Visual Input and Orthographic Knowledge in Word Reading of Children with Low Vision

Marjolein Gompel, Neeltje M. Janssen, Wim H. J. van Bon, and Robert Schreuder

Abstract: This study investigated whether the difficulties with reading of children with low vision are a matter of reduced visual input or also a consequence of a lack of orthographic knowledge because of less reading experience. The results indicated that reduced visual input is the only cause of these children’s lower reading performance.

Research has shown that children with low vision do not read as well as do sighted children of the same age (Corley & Pring, 1993a, 1993b; Daugherty & Moran, 1982; Fellenius, 1999; Gompel, van Bon, Schreuder, & Adriaansen, 2002; Tobin, 1985; van Bon, Adriaansen, Gompel, & Kouwenberg, 2000). The question, however, is whether reduced visual input is the only reading-related problem of children with low vision.

As Koenen, Bosman, and Gompel (2000) argued, the reading skill of children with low vision profits from practice. Fellenius (1996) found that the reading performance of children with low vision is closely related to an interest in reading; good readers in her study were those who read during their leisure time. Because of reduced visual input, reading may put a relatively great strain on the reader with low vision, which, in turn, may lower the children’s motivation to read and limit the children’s practice with reading. Fellenius (1999) indeed found that children with low vision do not read for leisure as often as do sighted children. She also found that the reading practice of children with low vision is limited because they have less exposure to incidental reading materials (e.g., advertisements and subtitles on television). The fact that children with low vision have less reading experience may result in their lack of development of orthographic knowledge (that is, the general rules that underlie the correspondence between written and spoken language and word-specific letter patterns). This lack of orthographic knowledge may, in turn, have a negative effect on the children’s reading skills and lower their motivation to read even more.

If the lack of orthographic knowledge is both a consequence and a cause of the reading problems of children with low vision, one may expect that these children also

The authors are grateful to the students, teachers, and staff of Bartiméus and Sensis for their participation and cooperation in this research.
have spelling problems. Some studies have found that children with low vision are poorer spellers than are sighted children (Arter & Mason, 1994; Corley & Pring, 1993c; van Bon et al., 2000). Arter and Mason (1994) and van Bon et al. (2000), however, noted that the poor spelling performance of children with low vision may be only a temporary problem, since these children seem to overcome their spelling problems by the end of elementary school. Moreover, Gompel et al. (2002) found that spelling problems are present only in children with low vision who have additional (cognitive) problems like learning disabilities or a general low cognitive ability; children with low vision but without additional problems are just as good spellers as are sighted children of the same age. Reading problems, on the other hand, do seem to persist, at least until the end of elementary school, and are present in children with no other problems than low vision (Gompel et al., 2002). This finding seems to indicate that although children with low vision have less reading experience than do sighted children, their orthographic knowledge is not affected, and thus their reading problems are likely to be caused only by reduced visual input.

Reading is not the only ability that is affected by this input problem. Wurm, Legge, Isenberg, and Luebker (1993) showed that their participants with low vision had slower reaction times on a picture-naming task than did their sighted participants. It is not clear, however, whether the effect of reduced visual input on reading is different from the effect on picture naming. Whereas pictures and words are similar in the need to recognize visual patterns, orthographic knowledge is required only for reading words.

The first aim of the study presented here was to investigate whether the poor reading performance of children with low vision can be explained solely by their reduced visual input or whether other factors, like orthographic knowledge, affect the children’s reading performance. In this study, we limited the investigation of reading performance to decoding skills because, as Rayner and Pollatsek (1989) argued, the encoding of words is an important stage in reading that operates the same in isolation as it does in context.

The second aim was to determine whether the generally poorer reading performance of children with low vision is mostly a matter of a slower reading speed or also a matter of lesser accuracy. Do children with low vision trade accuracy for speed, or are they both slower and less accurate than sighted children?

The third aim was related to word frequency. It is known that sighted children read words with a high frequency of occurrence faster than words with a low frequency (Ellis, 1993; Van der Leij, 1998; Van der Heijden, Schreuder, & La Heij, 1989). The question is whether children with low vision also show this frequency effect, despite their smaller amount of reading experience. If such a frequency effect cannot be demonstrated in these children, one may question the usefulness of word repetition in reading instruction.

To investigate these questions, we conducted three experiments. In the first experiment, the children had to read aloud words that were presented on a computer screen. Reaction times (latencies) and errors were recorded, and differences in the word-reading speed and word-reading accuracy of the children with low vision and the
sighted children were investigated. The second experiment explored the differences in speed and accuracy of the children with low vision and the sighted children in a picture-naming task.

If the between-group differences in the word-naming task are explained by the between-group differences in the picture-naming task, it will indicate that the reading rate of children with low vision is hampered by a deficiency in visual input to the same degree as picture naming is. There could be another explanation, however. It has often been shown that children with reading problems also have a problem with the rapid naming of pictures and objects (Snowling, Van Wagendorp, & Stafford, 1988; Swan & Goswami, 1997). This naming problem may be caused by deficient phonological skills (Stanovich, 1988). If the reading of children with low vision is slower because of phonological output problems, then the shared between-group variance of the first two experiments could be codetermined by a shared naming problem.

To investigate whether children with low vision indeed have a naming problem, we conducted the third experiment, which consisted of a rapid automatized naming (RAN) task that is frequently used to measure phonological processing skills (Manis, Doi, & Bhadha, 2000; Wolf, Bowers, & Biddle, 2000). In this experiment, the children had to name large geometric shapes. Because of the size of the shapes, reduced visual input was not likely to be a source of slowness for the children with low vision. Differences in the reaction times of the children with low vision and the sighted children would therefore indicate a difference in naming speed and thus in phonological processing skills.

Method

Experiment 1

Participants

In this study, 60 children participated: 20 with low vision, 20 age-matched sighted children, and 20 sighted children matched for reading level—all native Dutch speakers. At the time of the study, all the children with low vision had 25 months of formal literacy education (three of them attended a special school for visually impaired children; the remaining 17 attended a regular elementary school but received outreach support from an institution for students with visual impairments).

The children with low vision had the following diagnoses: albinism (six children); albinism and nystagmus (one child); congenital nystagmus (one child); congenital nystagmus and myopia (one child); congenital nystagmus and strabismus (one child); retinoschisis (three children); cone-rod dystrophy (one child); Stickler syndrome (one child); aniridia (one child); coloboma of the iris, choroid, and retina (one child); macular atrophy (one child); tapetoretinal dystrophy or achromatopsia (not determined; one child); and retinopathy of prematurity (one child). In the Netherlands, a functional vision examination is not a standard procedure for every child with low vision, so no systematic information about the children’s functional vision was available.

In the Netherlands, children are considered visually impaired and therefore eligible for institutional support when they have a visual acuity of 3/10 or less and/or a visual field smaller than 30 degrees (Hover & Harperink, 1998). All the participating children with low vision were registered at one of the Dutch institutions for
the visually impaired and, consequently, had vision that was in accordance with these criteria.

The two groups of sighted children—one matched by age level and one matched by reading level with the children with low vision—were selected from the class- or schoolmates of the children with low vision in regular schools. The children in the reading-level control group had a reading level equal to that of the children with low vision ($F < 1$), but a lower mean age ($F(1,38) = 16.24, p < .01$). The children in the age-level control group were the same age as the children with low vision ($F < 1$), but had a higher reading level ($F(1,38) = 5.6, p < .05$). The ages, reading scores, and genders of all the children are presented in Table 1.

The reading level of the children was determined by means of the second card of the Drie Minuten Toets (Three-Minute Test, DMT; Verhoeven, 1995). The DMT is a standardized word-decoding test, consisting of three cards. The score is the number of correctly read words within one minute.

**Materials**

The stimuli of Experiment 1 were 60 words, with a mean word length of 7 letters ($SD = 2$), a minimum of 4 letters, and a maximum of 9 letters. All 60 words were part of the reading curriculum of the average child in grade 3 (the age of our group of children with low vision) according to the AVI-reading level method (Van den Berg & te Lintelo, 1975).

Of these words, 30 had a low frequency (100–400 per 42 million) and 30 had a high frequency (more than 3,000 per 42 million). High- and low-frequency words were matched on length and type of word. Word frequencies were determined on the basis of the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995).

**Procedure**

This and the following experiments were conducted on an Apple Macintosh Powerbook computer, with a screen resolution of 1024 by 768 and a screen diameter of 35 centimeters (cm) (1.15 feet [ft]). Children were free to choose a viewing distance that was the most comfortable for them. In Experiment 1, most children adopted a viewing distance of approximately 30–40 cm (0.98–1.31 ft), but a few children with low vision needed a viewing distance of 15–20 cm (0.49–0.66 ft). Stimulus presentation and response registration were controlled by a C++ program. Latencies were registered in milliseconds by means of a voice key. Response evaluations by the experimenter were made by means of a button.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age (in months)</th>
<th>Reading scores (DMT)</th>
<th>Number of Girls/boys</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low vision</td>
<td>107 (6, 0; 100–120)</td>
<td>59 (29; 18–108)</td>
<td>4/16</td>
<td>20</td>
</tr>
<tr>
<td>Age level matched</td>
<td>108 (3, 9; 100–115)</td>
<td>76 (15; 46–104)</td>
<td>12/8</td>
<td>20</td>
</tr>
<tr>
<td>Reading level matched</td>
<td>99 (6, 6; 90–117)</td>
<td>59 (28; 13–114)</td>
<td>15/5</td>
<td>20</td>
</tr>
</tbody>
</table>

*The number of boys in the low vision group is larger because there are more boys than girls in the Dutch population with low vision. The larger number of girls in the other two groups is coincidental. No differences, however, were found in the reading scores of the boys and the girls ($F(1,56) < 1$) on the DMT word-decoding test."
box. Responses could be correct, incorrect, or a voice-key error (when the voice key did not respond or was triggered by a sound other than the onset of the pronunciation of the target).

In Experiment 1, words were presented in a frame of 200 by 400 pixels, which corresponds to 5.7 cm by 11.4 cm (0.19 ft by 0.37 ft). Outside the frame, the screen was black, and words were displayed inside the frame in black on a white background. Words were displayed in 40-point font Geneva (for example, the letter “o” had a width of 5 millimeters (mm) (0.016 ft) and a height of 6 mm (0.02 ft).

Every trial started with an auditory signal 100 milliseconds (ms.) before the presentation of the stimulus. The stimulus was visible until the child responded. If there was no reaction within 10 seconds, the stimulus disappeared from the screen. After the child reacted, the experimenter registered whether the given response was correct, incorrect, or erroneous (a voice-key error).

The 60 stimuli were preceded by five practice trials. After every 20 trials, a short break was inserted. To control for order effects, stimuli were presented in two different orders.

Children were instructed to read the words on the screen out loud and to avoid any other sounds.

EXPERIMENT 2

Participants and materials

The same children who participated in Experiment 1 participated in Experiment 2.

The pictures used in this experiment were black-on-white line drawings of familiar objects, body parts, or animals (e.g., an umbrella, an ear, and a butterfly). They were derived from a study by Snodgrass and Vanderwart (1980), who investigated the “name agreement” of 260 pictures. For this experiment, 60 pictures were selected with a high name agreement (according to Snodgrass & Vanderwart). Selection of the pictures was also based on our agreement about their meaningfulness for Dutch children of the age of the participants.

Procedure

The apparatus in Experiment 2 was the same as in Experiment 1. The 60 pictures of this experiment were also displayed in a frame of 200 by 400 pixels. Outside the frame, the screen was black, and pictures were displayed inside the screen in black lines on a white background. The size of each picture was such that it would just fit in a square 2 cm by 2 cm (0.07 ft by 0.07 ft).

Stimulus presentation was preceded by the display of a fixation cross, 100 milliseconds before the stimulus presentation. The remainder of the procedure was similar to that of Experiment 1.

EXPERIMENT 3

Participants and materials

The same children participated in Experiment 3 as participated in Experiments 1 and 2. The stimuli for this experiment were five simple shapes—a circle, square, triangle, star, and cross. These shapes were simple line drawings with thick black lines.

Procedure

The procedure for this experiment was similar to that of Experiment 2, except for the size of the displayed shapes, which was such that the shape would just fit in a square 13 cm by 13 cm (0.43 ft by 0.43 ft). Each shape was presented 4 times, and the experiment was preceded by 10 practice trials.
Results
For all three experiments, median latencies on the correct responses were computed for each child. For Experiment 1, median latencies were also computed separately for words with high- and low frequencies. Subsequently, the means of the median latencies of the three groups of participants were compared. In the remainder of this article, “mean latencies” is used to refer to the mean median latencies of a group.

Word naming
Because of computer failure, only the first 20 out of 40 responses were registered for one child with low vision. The median latency of this participant was computed on the basis of the responses on these first 20 items.

First, the reading speed on the word-naming test of the children with low vision was compared with that of the two control groups. Table 2 shows the mean latencies in milliseconds of this and of the other two experiments. An analysis of variance (ANOVA) showed that there was a significant difference between the mean latencies on the responses of the three groups \((F(2,57) = 5.7, p < .01)\). A post hoc test (Tamhane) showed that the age-level control group read the words significantly faster than did the children with low vision \((p < .05)\) and than the reading-level control group \((p < .01)\). The difference between the children with low vision and the reading-level control group was not significant \((p = .14)\).

In a second analysis, the effect of word frequency on the reading speed of the three groups of children was investigated. The mean latencies on high- and low-frequency words for all groups are shown in Figure 1. An ANOVA showed a significant main effect of word frequency \((F(1,57) = 25.8, p < .01)\). No significant interaction effect between group and frequency was found \((F(2,57) = 2.3, p = .11)\).

We also compared the error proportions of the children with low vision with those of the other children. The error proportion of a child is the number of errors he or she made divided by the number of trials of that child that were registered correctly. An ANOVA showed that there were no significant differences in the mean error proportions of the three groups \((F(2,57) = 2.2, p = .12)\). Children with low vision do not make more errors than do other children of the same age or same reading level. For all three groups, we found a positive correlation between the proportions of errors and the mean latencies \((R = .43, .19, \text{and} .86, \text{for the children with low vision, the age-level control group, and the reading-level control group, respectively})\). This finding means that the slower a child reads, the more errors he or she makes. It indicates that children with low vision do not trade accuracy for speed because if they did, we would have found a negative correlation between their error proportions and mean latencies (which would imply that the shorter the latency, the more errors).

Picture naming
The mean latencies in the picture-naming experiment are displayed in Table 2. An ANOVA on the mean latencies in this experiment showed a significant difference between the three groups \((F(2,57) = 27.1, p < .01)\). A post hoc test (Tamhane) showed that the children with low vision were significantly slower than both the age-level and reading-level control groups \((p < .01)\). No significant difference between the mean latencies of the latter two groups was found \((p > .05)\).
Figure 1. Mean reaction times on high-frequency (HF) and low-frequency (LF) words.
Table 2
Mean latencies, in milliseconds, of the three groups of participants on all three experiments (standard deviations in parentheses).

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Participant group</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low vision</td>
<td>Age level</td>
</tr>
<tr>
<td>Word naming</td>
<td>1711.6 (1316.22)</td>
<td>755.2 (245.61)</td>
</tr>
<tr>
<td>Picture naming</td>
<td>1218.8 (160.80)</td>
<td>923.2 (113.39)</td>
</tr>
<tr>
<td>Shape naming</td>
<td>1113.74 (294.24)</td>
<td>936.19 (220.58)</td>
</tr>
</tbody>
</table>

As with the word-naming experiment, the error proportions of the three groups were also compared. An ANOVA showed a significant difference between the groups (F(2,57) = 14, P < .01). A post hoc test (Tamhane) showed that the children with low vision made significantly more errors (5.1%) than did the age-level control group (1.6%; p < .01) and the reading-level control group (1.5%; p < .01). The difference between the latter two groups was not significant (p = .81).

The fact that the regression of word naming on picture naming was not different for the three groups justified the use of an analysis of covariance (ANCOVA). With an ANCOVA with the mean latency on the picture-naming task as the covariate, the mean latency on the word-naming task as the dependent variable, and group (low vision, age matched, reading level matched) as the factor, we investigated whether the between-group variance on the word-naming task can be explained by the between-group variance on the picture-naming task. This ANCOVA showed that the observed variance in the word-naming task can be fully explained by the variance in the picture-naming task. With the between-group variance of the picture-naming task canceled out, no significant between-group differences were found in the word-naming task (F < 1). Mean latencies corrected for picture-naming differences for the children with low vision, the age-level control group, and the reading-level control group are 1185, 1145 and 1420, respectively.

SHAPE NAMING

For one child in the reading-level control group, no data were available for the shape-naming experiment. Thus, analyses for this experiment are based on the data of 59 children. Mean latencies are displayed in Table 2. An ANOVA on the mean latencies in the shape-naming experiment showed no significant difference among the three groups (F(2,57) = 2.7, P = .08). All three groups had a low percentage of errors on this task. No significant differences were found between the groups (F < 1).

Discussion

The results of Experiment 1 confirm previous findings (Corley & Pring, 1993a, 1993b; Daugherty & Moran, 1982; Fellennius, 1999; Gompel et al., 2002; Tobin, 1985; van Bon et al., 2000), that children with low vision are generally poorer readers than are sighted children of the same age, at least with respect to their word-decoding skills. The first question, whether this poorer reading performance of children with low vision can be explained only by reduced visual input, is answered by the
Analysis of Covariance

The investigators wanted to study mean latency on the word-naming task after those scores were adjusted for the mean latency on the picture-naming task. Analysis of covariance (ANCOVA) is an extension of analysis of variance (ANOVA) that allows for this type of adjustment. ANCOVA is used for three major purposes. In an experimental setting, an ANCOVA can remove predictable variance in the dependent variable that is associated with another variable, labeled the covariate. In a nonexperimental setting where random assignment to treatments is not possible, ANCOVA is used as a statistical matching procedure to control for variation in the covariate. Finally, an ANCOVA can be used to interpret the contributions of individual dependent variables by using them as covariates and removing their effects.

In all of these applications, the statistical operations are identical. They all serve to adjust the dependent variable so that its value is equivalent to what it would be if all subjects had the same score on the covariate. For example, if the age of the subject was related to the score on a test of interest, one could use age as a covariate in an ANCOVA. By doing this, the test scores would be adjusted to reflect what would happen if all the subjects were of the same age. Needless to say, this is a powerful statistical tool that should be used with caution.

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combined results of Experiments 1, 2, and 3. Because the differences among the groups in word-naming speed were no longer present when the differences in picture-naming speed were controlled for, the difference in word-reading achievement between the children with low vision and the sighted children can be explained entirely by the difference in their picture-naming speed. This finding means that reduced visual input is the main and only word-decoding problem of children with low vision.

One may argue that the size discrepancy between the stimuli in Experiment 1 and Experiment 2 could have affected the results. This discrepancy, however, is inevitable because the shape of words is different from the shape of most pictures. Words are always rectangular with a larger width than height. There are not many objects or animals with a similar shape. This is no problem for the rationale of the experiments. An important factor in reading is recognizing the visual patterns. Naming a picture requires that same ability to recognize visual patterns, although these patterns are different. The results of the covariance analysis show that performance on both tasks depends on the same underlying ability (visual input), since all differences in word-naming speed between the children with low vision and the sighted children are explained totally by the differences in their picture-naming speed.

Word reading seems to be affected by the fact that children with low vision need more time to identify the letters and words. There is no reason to assume an underlying or consequential orthographic problem. Experiment 3 showed that when the pictures are large enough, the naming speed of children with low vision does not differ from that of sighted children. This result assures
us that a naming problem can also be excluded as a source of the poorer reading achievement of children with low vision.

Because the results of Experiment 1 also showed that the children with low vision did not make more errors than did the sighted children (the second question), one may conclude that their poorer word reading is accounted for by their slower reading rate. Children with low vision do not seem to trade accuracy for speed. They also show a word-frequency effect comparable to that of sighted children (question 3). This finding supports the idea that despite the lesser reading experience of children with low vision, their acquisition of word-specific knowledge is not different from that of sighted children.

The finding that children with low vision are not only slower in picture naming than age-level-matched children, but are slower in picture naming than reading-level-matched children indicates that their lower picture-naming speed is specific to children with low vision and has no relation to age or developmental level.

In summary, two conclusions can be drawn from this study. First, children with low vision read words more slowly but not less accurately than do sighted children, and second, this slower reading speed is caused by reduced visual input, rather than by the lack of orthographic knowledge. On the one hand, our conclusion is positive with regard to the literacy development of children with low vision: Despite their visual-input restrictions, they nevertheless seem to develop normal orthographic knowledge. On the other hand, their reading speed is a reason for concern.

Since the results showed that visual input is the main factor in the word-reading speed of children with low vision, one may argue that the lower reading performances of children with low vision should not be considered and treated as a learning difficulty that can be remedied by practicing orthography. To improve the reading of children with low vision, one should focus on adapting the visual input to their specific needs, which can vary from child to child. Factors related to visual input that have been studied with adult readers with low vision are font (Mansfield, Legge, & Bane, 1996), contrast (Rubin & Legge, 1989), and print size (Chung, Mansfield, & Legge, 1998). The adult participants in these studies, however, often had acquired age-related eye conditions and years of reading experience with typical vision, whereas children with low vision generally start their reading careers with a visual impairment. Moreover, the prevalence of different eye anomalies and functional restrictions is different in adults than it is in children. Because of these differences, more research is necessary to determine how to improve the visual input of different groups of children with low vision.

This study also showed that children with low vision do not read less accurately than do sighted children, they just read slower. This finding seems to imply that children with low vision do not apply a guessing strategy while they are reading. However, our study considered only the reading of isolated words. To gain more insight into the reading strategies of children with low vision, subsequent research should address the topic of reading sentences and the role of context for children with different eye anomalies.

References


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