The finding that children with low vision profit more from context than do sighted children of the same age is in accordance with the findings of other studies (Nation & Snowling, 1998; Perfetti et al., 1979; Stanovich et al., 1981; West & Stanovich, 1978) that less-skilled readers appear to rely more on context than do more skilled readers. Because the effect of the type of context was the same for the children with low vision as for the reading-matched group, it can be concluded that children with low vision do not seem to differ from other less-skilled readers (here, the younger reading-matched group) in the extent to which they profit from contextual information. Since children with low vision are less-skilled readers because of a degraded visual input (Gompel et al., 2003), it is likely that it is this degraded visual input that causes more reliance on contextual information, which is in accordance with findings that a degraded visual input causes a greater reliance on context in sighted readers (Becker & Killion, 1977; Massaro et al., 1978; Sanford et al., 1977; Sperber et al., 1979; Stanovich & West, 1979, 1981).

The results of the study also show that the reading rate is facilitated not only by a semantically meaningful context (as is provided in the congruent condition of the context experiment), but by the syntactic constraints of the noncongruent condition. A remarkable result of the context experiment is that even on the words in the neutral context, the children with low vision had significantly longer naming latencies than did the sighted children of the same reading level, whereas there was no difference between the two groups on the DMT scores. A difference in contextual facilitation cannot explain these differences in naming latencies because there was no meaningful context in this condition. Nor can the difference be explained by a disadvantage of the children with low vision in reading sentences because the actual task on which the latencies were measured was the reading of isolated words. An explanation may be that reading from a computer screen is relatively more difficult for children with low vision than is reading printed words. This is mere speculation, however, and further research is needed to investigate this possibility.

The results of this study show that the comprehension skills of children with low vision do not differ from those of sighted children. This finding is in accordance with prior findings (Gompel et al., 2002). What is remarkable, however, is that the syntactic processing (as gauged by the performance of the children with low vision on the function-words task of the TAK) was also not hampered by the children's lower reading speed. Baddely and Wilson (1988) and King and Just (1991) found that syntactic processing is related to the amount of working capacity. Undoubtedly, children with low vision have to allocate much of their processing capacity to the decoding process and need to keep the elements of a sentence longer in working memory because of their slower reading rate. Therefore, it was expected that children with low vision would have problems with the syntactic component of reading comprehension. Although the children needed more time to complete the TAK than did the sighted children, the extra time they needed was no different for semantic processing than for syntactic processing.

Contrary to the findings of Rubin and Turano (1994), this study did not reveal any differences in the text-reading skills of children with low vision who had and did not have different kinds of visual field restrictions. Although the instrument we used, the Friedman Visual Field Analyser, is not sensitive enough to detect minimal central scotomas, we do not believe that the detection of those small scotomas would have altered the results. On the basis of the children's diagnoses, it is not likely that scotomas were missed in their examinations. It is also not likely that, if larger scotomas do not seem to make a difference in reading, smaller scotomas would have made a difference. A more plausible explanation for the difference between our results and those of Rubin and Turano is that in Rubin and Turano's study, the participants were adult readers, who may have developed low vision later in life, whereas in our study, the children were born with low vision. It is likely that children who are confronted with a degraded visual input from the beginning have developed a compensating strategy for this disadvantage by efficiently using additional resources like contextual information. In contrast, adult readers who were skilled readers before the onset of their low vision have not developed such a compensating strategy.

Implications for practice

The results of this study seem to imply that as long as children with low vision (regardless whether or not their specific visual impairment involves a visual field restriction) are given enough time to read (about 1½ to 2 times as much time as sighted children seems reasonable), comprehending texts is no problem for them. Thus, classroom teachers should give children with low vision sufficient time to study. If this time is not available, the teachers may consider using auditory reading aids, such as Talking Books or text-to-speech computer software. On tests, children with low vision also need to be allowed extra time.

Our finding that children with visual field restrictions seem to rely even more on contextual information than do other children with low vision may indicate that children adapt their compensating strategies to the severity of their impairments. This finding shows how resilient and persistent children are; in spite of severe visual impairments, most children manage to decode the words and understand what they read even though they do so more slowly than do sighted children. This situation should inspire teachers to foster the possibilities of children with low vision but, at the same time, to take into account the children's limitations with regard to their reading speed.

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