Literacy Skills of Children with Low Vision

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General acknowledgements
This study was financially supported by Sensis, Grave
Cover design: Visual Construct, Yorick de Vries
Print: MacDonald|SSN bv, Nijmegen
ISBN: 90-9018834-7

Literacy Skills of Children with Low Vision

Een wetenschappelijke proeve op het gebied van de Sociale Wetenschappen

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen,
op gezag van de Rector Magnificus,
Prof. dr. C. W. P. M. Blom,
volgens besluit van het College van Decanen
in het openbaar te verdedigen
op maandag 31 januari 2005
des namiddags om 3.30 uur precies

door
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geboren op 9 mei 1959
te Rotterdam

Nijmegen 2005

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Introduction

This thesis is a study on the literacy skills of children with low vision. According to a report of Melief and Gorter (1998), in the Netherlands, the prevalence of visual impairment in children is 0.1 to 0.2 percent. This figure includes blind children, children with low vision, and multiply handicapped children. In the Netherlands, children are generally considered visually impaired, and therefore eligible for institutional support, if their functional vision is less than 3/10 and/or their visual field is less than 30^o. In 1998, 2100 children were registered as being visually impaired. Those children were either attending special schools for visually impaired children, or went to regular schools but received outreaching support from one of the institutions for the visually impaired (Grevink, 1998). In this study, we concentrate on children with low vision but sufficient residual vision to read print. Braille reading is a different topic and beyond the scope of the research presented in this thesis. We also limit our study to children with normal cognitive abilities, because cognitive handicaps (although possibly related to the visual impairment) might confound the results. A final constraint of the research group is the age range. We will study the literacy skills of children with low vision in grades 1 to 6 of the primary school (equivalent to group 3 to 8 of the Dutch school system), because these are the grades in which literacy skills are taught. Information obtained from the three Dutch educational institutes for the visually impaired (Bartiméus, Convergo, and Visio) showed that approximately 635 of the children registered at one of the institutions as being visually impaired, met these criteria.

Teachers and others who work with children with low vision often report that children with low vision do not attain a reading level comparable to that of sighted children. There is evidence from research to support this impression that children with low vision are poorer readers than sighted children are (Corley & Pring, 1993a, 1993b; Daugherty & Moran, 1982; Fellenius, 1999; Tobin, 1985; van Bon, Adriaansen, Gompel, & Kouwenberg, 2000). Several studies with adults also have shown that low vision can have a negative effect on reading (Ahn, Legge, & Luebker, 1995; Krischer, Stein-Arsic, Meissen, & Zihl, 1985; Legge, Rubin, Peli, & Schleske, 1985; Lovie-Kitchin, Bowers, & Woods, 2000; Raasch, & Rubin, 1993; Rubin, 1986; Watson, Wright, Long, & De-l'Aune, 1996). One should be cautious, however, in generalizing findings from studies with adult participants to the reading of children with low vision. The first reason is that the prevalence of specific eye anomalies in adult people is different from that in children, which indicates a different causality and therefore possibly different consequences for reading. A leading cause of low vision in (elderly) adults, for instance, is Age Related Maculopathy* (Rubin, 1986), a degeneration of the macula which results in scotomas (blind spots) in the central visual field. According to Meire (1998), however, the most common causes of low vision in children are albinism

(13.6%), tapetoretinal dystrophies (13.6%), congenital cataract (10.4%), congenital nystagmus (8.1%), optic nerve athrophy (7.9%) and amaurosis congenita Leber (7.2%). Of these eye anomalies, only optic nerve athrophy usually causes central scotomas. In children with Amaurosis Congenita Leber, the cones can also be affected, but most children with this disease are not able to read print at all (Meire, Delleman, & La Grange, 1995). Because of such differences in the functional vision between children and adults, the reading performance and strategies of these groups are difficult to compare.

The second difficulty when generalizing results from studies with adult readers with low vision to children with low vision is that many adults have acquired their visual impairment at an older age and thus have a past of normal reading. It is conceivable that they cope by adjusting the reading strategies they have used before to their visual restrictions. In children with low vision, the visual impairment is usually already present at birth or at an early age, before literacy education starts. Therefore, children with low vision start learning to read with a visual restriction from the beginning. The resulting reading strategies can be expected to be different from an adjusted existing reading strategy.

In case of children, it is far from clear which subtypes of low vision affect which aspects of literacy performance. As pointed out above, the causes of visual impairment in children are very diverse, as are the consequences for functional vision. It is possible that different kinds of visual anomalies have different effects on reading. Teachers, for instance, told us that, in their experience, children with albinism are relatively poorer readers than other children with low vision are. The evidence on this topic, however, is not consistent. Fulcher et al. (1995) found that albino children scored significantly lower on reading, spelling and arithmetic tests than other children with low vision. Van Bon et al. (2000), however, did not find a difference between the reading competence of albino children and other visually impaired children. On the other hand, they found visual field restrictions to be the major cause of reading problems in children with low vision, with central field loss having a more negative effect than peripheral field restrictions. In other studies, non-visual factors were found to be even more important in the reading process of visually impaired children than visual factors. Fellenius (1996) found that the reading competence of Swedish visually impaired students was related to verbal cognitive ability and to interest in reading, but not to any visual factors. Daugherty and Moran (1982) related the delays they found in the reading development

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* Ophthalmological terms are explained in Appendix A

of children with low vision to the higher incidence of learning disabilities and structural brain damage in their sample of visually impaired children than in the general population.

The development of another aspect of literacy, spelling, is even less well documented for children with low vision. The few studies that did address this topic yielded inconsistent results. Van Bon et al. (2000) and Corley and Pring (1993c) found that children with low vision start out as relatively poor spellers, but catch up with their sighted peers during primary school. In a study of Arter and Mason (1994), on the other hand, 54% of the tested children with low vision over the age of eight turned out to be more than two years behind their sighted peers in spelling.

Although there seems to be agreement that visually impaired children are, on average, poorer readers and spellers than are sighted children, there is less agreement about the sources of variance and the course of development in literacy achievement within the group of visually impaired children. Many questions concerning the literacy of children with low vision are still unanswered. The present study investigates the topic of literacy skills and their development in case of visual impairment extensively, by studying a large part of the Dutch population of children with low vision. The goal of the research we report in this thesis is to add to the knowledge of the literacy (reading and spelling) performance and development of children with low vision.

In the present study, first of all, an attempt will be made to uncover the literacy performance and development of children with low vision in the Netherlands. The central question in Chapter 2 is to what extent children with low vision differ from their sighted peers in the development of reading and spelling skills. The development of reading skills will be investigated both at the level of decoding and at the level of reading comprehension. A related question concerns the individual variation in literacy skills among children with low vision. In an earlier study, van Bon et al. (2000) had found that some children with low vision read just as well or even better than their sighted peers do. What are the factors that discriminate between children with low vision with good literacy skills and children with low vision with poor literacy skills? The findings of van Bon et al. suggest that visual field restrictions are a major cause of reading problems in children with low vision. In this study, we will attempt to verify this finding and try to identify additional factors that contribute to the variance in reading and spelling performance of children with low vision. All these topics will be studied by gathering information in a larger sample of children with low vision. For all relevant research questions in Chapter 2, the process of reading will be investigated both at the level of decoding and at the level of reading comprehension.

Over 400 children participated in the study to be reported in Chapter 2, which is about two third of the population that met our criteria as described in the beginning of this chapter. From these children, data were obtained with respect to word decoding, reading comprehension, spelling, educational and language background, and visual pathology.

From the study to be reported in Chapter 2, it turned out that children with low vision are not behind in spelling compared to sighted children, but are significantly behind in reading. Therefore, the subsequent studies focus on the factors that determine the reading performance of children with low vision, e.g., orthographic knowledge, context use, letter identification and letter order.

Reading is at least partly a visual process. Wurm, Legge, Isenberg, & Luebker (1993) showed that their participants with low vision needed more time than do sighted people to name pictures, which is also a visual task. The central question in chapter 3 is whether this visual limitation is a sufficient explanation for the poorer reading skills of children with low vision or whether (a lack of) orthographic knowledge is also a factor.

Poor reading skills might cause children with low vision to loose interest and enjoyment in reading for leisure. Fellenius (1999) indeed found a relationship between reading skill and reading interest. Good readers in her study were those children who read during their leisure time. The direction of this relationship, however, can go both ways: poor reading might cause an aversion to reading, but less time spent reading (implying less reading experience) might cause a less developed reading skill. If this latter argument is true, then children with low vision are at risk to get caught in a vicious circle. They start out with a disadvantage in reading, because the visual input is limited. Consequently they are not inclined to read for pleasure. The result of this is less reading experience, which in its turn will have a negative consequence for the development of orthographic knowledge, which in its turn hampers progress in reading skills and thus results in even less motivation to read. This way, children with low vision are at risk to become trapped into a downward spiral, with a less developed orthographic knowledge as a consequence. The question of the third chapter is whether the orthographic knowledge of children is indeed less developed than that of their sighted peers or whether the poorer reading skills of these children can be attributed solely to a visual input constraint. To investigate this, the naming latencies on a word naming task and a picture-naming task of children with low vision and sighted children were compared. If the difference between those children is larger in the word naming task than in the picture naming task, visual recognition is not the only factor that differentiates between the word reading of children with low vision and that of sighted children. If, on the other hand, the difference in naming latencies between both groups of children is the same in both tasks, the lower reading rate of children with low vision can be explained by a visual input constraint only.

In Chapter 4, the focus is on the reading of text. Although it is possible to attain acceptable levels of text comprehension in spite of poor decoding skills, compensating for poor decoding skills is only possible within rather narrow limits (Stothard & Hulme, 1996; Shankweiler et al., 1999). In Chapter 4, several aspects of text reading by children with low vision will be addressed and compared with those of sighted children, with two experiments.

In one experiment of Chapter 4, the use of contextual information is studied. Studies with sighted children and adults have shown that a meaningful context can facilitate the reading process, especially for less skilled readers (Nation & Snowling, 1998; Perfetti, Goldman, & Hogaboam, 1979; Stanovich, West, & Feeman, 1981; West & Stanovich, 1978). Because children with low vision are less skilled readers than sighted children of the same age are (as shown in Chapter 2), we expect them to profit more from contextual information than do their sighted peers. By manipulating the contextual information in which words are presented, we will investigate whether children read words presented in a meaningful context faster than words presented in a nonsense or in a neutral context. If the reading process of children with low vision is indeed facilitated by a meaningful context, then text reading would be relatively easier for them than the reading of isolated words. On the other hand, text reading also has a disadvantage for children with low vision, compared to the reading of isolated words. Text requires more eye movements than isolated words do. For some children with low vision this might be problematic. Therefore, although these children might profit from the contextual information a text provides, this advantage might not weigh up against the disadvantage of the burden of eye movements. In the study reported in Chapter 4, time needed for reading and comprehending a text is therefore compared with the time needed to read isolated words.

Chapter 5 is concerned with word decoding again. Previous studies (Corley & Pring, 1993a; Koenen, Bosman, & Gompel, 2000) did not find qualitative differences between the word reading strategies of children with low vision and those of sighted children. In this Chapter, we will report two experiments that investigated two aspects of word decoding in which children with low vision might differ from sighted children. The first experiment investigates the strategies children use to identify a word. According to Rayner and Pollatsek (1989), there are two ways in which unknown words can be identified. One way is by the use of grapheme/phoneme conversion rules, the other way is by the analogy with known words. The main question of the first experiment is whether children with low vision differ from sighted children in the strategy they apply in word identification. The experiment is a non-word naming task. The non-words were all derived from existing words by substituting one letter of that word by another one. Half of the non-words in this experiment were derived from words with a high frequency and half of them from words with a low frequency. The effect of the frequency of the orthographic neighbor can be an indication for the strategy used to read isolated words. If non-words with a high frequency neighbor are read faster than non-words with a low frequency neighbor are, this will be an indication for an analogy based reading strategy. If the frequency of the neighbor does not make a difference, it is plausible that only grapheme/phoneme conversion rules are used in the decoding of the non-words.

In this same experiment, three other features were manipulated: word length, visual similarity of the substituted letter, and position of the substituted letter. The question was whether the effects on reading speed of these features in children with low vision differ from those in sighted children. The answer to this question can be relevant for educational adjustments for children with low vision. If, for example, it turns out that children with low vision have more problems with long words and focus on different letter positions than sighted children do, teachers could train children with low vision to acknowledge the importance of different parts of words. If visual discrimination between similar letters turns out to be a problem, adaptation of the visual input (the printed text) might need more attention.

The second experiment that is reported in Chapter 5 investigates the processing of letter order information. Children with low vision might have a problem with the order of the constituent letters of a word because they need more time to identify the letters in a word. This implies that they have to keep the identified letters longer in working memory, which might interfere with the process of keeping track of the position of the letters. Children with central visual field restrictions might even have an additional disadvantage in processing letter order information, because the scotomas can conceal some letters of a word, which makes regressions necessary. In this word naming experiment, the role of letter order is investigated by presenting two kinds of words: anagrams (words of which the letters can be rearranged to form one or more other words) and unique words (words of which the letters cannot be rearranged to form another word). If children with low vision indeed have a problem with the processing of letter order information, we expect longer naming latencies on anagrams than on unique words for these children.

Finally, in Chapter 6 all findings from the previous chapters will be summarized and general conclusions will be drawn. In this chapter, we will also discuss what the results of these studies implicate for the literacy education of children with low vision.

References

Ahn, J., Legge, G. E., & Luebker, A. (1995). Printed cards for measuring low-vision reading speed. *Vision Research, 35,* 1939-1944.

Arter, C., & Mason, H. (1994). Spelling for the visually impaired child. *The British Journal of Visual Impairment, 12,* 18-21.

Corley, G., & Pring, L. (1993a). Reading strategies in partially sighted children. *International Journal of Rehabilitation Research, 16,* 209-220.

Corley, G., & Pring, L. (1993b). The oral reading errors of partially sighted children. *The British Journal of Visual Impairment, 11,* 24-27.

Corley, G., & Pring, L. (1993c). The spelling competence of partially sighted children. *The British Journal of Visual Impairment, 11,* 105-108.

Daugherty, K. M., & Moran, M. F. (1982). Neuropsychological, learning, and developmental characteristics of the low vision child. *Visual Impairment and Blindness, 76,* 398-406.

Fellenius, K. (1996). Reading Competence of Visually Impaired Pupils in Sweden. *Journal of Visual Impairment and Blindness, 90,* 237-246.

Fellenius, K. (1999). Reading environment at home and at school of Swedish students with visual impairments. *Journal of Visual Impairment and Blindness, 93,* 211-224.

Fulcher, T., O'Keefe, M., Bowell, R., Lanigan, B., Burke, T., Carr, A., O'Rourke, M., & Bolger, M. (1995). Intellectual and educational attainment in albinism. *Journal of Pediatric Ophthalmology and Strabismus, 32,* 368-372.

Grevink, F. (1998). Speciaal onderwijs en speciale begeleiding voor visueel gehandicapte kinderen in Nederland [Special education and special support for visually handicapped children in the Netherlands]. In: G. H. M. B. van Rens (Ed.), *Revalidatie van slechtziende kinderen, Symposiumboek* [Rehabilitation of children with low vision, symposium book] the Netherlands: Vereniging voor Revalidatie bij Slechtziendheid.

Koenen, M., Bosman, A. M. T., & Gompel, M. (2000). Kijk eens hoe ik lees; Een onderzoek naar het leesgedrag van slechtziende en normaalziende kinderen [Watch me reading: A study into the reading behavior of children with low vision and sighted children]. *Tijdschrift voor Orthopedagogiek, 39,* 95-106.

Krischer, C. C., Stein-Arsic, M., Meissen, R., & Zihl, J. (1985). Visual performance and reading capacity of partially sighted persons in a rehabilitation center. *American Journal of Optometry & Physiological Optics, 62,* 52-58.

Legge, G. E., Rubin, G. S., Peli, D. G., & Schleske, M. M., (1985). Psychophysics of reading II: Low vision. *Vision Research, 25,* 253-266.

Lovie-Kitchin, J. E., Bowers, A. R., & Woods, R. L., (2000). Oral and silent

reading performance with macular degeneration. *Ophtalmological Physiology, 20,* 360-370.
Meire, F. M. (1998). Aetiology of visual handicaps in children. *Bull. Soc. Belge Ophtalmol., 269,* 17-30.
Meire, F. M., Delleman, J. W., & La Grange, N., (1995). *Kinderen met een Visuele Handicap* [Children with a visual handicap]. Leuven, Belgium/Amersfoort, the Netherlands: Acco.
Melief, W. B. A. M., & Gorter, K. A., (1998). *Slechtzienden en blinden in Nederland. Deelrapport I: Aantallen en kenmerken* [People with low vision and blind people in the Netherlands. Report I: Numbers and characteristics]. Tilburg, the Netherlands: Verwey-Jonker Instituut, Utrecht, the Netherlands: Regeer & Reijnen BV.
Nation, K., & Snowling, M. J. (1998). Individual differences in contextual facilitation: Evidence from dyslexia and poor reading comprehension. *Child Development, 69,* 996-1011.
Perfetti, C. A., Goldman, S. R., & Hogaboam, T. W. (1979). Reading skill and the identification of words in discourse context. *Memory & Cognition, 7,* 273-282.
Raasch, T. W., Rubin, G. S. (1993). Reading with low vision. *Journal of the American Optometric Association, 71,* 165-176.
Rayner, K. & Pollatsek, A. (1989). *The Psychology of Reading*. Englewood Cliffs, NJ: Prentice-Hall
Rubin, G. S., (1986). Predicting reading performance in low vision observers with age related maculopathy (ARM), in: G. C. Woo (Ed.). *Low Vision. Principles and Applications*.
Shankweiler, D., Lundquist, E., Katz, L., Stuebing, K. K., Fletcher, M., Brady, S., Fowler, A., Dreyer, L. G., Marchione, K. E., Shaywitz, S. E., & Shaywitz, B. A. (1999). Comprehension and decoding: patterns of association in children with reading difficulties. *Scientific Studies of Reading, 3,* 69-94.
Stanovich, K. E., West, R. F., & Feeman, D. J. (1981). A longitudinal study of sentence context effects in second-grade children: Tests of an interactive-compensatory model. *Journal of Experimental Child Psychology, 32,* 185-191.
Stothard, S. E., & Hulme, C. (1996). A comparison of reading comprehension and decoding difficulties in children. In : C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and intervention* (pp. 93-112).
Tobin, M. (1985). The reading skills of the partially sighted: their implications for integrated education. *International Journal of Rehabilitation Research, 8,* 467-472.

van Bon, W. H. J., Adriaansen, L., Gompel, M., & Kouwenberg, I. (2000). The reading and spelling performance of visually impaired Dutch elementary schoolchildren. *Visual Impairment Research, 2* (1), 17-31.

Watson, G. R. Wright, V., Long, S., & De-l'Aune, W. (1996). A low vision comprehension test. *Journal of Visual Impairment & Blindness, 90,* 486-494.

West, R. F., & Stanovich, K. E. (1978). Automatic contextual facilitation in readers of three ages. *Child Development, 49,* 717-727.

Wurm, L. H. , Legge, G. E., Isenberg, L. M., & Luebker, A. (1993). Color improves object recognition in normal and low vision. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 899-911.

2

Reading and Spelling Competence of Dutch Children with Low Vision

Marjolein Gompel, Wim H. J. van Bon, Robert Schreuder, and Julia J. M. Adriaansen

This comparison of the reading comprehension, decoding, and spelling skills of 404 children with low vision and a norm sample of same-age sighted children found that the children with low vision with no additional disabilities performed less well than the sighted children only on decoding, whereas those with additional disabilities performed less well on all the tests.

This chapter is a slightly adapted version of an article that was published in 2002, in the Journal of Visual Impairment & Blindness, 96, 435-447.

Introduction

Teachers of children with low vision often report that, in general, their students are poor readers. Research has supported the observation 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; Tobin, 1985).

Some children with low vision, however, do perform in accordance with their age or even better (van Bon, Adriaansen, Gompel, & Kouwenberg, 2000). It is not clear which factors contribute to the variability in the reading achievement of children with low vision. One possibility is that specific eye anomalies are more detrimental to reading than are others. The few studies that investigated this topic have not come to consistent conclusions. Fulcher et al. (1995) found that children with albinism scored significantly lower on reading, spelling, and arithmetic tests than did other children with low vision, whereas van Bon et al. (2000) did not find a difference between the reading competence of these children and other children with low vision.

Comparing the effect of different functional impairments, rather than that of different eye diseases, on reading and spelling, van Bon et al. (2000) found that visual field restrictions were the major cause of reading problems, with central field loss having a more negative effect than peripheral field restrictions. Legge, Rubin, Peli, and Schleske (1985) found that 64% of the variance in the reading speed of adult readers with low vision could be accounted for by two major functional distinctions: intact central fields versus central field loss and cloudy versus clear ocular media. Krischer, Stein-Arsic, Meissen, and Zihl (1985) showed that reading speed is related to visual acuity (the higher the visual acuity, the better the reading performance).

Some researchers have found that non-visual factors are of more importance than visual factors in the reading process of children with low vision. Fellenius (1996) found that the reading competence of Swedish students with low vision was related to verbal cognitive ability and to interest in reading, but not to any visual factors. Daugherty and Moran (1982) observed that children with low vision in general exhibit significant delays in cognitive, psychomotor, and academic development (including reading), but noted that the incidence of learning disabilities and structural brain damage was much higher in their sample of children with low vision than in the general population. They claimed that a neuropsychological profile would be a better predictor of school achievement than would visual acuity.

Besides reading, spelling may also be a problem for children with low vision. As van Bon and Duighuisen (1995) showed, spelling is easier when one can see the letter; this feedback helps to keep track of the process. A child with low vision can profit less from the feedback from his or her own spelling product. Spelling may be hampered indirectly because, as a consequence of their alleged reading problems, children with low vision may not acquire the same amount of orthographic knowledge as sighted children do.

Both van Bon et al. (2000) and Corley and Pring (1993c) found that children with low vision start as relatively poor spellers, but seem to catch up with their sighted peers during primary school. Arter and Mason (1994), on the other hand, observed that 54% of the children with low vision they tested, mostly children over age 8, were more than two years behind their sighted age-mates in spelling.

Although most authors agree that children with low vision are, on average, poorer readers and spellers than are sighted children, there is less agreement about the sources of variance and the course of development in literacy achievement within the group of children with low vision. The present study investigated the topic of low vision and literacy development extensively by studying a large part of the population of Dutch children with low vision.

The first research question was whether children with low vision actually experience problems with reading and spelling, compared to their sighted peers. If evidence of such problems was found, we were also interested in the course of the children's development over the primary school period. With respect to reading, both word-decoding skills (the skill of converting graphemes to phonemes without the need to access the meaning of the word) and reading comprehension were of interest. The second question was which visual and non-visual factors are related to the reading and spelling performance of children with low vision.

Method

Participants

The participants in this study were children with low vision in grades 1 to 6, who had typical cognitive ability and sufficient residual vision to read print. Information obtained from the three Dutch educational institutes for children who are visually impaired (Bartiméus, Convergo, and Visio) showed that approximately 635 of the children who were registered at one of the three institutes as being visually impaired, met these criteria. All children who are not placed in classes for children with multiple disabilities were considered to have typical cognitive ability. For various reasons, only 404 children (64% of the population) participated in this study, however some of the analyses were performed on a smaller sample. The mean age of the children at the time of testing was 9.5 years, with a minimum of 6 years and a maximum of 13.5 years. Dutch children with low vision attend either special schools for children with low vision or regular primary schools. Some of them visit other special schools (e.g., schools for children who are chronically ill or have learning disabilities). The characteristics of the participating children are summarized in Table 1.

Table 1. Distribution of participating visually impaired children over schooltype, sex, and language.

Type of school	Boys		Girls		
	Native speakers	Non-native speakers	Native speakers	Non-native speakers	Total
Regular primary school	135	22	100	11	268
Special school for visually impaired students	65	14	32	9	120
Other special schools	7	2	7	_	16
Total	207	38	139	20	404

In the Netherlands, children are considered visually impaired, and therefore eligible for institutional support, if their functional vision is less than 3/10 and/or their visual field is less than 30 degrees. The vision of the participating children was in accordance with these criteria. The reported medical diagnoses and functional disorders of the participating children are presented in Table 2.

We compared the reading and spelling performance of the children with the norm scores of nationwide samples of primary school children that are given in the test manuals (hereafter called the “norm sample scores”). These norm sample scores are reported for different grade levels. Because special schools do not always work with grade levels, we determined the grade a child should be in by counting the years of formal literacy education the child had (hereafter called “instructional age”).

Table 2. Reported diagnoses and functional conditions of the participants.

	Number of times reported
Diagnosis	
Albinism	74
Cone and/or Rod disorders	55
Congenital Nystagmus	38
Myopia	24
Nervus Opticus Disorders	16
Retinoschizis	14
Combination of disorders	19
Unknown	61
Various other disorders	103
Functional disorder	
Central visual field restrictions	38
Peripheral visual field restrictions	44
Other visual field restrictions	52
Restricted contrast sensitivity	77
Strabismus	128
Nystagmus	223
Photophobia	82

Note: Because one person can have several functional disorders, the sum of the number of reported disorders exceeds the number of participating children.

Materials

Word decoding, reading comprehension, and spelling competence were all measured by standardized tests (see Table 3). The teachers of the children with low vision completed a questionnaire, in which they were asked for information about their students: their intelligence level, their native language, any additional (physical or cognitive) problems, number of years of literacy education, and use of optical reading aids. Information about the visual conditions of the children was acquired through their medical files.

Table 3. Used Tests.

Test	Measures	Reference	Grade
DMT (Drie Minuten Toets [Three Minutes Test])	Word decoding	Verhoeven, 1995	1 - 6
Lezen met Begrip (Reading with Comprehension)	Reading Comprehension	Verhoeven, 1997	1 - 2
Toetsen Begrijpend Lezen (Tests for Reading Comprehension)	Reading Comprehension	Staphorsius & Krom, 1995	3 - 6
SVS (Schaal Vorderingen Spellingvaardigheid [Scale Progresses in Spelling Competence])	Spelling	van den Bosch, Gillijns, Krom, & Moelands, 1991	1 - 2
		idem, 1993	3 - 4
		Geurts, Gillijns, Krom, & Moelands, 1996	5 - 6

Procedure

The reading and spelling tests and the questionnaire were mailed to the children's schools (the three institutes for the visually impaired and over 300 regular schools or other special schools) with a request to the teachers to administer or complete them. This procedure was justified because all the tests were specifically developed to be administered by teachers and are part of the regular monitoring system at most primary schools. If children were used to reading with optical reading aids, they were allowed to use these aids when completing the tests. For all three tests, quartile norms from national samples of fully sighted primary school children are available. Children can be assigned a level score from A to E, with A and B each corresponding to 25% of the norm sample above the median and C, D and E corresponding to 25%, 15%, and 10% below the median, respectively. On the basis of their raw scores and instructional age, the participants were assigned to one of these levels. To be able to compare groups of children with low vision, we converted the level scores into z-scores, corresponding to the middle percentile of the level a child was assigned to. By definition, the mean z-score of the norm sample is 0, with an SD of 1. Hence a significant negative mean z-score indicates a level of performance below that of the norm sample.

Results

For all the tests, we compared the levels (A to E) that the participants attained with the norm sample scores. Table 4 shows the distribution over the levels for all three tests.

Table 4. Percentage of participants scoring at each level on all tests compared to the norm sample.

Test	*n*	**A**	**B**	**C**	**D**	**E**
Norm sample scores on all tests		25	25	25	15	10
Word decoding (mean scores over three reading cards)						
Regular schools	242	14.4	18.5	25.2	22.2	19.8
Special schools	119	3.3	4.9	10.0	10.7	70.0
Reading Comprehension						
Regular schools	197	33.5	25.7	24.7	11.4	4.6
Special schools	63	12.1	19.3	15.3	23.4	29.9
Spelling						
Regular schools	209	23.9	22.9	28.7	13.9	10.5
Special schools	91	4.2	4.2	18.9	18.9	53.7

Word decoding
The distribution over the levels of children with low vision as an undivided group differed significantly from the distribution of the norm sample ($X^2 = 362.73$, $X^2 = 263.07$, $X^2 = 309.22$ (all $df = 4$, all $p < .01$) for each of the three word decoding cards, respectively). As can be seen in Table 4, some of the participants had good word decoding skills. On average, however, the participants were relatively poor readers.

An analysis of variance (ANOVA) was performed to investigate the difference between the two types of schools (regular versus special schools). Table 5 shows the mean z-scores and error percentages of the different groups of children. Although the participants in the regular schools were better decoders than were those in the special schools, they were still not as good as sighted children of the same instructional age ($t(252) = 6.69$, $p < .01$).

The participants in the two types of schools also differed from each other in the developmental pattern of word decoding skills. There was no significant difference between the mean z-scores for word decoding for different instructional age groups in the special schools ($F(5,118) = 0.36$, $p = .87$). These children had a delay in word decoding skills that did not change from grade to grade.

An ANOVA on the mean z-scores of the participants in the regular schools, however, did show a significant effect of instructional age level ($F(5,247) = 5,96$, $p < .01$). The mean z-scores on word decoding of children in grades 1 and 2 did not differ significantly from those of the norm sample ($t(80) = -.15$, $p = .88$), but the mean z-scores of the children in higher grades were significantly below those of the norm sample ($t(171) = -8.29$, $p < .0$ l). This finding indicates that children with low vision in regular schools start out with a word decoding level that is not different from that of their sighted peers, but start to experience reading difficulties from third grade on.

Table 5. Mean z-scores on the DMT word decoding test.

	n	Mean z-score	SD	Error Percentage
Norm Sample		0	1	
Regular Education	253	-.36	.86	.089
Special Schools for Visually Impaired	110	-1.2	.69	.170
Other Schools for Special Education	15	-1.47	.37	.199

Note: The difference in z-scores and error percentages between children with low vision in regular schools and in special schools (both types) was significant ($F(1,376) = 96.34$, $p < .01$, $F(1,377) = 20.83$, $p < .01$ respectively). The differences between children in both types of special schools was not significant.

Reading comprehension

A comparison with the norm sample on the reading comprehension test showed that the distribution over the levels (Table 4) of participants in special schools did ($X^2 = 55.8$, $df = 4$, $p < .01$), and of those in the regular schools did not ($X^2 = 6.87$, $df = 4$, $p > .05$) differ from that of the norm sample. This result may be biased, however, by the fact that of the 404 children of the sample, only 260 participated in the reading comprehension test. A possible reason for this low response is that teachers were reluctant to administer a difficult and therefore frustrating task to their students with low vision. Moreover, they may have been inclined not to administer the test to poorer readers. To test for such a bias, we compared the word decoding scores of the children who participated in the reading comprehension test with those of the nonparticipating children. We found that the children who participated in the reading comprehension test indeed were better decoders (mean z-score = -.51) than were the children who did not participate (mean z-score = -.89). This difference was significant ($F(1,376) = 15.99$, $p < .01$). Since the correlation between word decoding and reading comprehension was .45, this bias could be an explanation for the good reading comprehension scores of the participants in regular schools.

A second ANOVA, however, showed that the difference in word decoding scores between the participants in the regular schools who did and did not take the reading comprehension test was not significant ($F(1,25\ 1) = 3.07$, $p > .05$). Moreover, the mean z-score on the word decoding test of the participating children (-.30) was still significantly below the mean score of the norm sample ($df = 183$, $t = -4.995$, $p < .01$). Furthermore, 38.5% of the children who scored at an A level for reading comprehension scored at an E level for word decoding. Other possible explanations for the good reading comprehension results of these children are presented in the Discussion section.

The development of reading comprehension over the primary school period was examined by comparing the mean z-scores at different instructional age levels. An ANOVA showed that there was a significant difference among the z-scores at the different grade levels ($F(5,253) = 3.16$, $p < .01$). The mean z-scores for reading comprehension seem to have decreased over the primary school period for the total sample.

Subsequent analyses of the two separate groups of children, however, showed that this pattern represents mainly the development of children with low vision in regular schools. For these children, the difference among the instructional age levels was significant ($F(5,190) = 2.58$, $p < .05$). No significant effect of instructional age level was found for the children in special schools ($F(4,58) = 2.42$, $p > .05$).

Spelling

As with both reading scores, we compared the spelling scores of the participants with those of the norm sample. No difference was found between the spelling scores of the norm sample and those of the participants in regular schools ($X^2 = 1.83$, $df = 4$, $p > .1$), but a significant difference was found between the norm sample and the participants in special schools ($X^2 = 227.29$, $df = 4$, $p < .01$, see Table 4 for the distribution of scores over the various levels).

To determine if the spelling results were flawed by selective participation, we compared the word decoding scores of the participants who took the spelling test with those of the participants who did not. No significant difference was found between the word decoding scores of the two groups (F(1,376) = 2.69, p > .l), which indicates that selective participation was not likely.

These results indicate that no spelling problem exists for children with low vision in regular primary schools, but that children in special schools seem to experience problems with spelling. This lag in spelling achievement for children in special schools seems quite stable; no significant difference was found among the z-scores for different grades ($F(5,85) = .83$, $p > .l$).

Diagnostic categories and functional visual impairment

Because a certain visual disorder can have different functional consequences for different individuals, we also explored the relation between literacy attainment and functional visual impairments like visual field restrictions, decreased contrast sensitivity, problems with binocular vision, photophobia, and nystagmus. An overview of the reported visual disorders is presented in Table 2. It should be noted that a visual function examination is not always part of the standard assessment procedure. Consequently, for some participants, no data on their visual functioning were available.

To examine the relation between diagnostic categories or functional disorders and the attainment of literacy, we compared the z-scores of the participants with a specific disorder with those of the participants without that specific disorder. If no information was available about the disorder for a particular child, that child was excluded from the analysis.

It was found that none of the diagnostic categories and no functional visual impairments were associated with markedly poor spelling or reading comprehension. On the word decoding test, however, one group of children did show a slightly different pattern of performance. The children with visual field restrictions ($n = 126$) had lower mean z-scores on the word decoding test (-.77, -.75, and -26, on the three word decoding cards, respectively) than did the children without visual field restrictions ($n = 208$) (-.68, -.52, and -.61), but this difference was statistically significant ($F(1,332) = 4.67$, $p < .05$) only for the second word decoding card. Although this result is not strong, the trend is in line with the results of van Bon et al. (2000) and Legge et al. (1985) in that they also found that people with visual field restrictions are poorer decoders than other people with low vision. Van Bon et al. also found a significant difference in word decoding skills between children with central and children with peripheral field restrictions. This latter finding was not replicated in the present results.

Because the visual field of a child with low vision can also be restricted by the use of optical reading aids, we compared the word decoding scores of the participants who used an optical reading aid ($n = 35$) with those of the participants who did not ($n = 313$). The latter group performed significantly better than did the group who used an optical reading aid ($F(1,346) = 5.09$, $p < .05$).

Non-visual factors

For 185 children, some measure of general cognitive ability was reported in their medical records. Unfortunately, cognitive ability was measured with several different instruments and reported in different ways, often without any information about the instrument used and usually only in terms like "average" or "below average". IQ was expressed in a number only for 56 children. The questionnaire asked the teachers to assess the general cognitive abilities of their students on a scale from 1 (poor) to 5 (high). Because of the lack of measured IQ rates, the teachers' ratings were used in the analyses. This use of teacher ratings was justified by the high correlation between those ratings and the 56 reported measured IQ scores ($r = .76$). The correlations between estimated cognitive ability and word decoding, reading comprehension, and spelling were .44, .53, and .53, respectively, which means that cognitive ability does explain some of the variance in literacy attainment.

Another factor that was considered was the participants' native language. Of the participants, 14.3% had a native language other than Dutch. The percentage of non-native speakers of Dutch in the norm sample is approximately 5%. This difference between the norm sample and the sample of children with low vision might have biased the results in favor of the norm sample. On all literacy tests, the native Dutch participants performed better than did their non-native peers. This difference was significant for the third word decoding card ($F(1, 359) = 5.72$, $p < .05$), for reading comprehension ($F(1,257) = 23.18$, $p < .01$), and for spelling ($F(1,297) = 8.58$, $p < .01$).

Furthermore, additional (non-visual) problems were reported for 53.2% of the participants. The incidence of additional problems was higher in the group of participants in special schools (70.9%) than in the group in regular schools (45%). Reported additional problems are summarized in Table 6.

Table 6. Participants with specific additional problems (within the group of participants with reported additional problems).

Reported problems	Percentage of participants
Social/emotional/conduct problems	20.3%
Physical problems	19.3%
Hearing deficiencies	5.2%
Learning/attention/concentration problems	40.6%
Other problems	14.6%

The majority (40.6%) of the reported additional problems were learning difficulties or attention deficit/hyperactivity-like problems. This finding seems to support Daugherty and Moran's (1982) claim that the comorbidity of visual impairment and neurological problems is relatively high. An ANOVA showed that the participants with additional problems performed worse on all the tests than did the participants with no additional problems (see Table 7).

To examine if the delay in reading and spelling can be attributed solely to the factors just mentioned, we performed another analysis with the data of all the participants with low estimated IQs, additional problems, or Dutch as a second language omitted. This analysis showed that the native Dutch-speaking participants with normal cognitive ability and no additional problems still had mean word decoding scores that were below those of their sighted peers (mean z-score = -0.341, $t(148) = -4.55$, $p < .01$). The spelling scores of these participants were within the normal range (z-score = .035, $t(116) = .41$, $p = .68$), whereas their reading-comprehension scores were significantly above average (z-score = .327, $t(108) = 4.17$, $p < .01$).

Table 7. Mean z-scores and *SD*'s on all tests of the participants with and without additional problems.

	Mean z-scores and *SD*'s				
	additional problems		no additional problems		
	n		*n*		*F* test (*df*)
word decoding	203	-0.9 (0.82)	175	-0.36 (0.92)	$F(1,376)=35.71$, $p < .01$
reading comprehension	133	-0.17 (0.94)	127	0.25 (0.83)	$F(1,258)=14.18$, $p < .01$
spelling	163	-0.62 (0.95)	137	0.05 (0.9)	$F(1,298)=28.75$, $p < .01$

Discussion

From the data, it can be concluded that word decoding is a problem for most children with low vision, but not for all. There are children with low vision who are good or even excellent decoders; most of them are in regular schools. The question is: what accounts for the difference between children with low vision in regular schools and those in special schools? One may be inclined to conclude that children with low vision are better off in regular schools. A more plausible explanation, however, is that children with low vision are placed in special schools on the basis of their poor visual resources. To investigate this possibility, we performed an ANOVA on visual acuity, with type of school as a between-subjects factor. No significant difference in visual acuity was found between the children in the different types of schools ($F(2,299) = 2.19$, $p > .05$). This result supports the (informally acquired) opinion of teachers that school placement is not related to the visual characteristics of children with low vision, but depends on the children's learning capabilities.

Hence, another plausible explanation for the large difference between children with low vision in the two types of schools may indeed be differences in general cognitive or learning abilities. In this study, the incidence of additional problems (including learning disabilities) was larger in the group of children who attended special schools than in the group who attended regular schools. The authors also found that the children in regular schools had a higher estimated cognitive ability than did their peers in the special schools. This difference was statistically significant ($F(1,380) = 108.06$, $p < .01$).

This finding may explain the difference in the word-decoding results of the participants in the two types of schools. Those with no reported problems other than their low vision, however, still did not read as well as did sighted children. This finding means that having low vision is, at least for some children, an important obstacle to the attainment of decoding.

Moreover, with the information available in this study, it was not possible to disentangle the direction of the relation between the reported additional problems and the decoding problems. Specifically in the case of reported learning disabilities or attention deficits, it is possible that what teachers perceive as such might just as well be a result of the visual impairment instead of an independent disorder.

The only visual factor that proved to have a negative influence on the decoding performance of the participants was the presence of visual field losses (central as well as peripheral). This finding is a plausible explanation for some of the variance in the participants' decoding performance. Central visual field defects were also reported to have a negative effect on reading by Legge et al. (1985) and van Bon et al. (2000). To our knowledge, no previous research has been conducted on the effects of peripheral visual field losses. It is possible, however, that being able to perceive only a small part of what is to be read could slow down the speed of reading because more eye movements are necessary. The reading of texts instead of words may be hampered even more by peripheral field restriction because of the extra problems this restriction could give with larger saccades, when the eyes have to jump to the next line, and the inability to perceive word features in the periphery.

Children with peripheral visual field losses may not be the only ones with this problem. For many other readers with low vision, the visual field will be narrowed because of the use of necessary text enlargements or optical reading aids. As the results show, children who use optical reading aids are indeed poorer decoders than are children who do not.

Another question that the findings raise is why children with low vision seem to decode as well as do their fully sighted peers at the beginning of literacy education, but are, on average, poorer decoders from grade 3 on - a problem they do not seem to overcome during primary school. One possible cause may be the length of words. After grade 1, the words that children have to read get progressively longer. Especially for children who have a narrowed visual field (caused either by their eye condition or by the reading medium), these longer words could yield an extra problem that slows down their reading speed.

In sum, with regard to decoding, it can be concluded that there is a difference between children with low vision and their sighted peers. This difference seems to relate not only to the presence or absence of visual field restrictions, but to general cognitive ability, native language, and the presence or absence of additional problems.

It is notable that having low vision does not seem to have as large an impact on reading comprehension and spelling as it does on word decoding. The performance of children with low vision in regular schools was just as good as that of their sighted peers. On the other hand, the children with low vision in special schools performed worse on all literacy tests (decoding, reading comprehension, and spelling). Because no differences were found in visual acuity between the participants in the different type of schools, this finding suggests that other factors (like cognitive ability, additional non-visual problems, and native language) must be the cause of the reading comprehension and spelling problems of children in special schools. Another conclusion that can be drawn from these results is that fast word-decoding skills do not seem to be a prerequisite for good reading comprehension and spelling. This conclusion is suggested by the fact that children with low vision in regular schools do, on average, have lower word-decoding skills, but their reading comprehension and spelling results are just as good as those of sighted children.

For reading comprehension, this finding is in line with the findings of Stothard and Hulme (1996) and Shankweiler et al. (1999) that there are children who are poor decoders but reasonable comprehenders. In their studies, however, these researchers found that compensating for poor decoding skills is possible only within narrow limits; that is, the comprehension skills of the poor decoders were only relatively good, but still not as good as those of the children without any reading problems. Moreover, decoding skills need to be above a certain minimum level for there to be any comprehension (Shankweiler et al., 1999). In contrast, in this study, 38.5% of the participants with excellent reading comprehension scores (A level) had a word-decoding score at an E level (the lowest level), indicating that for some of the children with low vision, above average reading comprehension is possible with minimum decoding skills.

A difference between the children in the aforementioned studies and those in this study is that the causes of the poor decoding skills are likely to be different. The poor decoding skills of sighted children, as in Shankweiler et al.'s (1999) study, are usually caused by poor phonological skills (Mann, 1991; Stanovich, 1988; Wagner & Torgesen, 1987), whereas there is no reason to assume that children with low vision have phonological problems; their decoding problems seem to be caused mainly by a restricted visual input. Phonological shortcomings are a source not only of decoding problems, but also of sentence-comprehension problems of written as well as of spoken language (Mann, Cowin, & Schoenheimer, 1989). This difference between the children in the studies of Stothard and Hulme (1996) and Shankweiler et al. (1999) and the children in this study may explain why the discrepancy between decoding and comprehension was much larger for the children with low vision in this study than for the sighted children in Shankweiler et al.'s (1999) study.

It should be noted, however, that there was no time limit for the reading comprehension test in this study. This fact should make one cautious about concluding that poor vision is not a cause of reading comprehension problems. Although the performance of children with low vision with no other disabilities does seem to point in that direction, it is not known how these children would perform under time-constrained conditions that are comparable to everyday school situations.

Children with low vision in regular schools do not seem to have spelling problems either. Thus, our expectation that having low vision could be a cause of spelling problems was not supported by the results. In contrast to the findings of van Bon et al. (2000) and Corley and Pring (1993c), this study found no evidence of an improvement of the spelling performance of children with low vision over the primary school period.

It can be concluded from this study that the group of children with low vision is heterogeneous; not only are their eye conditions and functional visual consequences diverse, but the impact of these factors on the children's literacy attainment seems hard to predict. The heterogeneity pleads for an individual approach in the education of children with low vision, with attention paid to their visual needs as well as to their possible additional problems. On the basis of the results of this study, children with visual field restrictions need special care in learning to read, since these children seem most vulnerable to development of decoding problems.

A positive conclusion of the study is the finding that a relatively large number of children with low vision do not experience any problems with reading and spelling, despite their severe eye anomalies. It is important to investigate which factors these children or their circumstances have in common and which factors are different from those of children with low vision who are poor readers and spellers. More knowledge about these factors will be helpful in the education of children with low vision.

References

Arter, C., & Mason, H. (1994). Spelling for the visually impaired child. *The British Journal of Visual Impairment, 12,* 18-21.

Corley, G., & Pring, L. (1993a). The oral reading errors of partially sighted children. *The British Journal of Visual Impairment, 11,* 24-27.

Corley, G., & Pring, L. (1993b). Reading strategies in partially sighted children. *International Journal of Rehabilitation Research, 16,* 209-220.

Corley, G., & Pring, L. (1993c). The spelling competence of partially sighted children. *The British Journal of Visual Impairment, 11,* 105-108.

Daugherty, K. M., & Moran, M. F. (1982). Neuropsychological, learning, and developmental characteristics of the low vision child. *Visual Impairment and Blindness, 76,* 398-406.

Fellenius, K. (1996). Reading Competence of Visually Impaired Pupils in Sweden. *Journal of Visual Impairment and Blindness, 90,* 237-246.

Fellenius, K. (1999). Reading environment at home and at school of Swedish students with visual impairments. *Journal of Visual Impairment and Blindness, 93,* 211-224.

Fulcher, T., O'Keefe, M., Bowell, R., Lanigan, B., Burke, T., Carr, A., O'Rourke, M., & Bolger, M. (1995). Intellectual and educational attainment in albinism. *Journal of Pediatric Ophthalmology and Strabismus, 32,* 368-372.

Geurts, H., Gillijns, P., Krom, R., & Moelands, F. (1996). Schaal Vorderingen Spellingvaardigheid 3 [Scale Progress Spelling Competence 3]. Arnhem, the Netherlands: Cito.

Krischer, C. C., Stein-Arsic, M., Meissen, R., & Zihl, J. (1985) Visual performance and reading capacity of partially sighted persons in a rehabilitation center. *American Journal of Optometry & Physiological Optics, 62,* 52-58.

Legge, G. E., Rubin, G. S., Pelli, D. G., & Schleske, M. M. (1985). Psychophysics of reading-II. Low vision. *Vision Research, 25,* 253-266.

Mann, V. A. (1991). Language problems: a key to early reading problems. In B. Y. L. Wong, (Ed.), *Learning about Learning Disabilities* (pp. 129-162). San Diego, CA: Academic Press.

Mann, V. A., Cowin, E., & Schoenheimer, J. (1989). Phonological processing, language comprehension, and reading ability. *Journal of Learning Disabilities, 22,* 76-89.

Shankweiler, D., Lundquist, E., Katz, L., Stuebing, K. K., Fletcher, M., Brady, S., Fowler, A., Dreyer, L. G., Marchione, K. E., Shaywitz, S.E., & Shaywitz, B. A. (1999). Comprehension and decoding: patterns of association in children with reading difficulties. *Scientific Studies of Reading, 3,* 69-94.

Stanovich, K. E. (1988). Explaining the differences between the dyslexic and the garden-variety poor reader: the phonological-core variable-difference model. *Journal of Learning Disabilities, 21,* 590-603.

Staphorsius, G., & Krom, R. (1995). Toetsen Begrijpend Lezen [Tests for Reading Comprehension]. Arnhem, the Netherlands: Cito.

Stothard, S. E., & Hulme, C. (1996). A comparison of reading comprehension and decoding difficulties in children. In : C. Cornoldi, & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and intervention* (pp. 93-112). Mahwah, NJ: Lawrence Earlbaum.

Tobin, M. (1985). The reading skills of the partially sighted: their implications for integrated education. *International Journal of Rehabilitation Research, 8,* 467-472.

van Bon, W. H. J., Adriaansen, L., Gompel, M., & Kouwenberg, I. (2000). The reading and spelling performance of visually impaired Dutch elementary schoolchildren. *Visual Impairment Research, 2* (1), 17-31.

van Bon, W. H. J., & Duighuisen, H. C. M. (1995). Sometimes spelling is easier than phonemic segmentation. *Scandinavian Journal of Psychology, 36,* 82-94.

van den Bosch, L., Gillijns, P., Krom, R., & Moelands, F. (1991). *Schaal Vorderingen Spellingvaardigheid 1* [Scale Progress Spelling Competence 1]. Arnhem, the Netherlands: Cito.

van den Bosch, L., Gillijns, P., Krom, R., & Moelands, F. (1993). *Schaal Vorderingen Spellingvaardigheid 2* [Scale Progress Spelling Competence 2]. Arnhem, the Netherlands: Cito.

Verhoeven, L. (1995). *Drie Minuten Toets* [Three Minutes Test]. Arnhem, the Netherlands: Cito.

Verhoeven, L. (1997). *Lezen met Begrip* [Reading with Comprehension]. Arnhem, the Netherlands: Cito.

Wagner, R.K., & Torgesen, J.K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101,* 192-212.

3

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

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.

This chapter is a slightly adapted version of an article that was published in 2003, in the Journal of Visual Impairment & Blindness, 97, 273-284.

Introduction

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 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 Wagtendonk, & 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 (Mams, 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 primary 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, choroidea, and retina (one child); macular atrophy (one child); tapetoretinal dystrophy or achromatopsy (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 Minutes 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.

Table 1. Mean age, reading score and gender of the participating children.

Participants	Age (in months)	Reading scores (DMT)	Girls/boys [a]	*n*
Low vision	107 (6,0; 100-120)	59 (29; 18-108)	4/16	20
Age level matched	108.5 (3,9; 100-115)	76 (15; 46-104)	12/8	20
Reading level matched	99 (6,6; 90-117)	59 (28; 13-114)	15/5	20

[a] 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 ($F(1,58) < 1$) on the DMT word-decoding test.

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 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 of 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 of 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 ($F(2,5\ 7) = 2.3$, $p = .11$).

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, and *.86,* 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).

Table 2. Mean latencies, in milliseconds, of the three groups of participants on all three experiments (standard deviations in parentheses).

	Low vision	Age level	Reading level	ANOVA
Word naming	1711.6 (1316.22)	755.2 (245.61)	1283.2 (787.36)	($F(2,57)=5.7$, $p < .01$)
Picture naming	1218.8 (160.80)	923.2 (113.39)	1004.8 (113.12)	($F(2,57)=27.1$, $p < .01$)
Shape naming	1113.74 (294.24)	936.19 (220.58)	1082.62 (246.26)	($F(2,57)=2.7$, $p = .08$)

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 ($p > .05$).

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 ($p = .8$ l).

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 ($F <$ l). 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 ($F <$ l).

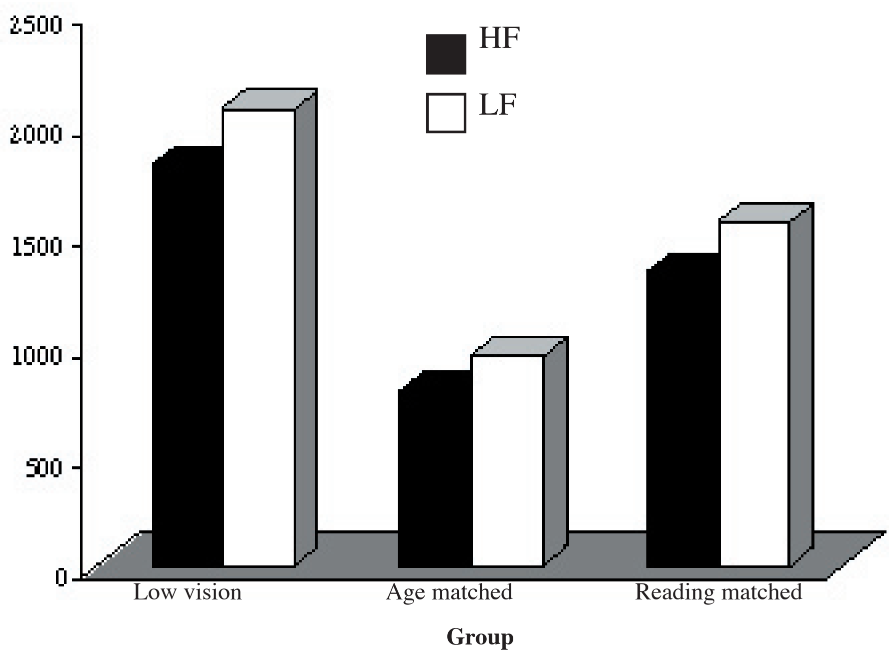

Figure 1. Mean reaction times (in ms.) on high-frequency (HF) and low-frequency (LF) words.

Discussion

The results of Experiment 1 confirm previous findings (Corley & Pring, 1993a, 1993b; Daugherty & Moran, 1982; Fellenius, 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 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 remediated 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 sentence reading and the role of context for children with different eye anomalies.

References

Arter, C., & Mason, H. (1994). Spelling for the visually impaired child. *The British Journal of Visual Impairment, 12,* 18-21.

Baayen, R. H., Piepenbrock, R., Gulikers, L. (1995). *The CELEX lexical database*. Philadelphia: Linguistic Data Consortium, University of Pennsylvania.

Chung, S. T. L., Mansfield, J. S., & Legge, G. E. (1998). Psychophysics of reading XVIII: The effect of print size on reading speed in normal peripheral vision. *Vision Research, 38,* 2949-2962.

Corley, G., & Pring, L. (1993a). The oral reading errors of partially sighted children. *The British Journal of Visual Impairment, 11,* 24-27.

Corley, G., & Pring, L. (1993b). Reading strategies in partially sighted children. *International Journal of Rehabilitation Research, 16,* 209-220.

Corley, G., & Pring, L. (1993c). The spelling competence of partially sighted children. *The British Journal of Visual Impairment, 11,* 105-108.

Daugherty, K. M., & Moran, M. F. (1982). Neuropsychological, learning, and developmental characteristics of the low vision child. *Visual Impairment and Blindness, 76,* 398-406.

Ellis, A. W. (1993). *Reading and writing and dyslexia: A cognitive analysis*. Hove: Psychology Press.

Fellenius, K. (1996). Reading Competence of Visually Impaired Pupils in Sweden. *Journal of Visual Impairment and Blindness, 90,* 237-246.

Fellenius, K. (1999). Reading environment at home and at school of Swedish students with visual impairments. *Journal of Visual Impairment and Blindness, 93,* 211-224.

Gompel, M., van Bon, W. H. J., Schreuder, R., & Adriaansen, J. J. M. (2002). Reading and spelling competence and development of Dutch visually impaired children. *Journal of Visual Impairment and Blindness, 96,* 435-447.

Hover, C. & Harperink, M. (1998). *Procedure en criteria voor de toelaatbaarheidsbepaling tot het 2/3-Onderwijs [Procedures and criteria for the admissibility to 2/3 education]*. The Hague, the Netherlands: Sdu.

Koenen, M., Bosman, A. M. T., & Gompel, M. (2000). Kijk eens hoe ik lees: Een onderzoek naar het leesgedrag van slechtziende en normaalziende kinderen [Watch me reading: A study into the reading behavior of children with low vision and sighted children]. *Tijdschrift voor Orthopedagogiek, 39,* 95-106.

Manis, F. R., Doi, L. M., & Bhadha, B. (2000). Naming speed, phonological awareness, and orthographic knowledge in second graders. *Journal of learning disabilities, 33,* 325-333, 374.

Mansfield, J. S., Legge, G. E., & Bane, M. C. (1996). Psychophysics of reading

XV: Font effect in normal and low vision. *Investigative Ophthalmology & Visual Science, 37,* 1492-1501.
Rayner, K., & Pollatsek, A. (1989). *The psychology of reading*. Englewood Cliffs, NJ: Prentice Hall.
Rubin, G. S., & Legge, G. E. (1989). Psychophysics of reading VI: The role of contrast in low vision. *Vision Research, 29* (1), 79-91.
Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174-215.
Snowling, M., Van Wagtendonk, B., & Stafford, C. (1988). Object-naming deficits in developmental dyslexia. *Journal of Research in Reading, 11,* 67-85.
Stanovich, K. E. (1988). Explaining the differences between the dyslexic and the garden-variety poor reader: The phonological-core variable-difference model. *Journal of Learning Disabilities, 21,* 590-604.
Swan, D., & Goswami, U. (1997). Picture naming deficits in developmental dyslexia: The phonological representations hypothesis. *Brain and Language, 56,* 334-353.
Tobin, M. (1985). The reading skills of the partially sighted: their implications for integrated education. *International Journal of Rehabilitation Research, 8,* 467-472.
van Bon, W. H. J., Adriaansen, J. J. M., Gompel, M., & Kouwenberg, I. (2000). The reading and spelling performance of visually impaired Dutch elementary schoolchildren. *Visual Impairment Research, 2,* 17-31.
van den Berg, R., & te Lintelo, H. (1975). *Analyse van Individualiseringsvormen [Analysis of Individualisation Norms]*. Den Bosch, the Netherlands: KPC Groep.
van der Heijden, A. H. C., Schreuder, R., & La Heij, W. (1989). Lezen [Reading]. In L. van Heyden Sr. (Ed.), *Psychologische functieleer: Theorie, techniek, toepassing* [Cognitive psychology: Theory, technique, application] (pp. 12-37). Houten, the Netherlands: Bohn Stafleu Van Loghum.
Van der Leij, A. (1998). *Leesproblemen: Beschrijving en aanpak* [Reading problems: Description and remediation]. Rotterdam, the Netherlands: Lemiscaat.
Verhoeven, L. (1995). *Drie minuten toets* [Three-minutes test]. Arnhem, the Netherlands: Cito.
Wolf, M., & Bowers, P. G. (2000). Naming-speed processes and developmental reading disabilities: An introduction to the special issue on the double-deficit hypothesis. *Journal of Learning Disabilities, 33,* 322-324.

Wurm, L. H., Legge, G. E., Isenberg, L. M., & Luebker, A. (1993). Color improves object recognition in normal and low vision. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 899-911.

4

Text Reading by Children with Low Vision

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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 seem to use this time with enough efficiency to process the semantic, as well as the syntactic, information.

This chapter is a slightly adapted version of an article that was published in 2004, in the Journal of Visual Impairment & Blindness, 98, 77-89.

Introduction

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 (2000) 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, text reading 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 it be words or sentences that are to be read - the third question is: 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.

Table 1. Mean educational age in months, reading scores (number of correct words read within one minute on the DMT) per experimental group.

	Educational age		Reading score	
Experimental group	Mean	SD	Mean	SD
Low vision (n = 41)	52.9	7.5	74	21
Age matched (n = 41)	52.9	7.5	88	16
Reading matched (n = 41)	37.6	7.7	74	22

At the time of the study, all 41 participants with low vision had an educational age of 40 to 60 months. Five children 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 for All 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 ($F(1,80) = 6.3$, $p < .05$).

Table 2. Words per minute (WPM) read on the DMT and the TAK.

Participants	DMT		TAK		Total	
	Mean	SD	Mean	SD	Mean	SD
Low vision	75.4	21.0	54.4	17.9	64.9	22.1
Age match	87.6	18.3	83.1	25.0	85.3	21.9
Reading match	75.7	20.7	63.9	16.3	69.8	19.5
Total group	79.5	20.7	67.1	23.2	73.3	22.8

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 ($F(1,78) = 1.5$, $p > .05$).

Table 3. Mean naming latencies in milliseconds on the context experiments for all three groups.

	Congruent context		Incongruent context		Neutral context		Total	
Participants	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low vision	953.1	305.1	1089.1	440.6	1153.2	421.6	1062.2	399.2
Age match	714.9	96.1	753.6	100.2	785.8	125.6	751.5	111.1
Reading match	797.6	219.8	901.2	312.5	941.9	293.3	880.2	262.5
Total group	821.9	219.8)	914.6	543.4	960.3	338.3	899	310.4

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 ($F(2,117)= 17.1$, $p < .05$).

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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 ($F(1,80) = 28.2$, $p < .05$).

Table 4. Score (number of correct answers) on the TAK.

	Content words		Function words		Total	
Participants	Mean	SD	Mean	SD	Mean	SD
Low vision	28.2	4.8	33.6	4.9	61.8	9.1
Age match	25.3	5.5	31.9	6.6	57.2	11.6
Reading match	22.5	5.2	27.3	6.7	49.8	11.2
Total group	25.3	5.6	30.9	6.6	56.3	11.7

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.

Table 5. Visual field specifications and diagnoses of the participating children with low vision.

Central visual field	Peripheral visual field	Diagnoses	Near visual acuity
Intact	Intact	albinism (n=3); Stickler syndrome; cataract; coloboma of the iris; oculomotor apraxia; microphthalmus OS, nystagmus, myopia OD; cone dysfunction; congenital stationary night blindness	0.5; 0.5; 0.1 0.32 0.5 0.32 0.5 0.25 0.12 0.4
Absolute scotoma(s)	Intact	perimacular atrophy; glaucoma; nystagmus, strabismus, myopia, retinal dysfunction	0.2 Unknown 0.2+
Absolute scotoma(s)	Absolute restriction (no tunnel vision)	atrophy of the optic nerve; microphthalmus, and coloboma of the iris, retina, and choroid; Bardet Biedl syndrome	0.3+ 0.16 0.4
Absolute scotoma(s)	Absolute tunnel vision	tapetoretinal dystrophy (TRD)	0.1
Absolute scotoma(s)	Relative restriction	atrophy of the optic nerve	0.16
Absolute scotoma(s)	Relative tunnel vision	TRD	0.25
Relative scotoma(s)	Intact	congenital nystagmus; retinopathy of prematurity (ROP); albinism (n=2); cone dystrophy; myopia and nystagmus; cataract OU and glaucoma OD	0.5+ 0.4+ 0.16; 0.2+ 0.16+ 0.2 0.12
Relative scotoma(s)	Absolute restriction	coloboma of the iris, retina and choroid	0.32
Relative scotoma(s) + lowered macula threshold	Intact	TRD; myopia gravis (n=3); strabismus and nystagmus (status after hydrocephalus); macular ectopy, nystagmus and coloboma	0.32 0.5-; 0.3+; 0.4- 0.25 0.5-

(Continued)

Table 5 (continued)

Central visual field	Peripheral visual field	Diagnoses	Near visual acuity
Relative scotoma(s) + lowered macula threshold	Absolute restriction	retinoblastoma OU; coloboma of the iris, retina, and choroid; coloboma of the optic nerve	0.12 0.12 0.1
Relative scotoma(s) + lowered macula threshold	Relative restriction	cataract; glaucoma and aniridia	0.32 0.06
Absolute scotoma(s) + lowered macula threshold	Intact	retinoblastoma	0.05
Lowered macula threshold	Intact	albinism	0.25
Unknown	Unknown	cataract	0.4

Note. For one of the children with low vision no visual field examination was performed.

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 the 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, 198l).

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 also 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 Analyzer, 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 1 1/2 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.

References

Abraham, R. G., & Chapelle, C. A. (1992). The meaning of cloze test scores: An item difficulty perspective. *Modern Language Journal, 76,* 468-479.

Baddely, A., & Wilson, B. (1988). Comprehension and working memory: A single case neuropsychological study. *Journal of Memory and Language, 27,* 479-498.

Becker, C. A., & Killion, T. H. (1977). Interaction of visual and cognitive effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 389-401.

Bouchard, D., & Tetrault, S. (2000). The Motor Development of Sighted Children and Children with Moderate Low Vision Aged 8–13. *Journal of Visual Impairment & Blindness, 94,* 564-573.

Bullimore, M. A., & Bailey, I. L. (1995). Reading and eye movement in age-related maculopathy. *Optometry and Vision Science, 72,* 125-138.

Fine, E. M., & Peli, E. (1996). The role of context in reading with CFL. *Optometry and Vision Science, 73,* 533-539.

Finegan, E. (1999). *Language: Its structure and use* (3rd ed.). Forth Worth, TX: Harcourt, Brace.

Gompel, M., Janssen, M. A., van Bon, W. H. J., & Schreuder, R. (2003). The Role of Visual Input and Orthographic Knowledge in Word Reading of Children with Low Vision. *Journal of Visual Impairment and Blindness, 97,* 273-284.

Gompel, M., van Bon, W. H. J., Schreuder, R., & Adriaansen, J. J. M. (2002). Reading and spelling competence and development of Dutch visually impaired children. *Journal of Visual Impairment and Blindness, 96,* 435-447.

Hartley, J., & Trueman, M. (1986). The effects of the typographic layout of cloze-tests on reading comprehension scores. *Journal of Research in Reading, 9,* 116-124.

King, J., & Just, M. A. (1991). Individual differences in syntactic processing: The role of working memory. *Journal of Memory and Language, 30,* 580-602.

Koenen, M., Bosman, A. M. T., & Gompel, M. (2000). Kijk eens hoe ik lees; Een onderzoek naar het leesgedrag van slechtziende en normaalziende kinderen [Watch me reading; A study into the reading behavior of children with low vision and normally sighted children]. *Tijdschrift voor Orthopedagogiek, 39,* 95-106.

Massaro, D. W., Jones, R. D., Lipscomb, C., & Scholz, R. (1978). Role of prior knowledge on naming and lexical decisions with good and poor stimulus information. *Journal of Experimental Psychology: Human Learning and Memory, 4,* 498-512.

Nation, K., & Snowling, M. J. (1998). Individual differences in contextual facilitation: Evidence from dyslexia and poor reading comprehension. *Child Development, 69,* 996-1011.

Perfetti, C. A., Goldman, S. R., & Hogaboam, T. W. (1979). Reading skill and the identification of words in discourse context. *Memory & Cognition, 7,* 273-282.

Rubin, G. S., & Turano, K. (1994). Low vision reading with sequential word presentation. *Vision research, 34,* 1723-1733.

Sanford, A. J., Garrod, S., & Boyle, J. M. (1977). An independence of mechanism in the origins of reading and classification-related semantic distance effects. *Memory and Cognition, 5,* 214-220.

Sperber, R. D., McCauley, C., Ragain, R. D., & Weil, C. M. (1979). Semantic priming effects on picture and word processing. *Memory and Cognition, 7,* 339-345.

Stanovich, K. E., & West, R. F. (1979). Mechanisms of sentence context effects in reading: Automatic activation and conscious attention. *Memory and Cognition, 7,* 77-85.

Stanovich, K. E., & West, R. F. (1981). The effect of sentence context on ongoing word recognition: Tests of two-process theory. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 658-672.

Stanovich, K. E., West, R. F., & Feeman, D. J. (1981). A longitudinal study of sentence context effects in second-grade children: Tests of an interactive-compensatory model. *Journal of Experimental Child Psychology, 32,* 185-191.

van Bon, W. H. J., Adriaansen, L., Gompel, M., & Kouwenberg, I. (2000). The reading and spelling performance of visually impaired Dutch elementary schoolchildren. *Visual Impairment Research 2* (1), 17-31.

Verhoeven, L. (1995). *Drie Minuten Toets* [Three Minutes Test]. Arnhem, the Netherlands: Cito.

Verhoeven, L., & Vermeer, A. (1993). *Taaltoets Alle Kinderen* [Language Test All Children]. Tilburg, the Netherlands: Zwijsen.

West, R. F., & Stanovich, K. E. (1978). Automatic contextual facilitation in readers of three ages. *Child Development, 49,* 717-727.

5

Children with low vision and sighted children compared: Word reading and the processing of letter identity and letter order

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In two word naming experiments, we studied two aspects of word reading: the identification of the constituent letters of a word, and the processing of letter order information. Children with low vision were compared with sighted children. Children with low vision with and without visual field restrictions were also compared. Both experiments showed qualitative differences between children with low vision and sighted children, but no quantitative or qualitative differences were found within the group of children with low vision.

A slightly adapted version of this Chapter is accepted for publication by the Journal of Visual Impairment & Blindness, and will be published in 2005.

Introduction

Children with low vision read more slowly than sighted children do (Corley & Pring, 1993a, 1993b; Daugherty & Moran, 1982; Fellenius, 1999; Gompel, van Bon, Schreuder, & Adriaansen, 2002; Tobin, 1985; van Bon, Adriaansen, Gompel, & Kouwenberg, 2000). A previous study showed that this difference in reading speed should not be attributed to a difference in orthographic knowledge between children with low vision and sighted children (Gompel, Janssen, van Bon, & Schreuder, 2003). A conclusion of that study was that it is visual processing only that constrains the reading speed of children with low vision.

When reading a text, a restricted visual field (caused by eye anomalies or by a short reading distance) and consequently the restricted use of information from the periphery can explain the slower reading rate of children with low vision. However, children with low vision do not only have slower reading rates when reading texts, but also when reading isolated words (Gompel, van Bon, & Schreuder, 2004). This suggests that the reading of these children is not just hampered at text or sentence level but already at word level. Therefore, in this study we will investigate some relevant aspects of word decoding.

We will compare the word recognition process of children with low vision with that of sighted children, but also investigate whether this process is different for children with low vision with and without visual field restrictions. Previous research has indicated that, of all visual impairments, central visual field defects have the highest adverse effect on decoding skills (Legge, Rubin, Pelli, & Schleske, 1985; van Bon et al., 2000). Gompel et al., 2002) also found that children with visual field restrictions were poorer decoders than children with other visual impairments, but no difference in decoding skills was found between children with central field defects and children with peripheral field defects. It is possible, however, that despite equality on global outcome measures, decoding processes are different in these groups of children with low vision. For children with central scotomas (blind spots), parts of words can fall on the retina just at the location of a scotoma (Legge, Klitz, & Tjan, 1997). This way, some of the constituent letters of a word may be invisible. This is in line with the finding of Bullimore and Bailey (1995) that readers with central scotomas need to make more regressions than readers without scotomas. A peripheral field restriction, however, narrows the field of view. Depending on the width of the visual field, more or less characters can be recognized within one fixation. This could not only affect the reading of sentences (Koenen, Bosman, & Gompel, 2000), but it is likely that the identification of isolated words is also hampered by a narrowed visual field, especially in the case of long words.

Two aspects of visual word recognition will be studied: first, the identification of the constituent letters of a word, and second, the processing of letter order information in words. The recognition and identification of the letters might be problematic for children with low vision, because some letters (e.g., “i” vs. “l”) differ only in a single feature from each other. It is conceivable that, when vision is not sharp, single features are hard to perceive or distinguish. But also when the visual field is restricted it is possible to miss one or more letters or parts of letters. Perception and identification of letters is essential, however, for a correct reading of words. A slight change can make all the difference in meaning as well as in pronunciation (e.g., CURE vs. CORE).

The order of the constituent letters is also essential in determining the pronunciation and the meaning of a word (e.g., ROSE vs. SORE). Identification of the constituent letters thus is not enough to identify a word; information about letter order should also be processed. The processing of letter order information might be more difficult for children with low vision than it is for sighted children, because children with low vision need more time to identify the single letters. This implies that they have to keep the identified letters longer in working memory. This might interfere with the process of keeping track of the position of the letters.

Children with central visual field restrictions might even have an additional disadvantage in processing letter order information. Legge, Klitz, & Tjan (1997) showed that people with central scotomas make more regressions while reading, because some letters of a word fall at the retina on the place of a scotoma and are thus not visible. These regressions might cause people with scotomas to perceive the letters of a word in a different order than people without scotomas do.

In this study, word recognition will be described in terms of connectionist (network) models (e.g., McClelland & Rummelhart, 1981). A property of this type of word recognition models is that word frequency determines the base level of activation of a word representation in the mental lexicon. This implies that for high frequency words less information is needed to reach a threshold than for low frequency words. Nonwords have no representations on the word level. Yet adults and even children are able to read nonwords. Rayner and Pollatsek (1989) explain the reading (pronunciation) of nonwords either by the use of grapheme/phoneme conversion rules, or by the analogy those nonwords may have with existing words. When a word is presented, not only its specific representation is activated, but also representations of orthographically similar words, specifically orthographic neighbors (words that differ in only one letter of the target word). Nonwords might therefore activate the representations of words that are orthographically similar to that nonword. Reasoning along these lines, we predict that the naming of nonwords will be facilitated by the activation of high frequency neighbors, because they provide the analogy to base the pronunciation on. Grainger (1990) indeed showed a facilitating effect of neighborhood frequency in word naming tasks. Words with at least one higher frequency neighbor had shorter naming latencies than words with no higher frequency neighbors. Laxon, Coltheart, and Keating (1988) found a facilitating effect of neighborhood size on accuracy in word naming. We expect such a facilitating effect of high frequency neighbors on the naming of nonwords for children with low vision as well as for sighted children. We also expect this effect to be stronger in children with low vision, because the restricted visual input impels them to use all possible resources for word recognition, such as knowledge of similar words.

Besides the possibility of investigating differences between children with low vision and sighted children in the effects of neighbor frequency, nonwords can also inform us about the reading accuracy of the different groups of children. In a previous study we did not find children with low vision to make more reading errors than sighted children do (Gompel, Janssen, van Bon, and Schreuder, 2003). Such errors would have been an indication for an inaccurate reading strategy, involving guessing for instance. This result, however, is based on the reading of existing words, in which a guessing strategy probably leads to correct responses most of the time, but in nonwords a guessing strategy is not very likely to result in correct responses. If children with low vision apply a guessing strategy more often than sighted children do, then the naming of nonwords would result in more errors for the first. Thus, when presented with nonwords, children with low vision would not only have longer response latencies and more errors than sighted children of the same age, but also longer response latencies and more errors than sighted children of the same reading level.

Two experiments were conducted to investigate the two aspects of word recognition in children with low vision and sighted children. In the first experiment the letter recognition process in word naming is investigated by studying the effects of orthographic neighbors on nonword naming. Since we expect that letter identification is more difficult for children with low vision, we predict that an effect of neighbor frequency will be larger for children with low vision than for sighted children. The second experiment was conducted to investigate the role of letter order information by studying the reading of anagrams, that is words of which the letters can be rearranged to form one or more other words (e.g., KERST [Christmas] is an anagram of STERK [strong] and of STREK [stretch]. We predict that the processing of letter order information will be more problematic for children with low vision than for sighted children, especially for children with visual field restrictions, as evidenced by the errors made and the time needed when reading anagrams.

EXPERIMENT 1

In this first experiment the letter recognition process is studied by presenting children with nonwords. Apart from neighbor frequency, three visual aspects of the nonwords were manipulated. The first aspect involves the visual features of individual letters. Some letters are more visually similar to each other than others (e.g., “f” and “t” are more alike than “p” and “w”). In half of the nonwords a letter of an existing word is substituted by a visually similar letter, in the other half a letter is substituted by a visually non similar letter. A second aspect is word length. Because of a peripheral field restriction or of a short reading distance, children with low vision might not be able to retrieve information from the same range of letter positions as do sighted children within one eye fixation. As a consequence, in long words, children with low vision would need to make more fixations than sighted children would, which could increase reading time. For short words one fixation could be sufficient for both groups of children. The third aspect is position of substitution. In half of the nonwords a letter of an existing word is substituted in the first part of the word, in the other half the substitution was in the last part of the word. Since the Dutch reading system, like that of many other languages, operates from left to right, it is possible that children with peripheral field restrictions process the first part of a word and respond on base of that information even before the later part is processed. If this is true, then nonwords with the substitution in the final part are likely to cause more activation of the orthographic neighbor than nonwords with the substitution in the first part.

The first research question in this experiment is whether children with low vision are more inclined to apply an inaccurate strategy in word decoding than sighted children are. The use of nonwords in this experiment makes it possible to investigate this. In nonwords a guessing strategy is not likely to result in the correct response. If children with low vision are inclined to guess, it is predicted that they will make more errors in the naming of nonwords than sighted children of the same word reading level do.

The second research question is whether effects of neighbor frequency are larger for children with low vision than for sighted children. If such a difference in effect size is found, this can indicate an analogy based reading strategy instead of a grapheme/phoneme conversion strategy. Because the visual input of children with low vision is of low quality, we expect them to compensate for this by the use of analogy, i.e. similar words. To investigate this, the presented nonwords were derived from existing words by changing one letter in the existing word. In this way, the existing word is an orthographic neighbor of the presented nonword. Half of the presented nonwords had a high frequency neighbor and half a low frequency neighbor.

The third research question concerns the effects of three visual aspects of the nonwords (word length, visual similarity of substitute letters, and position of the substitution) and their interaction with neighbor frequency. In this study we will explore whether these visual factors differentiate between the different groups of readers, which would indicate qualitatively different word recognition processes.

A fourth research question is whether any of the effects we find are different in children with visual field defects than in other children with low vision.

Method

Participants

In Experiment 1, 120 children participated, 40 children with low vision, 40 age matched children, and 40 reading level matched children. Sighted children were selected from a regular primary school. At the time of this study, all participating children with low vision had received 40 to 60 months of literacy education. Children in the reading level control group had a word reading score (determined by the DMT (Drie Minuten Toets [Three Minutes Test]; Verhoeven, 1995)) 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 ($F(1,78) = 79.8$, $p < .01$). Children of the age level control group were matched on educational age, but had a significantly higher word reading score ($F(1,80) = 8.8$, $p < .01$). All participating children were native speakers of Dutch.

Materials and procedure

To be able to study the effects of different visual field restrictions on word naming, all children with low vision had a visual field examination. Optometrists of two institutes for children with low vision carried out the visual field examinations. The peripheral visual field was determined by means of a Goldmann visual field exam or with the Tübinger perimeter. The central visual field was determined with the Friedmann Visual Field Analyzer. The results of this visual field examination and the diagnoses of the participating children with low vision are summarized in Table 1.

Reading level was determined by means of the second card of the DMT. The DMT is a standardized word-decoding test, consisting of three cards. The DMT was administered according to standard procedures, which means that children are presented a card with isolated words and are instructed to read those words as fast and as accurate as possible. The reading score is the number of correctly read words per card within a minute.

Table 1. Visual field specifications and diagnoses of the participating children with low vision.

Central visual field	Peripheral visual field	Diagnoses	Near visual acuity
Intact	Intact	albinism (n=3); Stickler syndrome; cataract; coloboma of the iris; oculomotor apraxia; microphthalmus OS, nystagmus, myopia OD; cone dysfunction; congenital stationary night blindness	0.5; 0.5; 0.1 0.32 0.5 0.32 0.5 0.25 0.12 0.4
Absolute scotoma(s)	Intact	perimacular atrophy; glaucoma; nystagmus, strabismus, myopia, retinal dysfunction	0.2 Unknown 0.2+
Absolute scotoma(s)	Absolute restriction (no tunnel vision)	atrophy of the optic nerve; microphthalmus, and coloboma of the iris, retina, and choroid; Bardet Biedl syndrome	0.3+ 0.16 0.4
Absolute scotoma(s)	Absolute tunnel vision	tapetoretinal dystrophy (TRD)	0.1
Absolute scotoma(s)	Relative restriction	atrophy of the optic nerve	0.16
Absolute scotoma(s)	Relative tunnel vision	TRD	0.25
Relative scotoma(s)	Intact	congenital nystagmus; retinopathy of prematurity (ROP); albinism (n=2); cone dystrophy; myopia and nystagmus; cataract OU and glaucoma OD	0.5+ 0.4+ 0.16; 0.2+ 0.16+ 0.2 0.12

(Continued)

Table 1. continued

Central visual field	Peripheral visual field	Diagnoses	Near visual acuity
Relative scotom(s)	Absolute restriction	coloboma of the iris, retina and choroid	0.32
Relative scotoma(s) + lowered macula threshold	Intact	TRD; myopia gravis (n=3); strabismus and nystagmus (status after hydrocephalus)	0.32 0.5-; 0.3+;0.4- 0.25
Relative scotoma(s) + lowered macula threshold	Absolute restriction	retinoblastoma OU; coloboma of the iris, retina, and choroid; coloboma of the optic nerve	0.12 0.12 0.1
Relative scotoma(s) + lowered macula threshold	Relative restriction	cataract; glaucoma and aniridia	0.32 0.06
Lowered macula threshold	Intact	albinism	0.25
Unknown	Unknown	cataract	0.4

Note: For one of the children with low vision no visual field examination was performed.

The orthographic neighbor experiment was a computerized word naming task. Stimuli in this experiment were 80 nonwords. All nonwords were derived from existing words by substituting one letter for another one. In half of the nonwords the substituted letter was replaced by a visually similar letter, in the other half the replacing letter was not visually similar. Similarity of letters was based on a study by Geyser (1977). The substitution was either in the first half of the word or in the last half. Half of the nonwords were long letter strings (8 to 10 letters, mean 8, SD 1), and half of the nonwords were short letter strings (4 to 6 letters, mean 5, SD 1). Half of the nonwords were derived from high frequency words (> 3000 per 42 million) and half from words with a low frequency (100-400 per 42 million). Word frequencies were determined on basis of the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). Every possible combination of the four factors was represented by five instances. For example, there were five long nonwords derived from a high frequency word, with a highly similar substitute letter in the first half of the letter string.

The experiment was executed on an Apple MacIntosh Powerbook computer, with a screen resolution of 1024 * 768, and a screen diagonal of 35 cm. (1.15 ft). Children were free to adopt the viewing distance most comfortable to them. Words were displayed in a 40-points font (for example the letter “o” had a width of 5 mm.

(0.016 ft) and a height of 6 mm. (0.02 ft)). The font type of the presented words was Monaco. Children were told that the words they were going to see were words that do not exist, and that they had to try to read them as quickly and accurately as possible. Naming latencies and errors were registered.

Naming 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 and conclusions

Due to a computer failure, the data of one of the children with low vision were not recorded. The data of the corresponding child in the reading matched and the corresponding child in the age matched group were also discarded. The analyses of Experiment 1 are based on the data of the remaining 137 children.

A 3(group: low vision vs. age matched vs. reading matched) by 2(neighbor frequency: high vs. low) by 2(position of substitution: begin vs. end) by 2(similarity of substitute: high vs. low) by 2 (length: long vs. short) analysis of variance (ANOVA) was carried out on the median response latencies and mean error proportions of all children. For the sake of brevity, we will only discuss the results pertaining to the research questions. Table 2 shows all mean naming latencies and mean error proportions.

Our first question was whether children with low vision use a more inaccurate word reading strategy than sighted children do. The ANOVA revealed no significant main effect for group on error proportions ($F(2,113) = 1.4$, $p = .26$). This result shows that children with low vision do not have relatively more problems with nonwords than do sighted children of the same reading level, and supports a previous finding that children with low vision do not apply guessing strategies in reading more often than do sighted children (Gompel, Janssen, van Bon, & Schreuder, 2003).

Our second question was whether the effect of neighbor frequency is larger for children with low vision than for sighted children. There was no significant main effect of neighbor frequency on response latencies ($F(1,107) = 1.9$, $p = .17$). The interaction between group and frequency, however, was significant ($F(2,107) = 9.2$, $p < .0001$). Children with low vision had significantly shorter response latencies on nonwords with a high frequency neighbor than on nonwords with a low frequency neighbor ($F(1,37) = 15.8$. $p < .001$).

Table 2. Mean naming latencies and mean error proportions for all word types (*SD*'s in parentheses).

High Frequency neighbor	Low vision	Age matched	Reading matched
High similarity	1470 (202) / .17 (.07)	1050 (197) / .14 (.08)	1572 (462) / .13 (.08)
Low similarity	1534 (292) / .16 (.03)	1117 (106) / .12 (.03)	1629 (357) / .12(.04)
Long words	1714 (87) / .20 (.04)	1212 (11) / .17 (.04)	1953 (38) / .17 (.03)
Short words	1290 (38) / .13 (.05)	955 (95) / .10 (.03)	1248 (101) / .09 (.06)
Substitution begin	1495 (262) /.18 (.05)	1098 (145) / .13 (.04)	1620 (399) / .14 (.05)
Substitution end	1509 (245) / .15 (.06)	1069 (177) / .13 (.07)	1581 (427) / .11 (.08)
HF neighbor mean	1502 (235) / .17 (.05)	1084 (151) / .13 (.05)	1601 (383) / .13 (.06)
Low frequency neighbor			
High similarity	1570 (298) / .19 (.11)	1057 (206) / .16 (.11)	1484 (492) / .17 (.12)
Low similarity	1697 (402) / .18 (.09)	1106 (194) / .15 (.07)	1610 (448) / .13 (.10)
Long words	1922 (194) / .26 (.06)	1237 (118) / .22 (.08)	1935 (194) / .22 (.10)
Short words	1344 (19) / .11 (.04)	926 (61) / .09 (.04)	1160 (125) / .08 (.05)
Substitution begin	1574 (278) / .16 (.07)	1023 (145) / .13 (.05)	1461 (381) / .11 (.06)
Substitution end	1693 (417) / .21 (.12)	1140 (226) / .18 (.12)	1633 (537) / .19 (.13)
LF neighbor mean	1633 (334) / .19 (.09)	1082 (187) / .16 (.09)	1547 (441) / .15 (.11)
Total	1568 (287) / .18 (.07)	1083 (164) / .14 (.07)	1574 (441) / .14 (.08)

No significant effect of frequency on response latencies was found in the groups of age matched children ($F < 1$) and reading matched children ($F(1,35) = 3.3$, $p = .08$). There was a significant main effect of frequency on the error proportions ($F(1,113) = 15.9$, $p < .0001$). More errors were made in nonwords with a low frequency neighbor than in nonwords with a high frequency neighbor. No significant interaction on the error proportions was found between group and frequency ($F(2,113) = 1.4$, $p = .91$), indicating a similar effect of frequency on the error proportions for all three groups. These results indicate that for children with low vision a high frequency neighbor has a facilitating effect for reading speed as well as for accuracy. For sighted children the data show a facilitating effect for accuracy only.

The third question concerns the effects of three visual aspects of the nonwords (word length, visual similarity of substitute letters, and position of the substitution) and their interaction with neighbor frequency. None of the visual aspects showed a significant interaction with group on naming latencies or error rates, except for word length on naming latencies ($F(2,107) = 7.4$, $p < .001$). The effect of word length on naming latency was significantly larger in both the low vision group and the reading matched group than in the age matched group ($F(1,72) = 4.1$, $p < .05$; $F(1,70) = 16.9$, $p < .0001$, respectively). The difference between the effect in the low vision group and the reading matched group was not significant ($F(1,72) = 3.2$, $p = .08$). For the naming latencies the interaction between group, neighbor frequency, and word length was not significant ($F < 1$). The interaction effect of frequency and word length was significant ($F(1,107) = 8.2$, $p < .01$), with larger frequency effects on long words than on short words, but the absence of an interaction with group indicates that this effect is not different for children with low vision than for sighted children. For the error rates the interaction between group, frequency, and word length was also not significant ($F < 1$).

For the naming latencies and the error rates the interactions between group, frequency, and position of substitution were not significant ($F(2,107) = 1.1$, $p = .33$; $F(2,113) = 1.5$, $p = .22$, respectively). For the naming latencies and the error rates the interactions between group, frequency, and visual similarity was not significant (both *F's* < 1). Although all manipulations did affect the effect of neighbor frequency, this effect was not different for the different groups.

To examine possible differences between children with different visual field defects and children without visual field defects (our fourth research question) all analyses were repeated with the following between groups contrasts: children with visual field defects vs. children with intact visual fields; with central field restrictions vs. without central field restrictions; with peripheral field restrictions vs. without peripheral field restrictions; with absolute field defects vs. with relative field defects. None of the ANOVAs revealed any significant main effect for group (all F's < 1). No significant interactions were found between group and word type (all F's < 1). This result indicates that the effects of word characteristics (neighbor frequency, length, similarity, place of substitution) is the same for all children with low vision, independent of the presence or absence of any kind of visual field restriction.

The results of this experiment show that the effect of neighbor frequency is larger for children with low vision than for sighted children. Neighbor frequency has no effect on the response latencies of sighted children, but does affect the response latencies of children with low vision; a high frequency neighbor facilitates the reading of nonwords in this latter group. Contrary to our expectations, the effects of word length, position and visual similarity of the substituted letter on the reading speed or accuracy is not different for children with low vision than for sighted children, or for children with low vision with and without visual field restrictions.

These results show that several visual letter or word features (word length, visual similarity, position of substitution) do not specifically facilitate or hinder the word reading of children with low vision. However, the effect of neighbor frequency is different for children with low vision than for sighted children. Furthermore, this effect of neighbor frequency is larger in long words than in short words for children with low vision. The fact that children with low vision read nonwords with a high frequency neighbor faster than nonwords with a low frequency neighbor is in line with the idea that these children rely more on an analogy based reading strategy than on a rule based reading strategy. This is a qualitative difference between children with low vision and sighted children and not just a developmental lag, because this difference is not only found between children with low vision and sighted children of the same age, but also between children with low vision and sighted children of the same reading level.

The finding that children with low vision do not make more errors than do sighted children in nonwords confirms previous results (Gompel et al., 2003) that children with low vision do not apply a guessing strategy in word reading more often than sighted children. If they did, they would have had higher error rates in this experiment than sighted children, because a word based guessing strategy cannot lead to a correct response in reading nonwords as it can in reading existing words.

EXPERIMENT 2

In this word naming experiment, the role of letter order is investigated by presenting two kinds of words: anagrams and unique words. The letters of an anagram can be rearranged to form one or more other words (e.g., KERST [Christmas] can be rearranged to form STERK [strong] and STREK [stretch]). The letters of a ‘unique word’ cannot be rearranged to form another word (e.g., with the letters of the word ZALM [salmon] no other Dutch word can be formed). We expect that for all children anagrams take more time to read than unique words, because both words are activated and are candidates for lexical access. The competition between both the word and its anagram(s) will increase the time needed for lexical access. In case of unique words no such competition has to be resolved. We also expect this effect of anagrams to be larger in children with low vision than in sighted children and specifically in children with visual field defects because of the difficulties that they might have in the processing of letter order information.

Method

Participants
The same 120 children of Experiment 1 participated in Experiment 2.

Materials and procedure
The stimuli in this word naming experiment were 40 words. Half of the words were anagrams. The other 20 words were unique words. Of an anagram set the anagram with the lowest frequency was presented. The selected (i.e., least frequent) anagrams and unique words were matched on frequency and word length. Word frequencies were determined on basis of the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). The mean frequency of the presented words of the anagram sets was 104.2; the mean frequency of the remaining words of an anagram set was 7405.3, and the mean frequency of the unique words was 109.8. The equipment and procedure of this word naming task were equal to those of Experiment 1.

Results and discussion

A 3(group: low vision vs. reading matched vs. age matched) by 2(word type: anagram vs. unique) ANOVA was performed on the median latencies of the correct responses. Group was treated as a between subjects variable and word type as a within subjects variable. Figure 1 shows the results.
The main effect of group was significant ($F(2,117) = 4.7$, $p < .05$). Both children with low vision and children in the reading matched group had significantly longer median response latencies than children in the age matched group (Fisher's PLSD, both $p < .001$). No difference was found between the median response latencies of children with low vision and those of children in the reading matched group (Fisher's PLSD, $p = .56$).

The main effect of word type was not significant ($F < 1$), indicating no difference in median response latencies on unique words and anagrams. The interaction effect, however was significant ($F(2,117) = 12.5$, $p < .0001$), indicating that the effect of word type was different for the groups of participants. Children with low vision had significantly longer median response latencies on anagrams than on unique words ($F(1,39) = 6.4$, $p < .05$). Both children in the age matched and in the reading matched group had significantly longer naming latencies on the unique words than on the anagrams ($F(1,39) = 4.2$, $p < .05$; $F(1,39) = 19$, $p < .0001$, respectively). Within the group of sighted children a significant

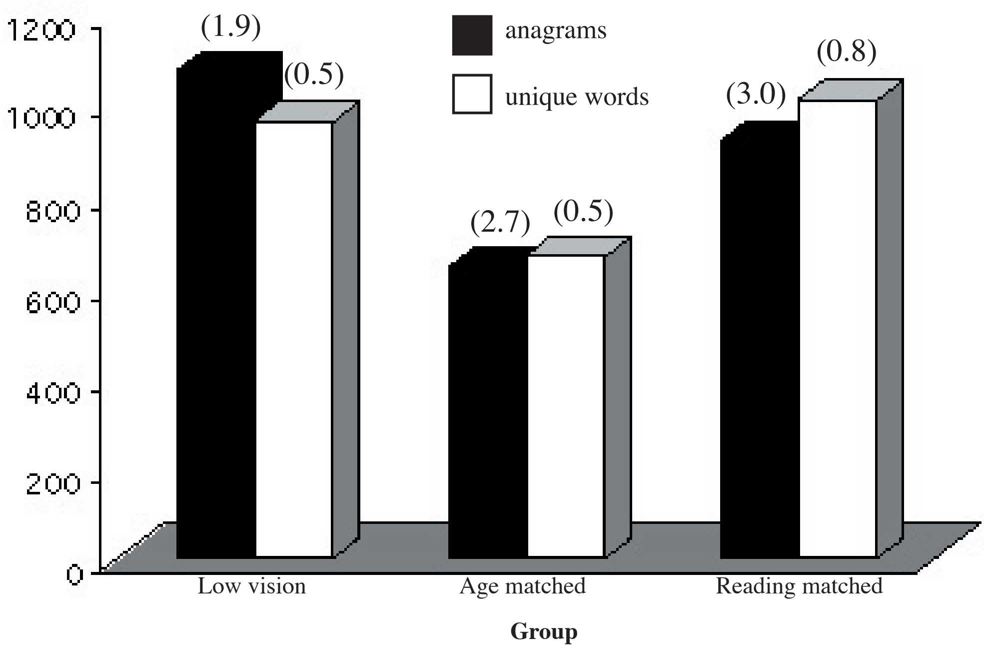

Figure 1. Median latencies and error rates (in parentheses) of the three groups on different word types.

interaction effect of word type was found ($F(1,78) = 6.4$, $p < .05$). The effect of word type was larger for the younger children in the reading matched group than for the children in the age matched group.

Another 3(group: low vision vs. reading matched vs. age matched) by 2(word type: anagram vs. unique) ANOVA was performed on the mean error rates of each of the participants. Group was treated as between subjects variable and word type as within subjects variable. The main effect of group was not significant ($F(2,117) = 2.0$, $p = .14$), indicating no differences in error rates between the groups. The main effect of word type was significant ($F(1,117) = 126.2$, $p < .05$). All groups made more errors on anagrams than on unique words. The interaction between group and word type was not significant ($F(2,117) = 2.2$, $p = .12$).

To examine possible differences between children with different visual field defects and children without visual field defects all analyses were repeated with the same between groups contrasts as those in Experiment 1. None of the ANOVAs revealed any significant main effect for group (all F's < 1). Nor were any significant interactions found between group and word type (all F's <1). This finding indicates that the effect of word type is the same for all children with low vision, independent of the absence or presence of any kind of visual field restriction.

The aim of this experiment was to investigate whether the processing of letter order information is affected by visual impairments. If this is the case, then anagrams would be relatively harder to read for children with low vision than for sighted children. The results of this experiment show that children with low vision need more time to read anagrams than to read unique words, whereas sighted children need more time to read unique words than to read anagrams. This difference between children with low vision and sighted children does not only apply to sighted children of the same age, but also to younger sighted children of the same reading level as the children with low vision. This shows a qualitative difference between children with low vision and sighted children and not just a developmental lag.

General discussion

In this study, two aspects of visual word recognition were investigated, letter identification and letter order information. In the first experiment, the effects of orthographic neighbor frequency were studied. The results of this experiment show a qualitative difference between children with low vision and sighted children. Children with low vision read nonwords with high frequency neighbors faster than nonwords with low frequency neighbors. For sighted children no such difference was found. In terms of a connectionist model of word recognition (e.g., McClelland & Rummelhart, 1981) this means that for children with low vision the activation of the representation of a relatively well-known word facilitates the reading of a similar target nonword. In sighted children this facilitating effect was not found. This confirms our hypothesis that the low quality of the input of children with low vision is partially compensated for by the use of analogy, i.e. similar words, as evidenced by the effect of neighbor frequency. We did not expect, however, an absence of an effect of neighbor frequency in sighted children. It is possible that this was a ceiling effect. The nonwords of the experiment might have been too easy for those sighted children to differentiate between high and low frequency neighbors. Although this can explain the absence of an effect of neighbor frequency in the age matched group, it does not explain the absence of an effect in the reading matched group, because they had the same reading level as the children with low vision. An explanation for the difference between children with low vision and sighted children of the same reading level might be the difference in reading experience of the two groups. The children in the reading matched group are on average younger than the children with low vision. Younger children generally have fewer reading occasions and read fewer words per occasion than older children. Therefore they meet with fewer words in their written form. It is possible that the words of which the nonwords were derived from are all less well known by the younger children of the reading matched group than by the children with low vision. If that were the case, the orthographic neighbors of all nonwords would be of low frequency for the children in the reading matched group. Whereas the absence of a frequency effect in the age matched group can be a ceiling effect, the absence of a frequency effect in the reading matched group might be a result of a floor effect.

Of the other conditions, visual similarity, position of substitution and word length, only the last factor increased the facilitating effect of neighbor frequency in the reading of children with low vision: the effect was larger in long words. Surprisingly, the effect of visual similarity of the substituted letter was the same for all groups of children; facilitating on response latency and interfering on accuracy. Children with low vision were not any more confused by visual similarity than sighted children were. Together with the finding that children with low vision do not make more errors in general, this indicates that children with low vision do not trade accuracy for speed. When reading, they seem to take into account their deficiency in recognizing visual patterns, and deal with this deficiency by not relying on a first impression, but analyze the visual patterns cautiously.

The second experiment was conducted to investigate the role of letter order in the word reading of children with low vision. The model of Legge, Klitz, and Tjan (1997) predicts that people with central scotomas need to make more regressions while reading. Therefore it was expected that children with central visual field restrictions would be more inaccurate and would need more time than other children with low vision and than sighted children. Our data indicate that all children with low vision, and not only those with central field restrictions, have more problems with letter order than sighted children do. This result can perhaps be explained by the burden reading places on the working memory of children with low vision. As indicated by the main effect of this experiment, children with low vision need more time to perceive and identify letters within words. This suggests that they have to keep the individual letters of a word longer in working memory, which might interfere with the process of keeping track of the order of the letters. If then, like in the anagrams of the experiment, the letters can constitute different words, children might be forced to reconsider all alternatives. Another explanation is that many children with low vision (with and without visual field restriction) also have nystagmus (an involuntary, rapid movement of the eyes). This could cause them to make more and less efficient fixations, which interferes with the processing of the correct letter order.

Children with low vision do not make more errors in either of the two word types than do sighted children. This result is in line with previous findings (Gompel, Janssen, van Bon, & Schreuder, 2003), and the results of the first experiment, that children with low vision do not seem to trade accuracy for speed.

Of the factors that we studied, only letter order seems to be more problematic for children with low vision, irrespective of the quality of their visual field. Perhaps making children with low vision more aware of the importance of letter order in reading might encourage them to apply reading strategies that help them keeping track of the letter order, like following the words with the finger or with a ruler. The overall conclusion of the present study is that children with low vision seem to adapt to their typical visual functioning fairly well. Although they need more time for reading than do sighted children, children with low vision read accurately and are not easily confused by visual similarity. The fact that no qualitative differences were found in the word reading between children with low vision with and without visual field restrictions indicates that children with low vision have learned to acknowledge their own specific visual deficiencies, and have found ways to compensate for these specific deficiencies.

References

Baayen, R. H., Piepenbrock, R., Gulikers, L. (1995). *The CELEX lexical database*. Philadelphia: Linguistic Data Consortium, University of Pennsylvania.

Bullimore, M. A., & Bailey, I. (1995). Reading and eye movements in age-related maculopathy. *Optometry and Vision Science, 72,* 125-138.

Corley, G., & Pring, L. (1993a). Reading strategies in partially sighted children. *International Journal of Rehabilitation Research, 16,* 209-220.

Corley, G., & Pring, L. (1993b). The oral reading errors of partially sighted children. The British Journal of Visual Impairment, 11 (1), 24-27.

Daugherty, K. M., & Moran, M. F. (1982). Neuropsychological, learning, and developmental characteristics of the low vision child. *Visual Impairment and Blindness, 76,* 398-406.

Fellenius, K. (1999). Reading environment at home and at school of Swedish students with visual impairments. *Journal of Visual Impairment and Blindness, 93,* 211-224.

Geyser, L. H. (1977). Recognition and confusion of the lowercase alphabet. *Perception & Psychophysics, 22,* 487-490.

Gompel, M., van Bon, W. H. J., Schreuder, R., & Adriaansen, J. J. M. (2002). Reading and spelling competence and development of Dutch children with low vision. *Journal of Visual Impairment and Blindness, 96,* 435-447.

Gompel, M., van Bon, W. H. J., & Schreuder, R. (2004). Reading of children with low vision. *Journal of Visual Impairment and Blindness, 98,* 77-89.

Gompel, M., Janssen, M. A., van Bon, W. H. J., & Schreuder, R. (2003). The role of visual input and orthographic knowledge in word reading of children with low vision. *Journal of Visual Impairment and Blindness, 97,* 273-284.

Grainger, J. (1990). Word frequency and neighborhood frequency effects in lexical decision and naming. *Journal of Memory and Language, 29,* 228-244.

Koenen, M., Bosman, A. M. T., & Gompel, M. (2000). Kijk eens hoe ik lees; Een onderzoek naar het leesgedrag van slechtziende en normaalziende kinderen [Watch me reading; A study into the reading behavior of children with low vision and normally sighted children]. *Tijdschrift voor Orthopedagogiek, 39,* 95-106.

Laxon, V. J., Coltheart, V., & Keating, C. (1988). Children find friendly words friendly too: words with many orthographic neighbors are easier to read and spell. *British Journal of Educational Psychology, 58,* 103-119.

Legge, G. E., Klitz, T. S., & Tjan, B. S. (1997). Mr. Chips: An ideal-observer model of reading. Psychological Review, 104, 524-553.

Legge, G. E., Rubin, G. S., Peli, D. G., & Schleske, M. M. (1985). Psychophysics of reading-II: Low vision. *Vision Research, 25,* 253-266.

McClelland, J. L., & Rummelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part I: An account of basic findings. *Psychological Review, 88,* 375-407.

Rayner, K. & Pollatsek, A. (1989). *The Psychology of Reading*. Englewood Cliffs, NJ: Prentice-Hall

Tobin, M. (1985). The reading skills of the partially sighted: their implications for integrated education. *International Journal of Rehabilitation Research, 8,* 467-472.

van Bon, W. H. J., Adriaansen, L., Gompel, M., & Kouwenberg, I. (2000). The reading and spelling performance of visually impaired Dutch elementary schoolchildren. *Visual Impairment Research 2* (1), 17-31.

Verhoeven, L. (1995). *Drie Minuten Toets* [Three Minutes Test]. Arnhem, the Netherlands: Cito.

6

Conclusion and discussion

The aim of the studies described in this thesis was to improve our insight into the literacy of children with low vision. Participants in the studies of this thesis were in the age range in which literacy skills are formally taught in primary school (grades 1 to 6).

In the study reported in the second chapter of this thesis, we compared the reading and spelling attainment of children with low vision with that of sighted children. In general, the results showed that children with low vision are behind in reading and spelling skills compared to sighted children. However, this conclusion needs some qualification. We found a difference between children with low vision in regular primary schools and children with low vision in special schools. Children with low vision in special schools were behind in all of the aspects of literacy studied (word decoding, reading comprehension and spelling). Children with low vision in regular schools, however, only showed to be poorer word decoders than sighted children (although the difference was not as large as the difference between children with low vision in special schools and sighted children). The reading comprehension and spelling skills of children with low vision in regular schools do not differ from those of sighted children. It turned out that visual acuity was not the discriminating factor between the two groups of children with low vision. The difference between children with low vision in different school types is in general cognitive ability and in the prevalence of additional disorders. From these findings, we concluded that spelling and reading comprehension are not affected by visual impairments, but word decoding is.

Another conclusion of the study reported in Chapter 2 is that, for children with low vision, good decoding performance apparently is not a prerequisite for good reading comprehension or spelling. A large number of the children with low vision who had excellent reading comprehension scores, had a word-decoding score at the lowest level, indicating that for some of the visually impaired children above average reading comprehension is possible with a minimum of decoding skills. Such a discrepancy is rare in sighted children (Shankweiler et al., 1999).

The population of children with low vision is very heterogeneous with respect to the causes and consequences of their eye conditions. Therefore, we investigated the impact of several different eye anomalies on literacy attainment. The only difference we found was between children with a visual field restriction and children with intact visual fields. On average, children with a visual field restriction were poorer decoders than other children with low vision. Contrary to the findings of van Bon, Adriaansen, Gompel, and Kouwenberg (2000), we did not find any differences between children with central visual field defects and children with peripheral visual field restrictions. A distinction between this study and the previous study of van Bon et al. (2000) lies in the larger number of participants in the study described in Chapter 2. Therefore, it is possible that the difference between children with central field defects and children with peripheral field restrictions found by van Bon et al. follows from sampling fluctuation and is coincidental. The fact that we did not find this difference in a larger sample (about two third of the population) is an indication that such a difference does not exist. It seems that visual field restrictions, whatever their kind, are more detrimental to the development of reading skills than are other visual impairments.

The study reported in Chapter 2, yielded important knowledge that can be used in the education of children with low vision. A first implication is that teachers should be aware of the relatively high prevalence of additional disorders, such as learning disabilities, in children with low vision. Although it might be difficult to discriminate between reading difficulties that are a direct result of low vision and those that are learning disorders that are not directly related to the eye condition, it is important to examine this carefully, so that remediating or compensating arrangements can be adapted to the specific needs of children.

A second implication comes from the result that children with visual field restrictions are at a higher risk to develop word decoding problems. These children might therefore need extra or different support in the education of literacy.

Because this study only allows conclusions about quantitative, not about qualitative differences in word decoding between children with and children without a visual field restriction, the studies described in Chapters 4 and 5 of this thesis investigated whether there is also a qualitative difference between these children.

The final implication of the study reported in Chapter 2 concerns children with low vision, but no additional disorders. A positive conclusion of our study is the finding that a relatively large number of visually impaired children do not experience any problems with reading and spelling at all, despite their serious eye anomalies. For these children, adaptation to their visual needs (e.g., by means of text enlargement or optical reading aids) seems to be sufficient to support the development of literacy. However, for the children with low vision who are poor decoders, it is not clear yet to what extent their decoding problems can be attributed only to visual problems or to other factors as well. This question was the main topic of Chapter 3.

The finding of the study discussed in Chapter 2, that children with low vision, but no additional disorders are not behind in spelling attainment seems to implicate that children with low vision have developed sufficient orthographic knowledge. However, the results make clear that they are relatively poor readers. The main question of the study described in Chapter 3 was whether these word decoding problems are explained entirely by the degraded visual input of children with low vision or whether there are also other factors that cause these decoding problems. To investigate this question, children with low vision and sighted children were presented with words, small line drawings and drawings of large geometrical shape in three naming experiments. Naming words and naming small line drawings have two factors in common: visual recognition and naming speed. Because of the size and simplicity of large geometrical shapes, visual recognition is not a factor of discrimination between children with low vision and sighted children. If both groups of children differ from each other on this task, this must be a result of a difference in naming speed. The results show that there was no difference in the speed of naming large geometrical shapes between children with low vision and sighted children. This indicates that problems with rapid naming are not the cause of the poorer decoding skills of children with low vision. The results of the word naming experiment showed a difference between children with low vision and sighted children. However, when we entered the difference between the two groups of children in naming the small line drawings (the picture naming task) as a covariate in the analysis, no significant differences were found between groups in naming latencies on the word naming task. Therefore, the slower reading speed of children with low vision can be explained entirely by the slower naming speed on pictures. Since naming speed per se showed to be no problem for children with low vision, it can be concluded that the visual input constraint is a sufficient explanation for the poorer decoding skills of children with low vision. The reading difficulties of children with low vision do not seem to be caused by any linguistic shortcomings.

A second question of the study reported in Chapter 3 was whether the poorer decoding skills of children with low vision are a result of a lower reading speed, a less accurate reading strategy, or a combination of those. We investigated this question by comparing the error percentages of children with low vision with those of sighted children on the word naming task. We found no differences between the error percentages of both groups of children. This means that children with low vision are not less accurate readers than sighted children are and thus that the poorer word decoding performance of children with low vision is a matter of speed, not of accuracy.

Since the results show that visual input is the only factor that decreases word decoding speed of children with low vision, one may argue that lower decoding speed performances of children with low vision should not be considered and treated as a learning difficulty which can be remediated 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 varies from individual to individual.

The fourth chapter of this thesis is concerned with text reading and understanding. Although the results of the study described in the second chapter already showed that children with low vision comprehend text just as well as sighted children do, time-on-task was not taken into account in that study. In chapter 4, we investigated whether children with low vision need more time to read and understand texts than sighted children do, and whether this difference between children with low vision and sighted children is larger than the difference in reading isolated words. A second question was whether children with low vision compensate for their decoding problems by a higher reliance on contextual information.

We conducted two experiments in the study reported in Chapter 4. In the first experiment, we compared children with low vision with sighted children on the time they need for reading isolated words and the time they need for reading and comprehending texts. We also determined comprehension itself. The results of this experiment were in line with the findings described in Chapter 2, with respect to the comprehension skills of children with low vision. Children with low vision show comprehension skills similar to those of sighted children. However, they need more time for reading and comprehending a text than sighted children do. This difference in time needed is larger than the difference we found between these groups in reading isolated words. The results of the second experiment showed that the lower reading rate of children with low vision is not caused by a less developed skill to use 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. These results implicate that, although contextual information helps children with low vision in the decoding of words, this help is not enough to compensate for the disadvantages (like the need for more eye movements, as Koenen, Bosman, and Gompel (2000) suggested) that these children have in reading texts.

In this study, we also investigated whether children with visual field restriction differ from other children with low vision in text reading speed, reading comprehension and context use. We found no differences between those two groups of children in speed and comprehension. The difference between children with a visual field restriction and other visually impaired children on context facilitation was also not significant. However, a trend ($p = .09$) was found, indicating that a meaningful context facilitates the reading of children with visual field restrictions somewhat more than that of other children with low vision.

The results of the study reported in Chapter 4 show that reading comprehension is not a problem for children with low vision, as long as they are given enough time to read (about one and a half to two times as much as normally sighted children). For the classroom, this implies that teachers should give visually impaired children ample time to study. If this time is not available, teachers might consider using auditory aids, like spoken books or text-to-speech computer software. On tests, children with low vision also need to be allowed extra time. The trend that children with visual field restrictions seem to rely even more on contextual information than other visually impaired children, can be an indication that children adapt their compensating strategies to the severity of their impairment. Even in spite of severe visual impairments, most children manage to decode the words and understand what they read, be it slower than sighted children.

The topic of Chapter 5 was word decoding again. We conducted two experiments in the study reported in Chapter 5, in which three aspects of word identification were addressed. In the first experiment, we investigated the visual processing and recognition of words and the strategy used in word identification. In the second experiment, we studied the processing of the information of letter order. We studied the visual recognition of words in a naming experiment in which the stimuli were nonwords that were derived from existing words by changing one letter. We manipulated three word characteristics in this experiment: word length, visual similarity of the substituted letter with the replacing letter, and position of the substituted letter. The results showed that the effects of visual similarity and position of substitution on word naming speed in children with low vision did not differ from those in sighted children. The effect of word length for children with low vision was different from that for sighted children. Children with low vision need more time to read long words than to read short words. This difference was not found in sighted children of the same age, but was found in younger sighted children of the same reading level as the children with low vision. We concluded that the visual characteristics manipulated in this experiment did not have a specific effect on the word recognition of children with low vision. The longer reading times we found in children with low vision on long words are more likely a consequence of the reading level of these children than a consequence of the visual impairment.

The second factor we manipulated in this word naming experiment was the frequency of the orthographic neighbor (the existing words, the nonwords were derived from). We found that the effect of the frequency of the orthographic neighbor for children with low vision differed from the effect for sighted children (both of the same age and of the same reading level). In children with low vision, a high frequency neighbor had a facilitating effect on the naming speed. Such an effect was not found in sighted children (both of the same age and of the same reading level). This result is an indication that additional to a strategy based on grapheme/phoneme conversion rules, children with low vision also apply an analogy based reading strategy.

In this experiment, we also found that children with low vision do not make more errors than sighted children do. This is in line with the findings discussed in Chapter 3. The difference, however, is that in this experiment the stimuli were nonwords. Whereas it is possible to successfully apply a guessing strategy in the reading of existing words, it is not very likely that guessing will lead to a correct response in the naming of nonwords. The finding that children with low vision are just as accurate in reading nonwords as sighted children are, indicates that children with low vision are not more inclined to guess than sighted children are.

In the second experiment discussed in chapter 5, we studied the processing of letter order. We presented two types of words: words of which the constituent letters can form one or more other words (anagrams), and words of which the constituent letters can form no other existing word (unique words). We expected that children with low vision would need more time to read the anagrams than the unique words because of two reasons. First, children with low vision need more time to identify the single letters. This implies that they have to keep the identified letters longer in working memory. This might interfere with the process of keeping track of the position of the letters. Second, children with low vision and central scotomas need to make more regressions while reading, because some letters of a word fall at the retina on the place of a scotoma and are thus not visible in a single fixation. These regressions might cause these children to perceive the letters of a word in a different order than children without scotomas do.

We indeed found that children with low vision need more time to read anagrams than to read unique words. For sighted children this effect was not found. We found no difference of this letter order effect between children with central scotomas and other children with low vision. These results indicate that children with low vision (with or without central scotomas) have more problems with letter order than sighted children do. This result should perhaps be explained by the burden reading places on the working memory of children with low vision. Another explanation is that many children with low vision also show nystagmus (an involuntary, rapid movement of the eyes). This could cause them to make more and less efficient fixations, which interferes with the processing of the correct letter order.

Children with low vision do not make more errors in either of the two word types (anagrams and unique words) than sighted children do. This result is in line with previous findings described in the third chapter and the results of the first experiment of this chapter, that children with low vision do not seem to trade accuracy for speed.

A practical implication of this study reported in Chapter 5 is that teachers should not be any more concerned about the reading accuracy of children with low vision than they are about the reading accuracy of sighted children. Both experiments have shown that children with low vision do read accurately, even when an inaccurate response is likely because of a similarity of the stimulus with another word. On the one hand, similarity can help children with low vision to read words faster, when letter identity is the discriminating factor between two or more words (as shown in the nonword experiment). On the other hand, similarity can hinder the reading speed of these children when the letter order is the factor that makes the difference between two or more words. It seems that children with low vision are aware of the necessity to cautiously identify the individual letters of a word, but are less aware of the importance of the letter order. In order to overcome problems related to letter ordering, teachers may help children to apply strategies, such as following words in the text and letters in the words with the finger or a ruler.

The aim of this thesis was to add to the insight in the literacy skills of children with low vision. The first conclusion that can be drawn from the studies described in this thesis is that children with low vision are behind sighted children in literacy skills. However, a distinction should be made between literacy problems that are a consequence of the visual impairment and literacy problems that are caused by additional impairments that coincide with visual impairment. Therefore it is important to recognize these impairments and to adapt the education to the visual as well as the other needs of these children. As Daugherty and Moran (1982) pointed out, a neuropsychological profile might be a better predictor of school achievement than is visual acuity.

When considering only those literacy problems that are related to the visual impairment, our conclusions are quite positive. Reading comprehension and spelling skills do not seem to be affected by the visual impairment. This is in contrast with the findings of Arter and Mason (1994), who found that children with low vision are poorer spellers than sighted children are. Van Bon et al. (2000) and Corley and Pring (1993c) found that children with low vision start out as relatively poor spellers, but catch up with their sighted peers later during the primary school period. In our study, children with low vision and no additional impairments did perform just as well as sighted children did, also the children with low vision in the lower grades. A difference between our study and the studies of van Bon et al. and of Corley and Pring, is that we made a distinction between children with low vision with and without additional problems. It is possible that the spelling problems of children with low vision in the other studies are a consequence of the higher prevalence of additional problems in the population of children with low vision. This seems to imply that the spelling problems found in children with low vision should be attributed to other factors than visual constraints.

Reading comprehension is also not a problem for children with low vision and no additional impairments. In our study, 38.5% of the children with low vision attained excellent reading comprehension scores, but had a word-decoding score at the lowest level. This result is (positively) surprising, because in sighted children excellent comprehension is rarely seen in extremely poor decoders (Shankweiler et al., 1999). We explained this discrepancy by the differences there are in the causes of poor decoding skills between children with low vision and poor readers in the general population. The poor decoding skills of sighted children are usually caused by poor phonological skills (Mann, 1991; Stanovich, 1988; Wagner & Torgesen, 1987), whereas children with low vision in general have no phonological problems (as the results of the study reported in Chapter 2 show). Their decoding problems seem to be mainly caused by a hampered visual input. Phonological shortcomings are not only a source of decoding problems, but are also a source of sentence comprehension problems of written as well as of spoken language (Mann, Cowin, & Schoenheimer, 1989).

Although word decoding and text reading skills of children with low vision are hindered, this is mostly a matter of speed. As long as children with low vision are given enough time, they do perform just as well as sighted children do. A question that we did not answer yet, is what the impact is of the extra time and effort children with low vision need to read on their motivation. As Fellenius (1996) showed, the reading competence of children with low vision is related to interest in reading. Future research should focus on the question which amount of reading practice is sufficient to develop literacy skills in children with low vision without being that much a burden that children loose interest in reading. A second focus should be on physical aids that can facilitate the visual process of reading.

In this study, we did not find much difference in reading skills between subgroups of children with low vision. Contrary to the beliefs of teachers of children with low vision and to the findings of Fulcher, O'Keefe, Bowell, Lanigan, Burke, Carr, O'Rourke, and Bolger (1995), we did not find that children with albinism are poorer readers than other children with low vision. The only difference we found was between children with visual field restrictions and other children with low vision. Children with visual field restrictions are poorer readers than other children with low vision. Our results are in line with the findings of van Bon et al. (2000). We conclude that among visual factors, the only one that has an exceptional detrimental effect on reading is the presence of a visual field restriction. As the results of the studies in Chapter 4 and 5 show, we did not succeed, however, in determining qualitative differences between the reading strategies of children with visual field restrictions and other children with low vision. This topic should be taken up in future research.

This study yielded several factors that should be taken into account in the education of children with low vision. First, because the visual input restriction proved to be the crucial factor that hinders the reading of children with low vision, the visual input should be optimized and adapted to the specific needs of a child. Second, children with low vision need to get ample time for every task that involves reading, including tests and exams. If this extra time is difficult to supply, the use of auditory aids should be considered. Third, children with visual field restrictions might need extra attention, for they seem to be more at risk to develop reading problems than other children with low vision. Fourth, to compensate for poor decoding skills, children with low vision seem to make efficient use of supporting resources, like contextual information and analogy to well known words. As far as teachers do not already do so, they should encourage children to apply these kind of compensating strategies. Fifth, reading exercises that focus on the importance of letter order should have more attention in the literacy education of children with low vision.

An overall conclusion of this thesis is that low vision does not necessarily imply low literacy skills. Literacy-related language skills develop normally, in spite of a poor and slow visual input and less frequent reading experience. With the necessary visual adaptations, the existing reading and spelling methods for sighted children can be used in the education of children with low vision. These conclusions apply to children with low vision in general; we found no single eye anomaly that inevitably leads to reading problems.

References

Arter, C., & Mason, H. (1994). Spelling for the visually impaired child. *The British Journal of Visual Impairment, 12,* 18-21.

Corley, G., & Pring, L. (1993). The spelling competence of partially sighted children. *The British Journal of Visual Impairment, 11,* 105-108.

Daugherty, K. M., & Moran, M. F. (1982). Neuropsychological, learning, and developmental characteristics of the low vision child. *Visual Impairment and Blindness, 76,* 398-406.

Fellenius, K. (1996). Reading Competence of Visually Impaired Pupils in Sweden. Journal of Visual Impairment and Blindness, 90, 237-246.

Fulcher, T, O'Keefe, M., Bowell, R., Lanigan, B., Burke, T., Carr, A., O'Rourke, M., & Bolger, M. (1995). Intellectual and educational attainment in albinism. Journal of Pediatric Ophthalmology and Strabismus, 32, 368-372.

Koenen, M., Bosman, A. M. T., & Gompel, M. (2000). Kijk eens hoe ik lees; Een onderzoek naar het leesgedrag van slechtziende en normaalziende kinderen [Watch me reading; A study into the reading behavior of children with low vision and normally sighted children]. *Tijdschrift voor Orthopedagogiek, 39,* 95-106.

Mann, V. A. (1991). Language problems: a key to early reading problems. In: Wong, B. Y. L. (Ed.), *Learning about Learning Disabilities* (pp. 129-162). San Diego, CA: Academic Press.

Mann, V. A., Cowin, E., & Schoenheimer, J. (1989). Phonological processing, language comprehension, and reading ability. *Journal of Learning Disabilities, 22,* 76-89.

Shankweiler, D., Lundquist, E., Katz, L., Stuebing, K. K., Fletcher, M., Brady, S., Fowler, A., Dreyer, L. G., Marchione, K. E., Shaywitz, S.E., & Shaywitz, B. A. (1999). Comprehension and decoding: patterns of association in children with reading difficulties. *Scientific Studies of Reading, 3,* 69-94.

Stanovich, K. E. (1988). Explaining the differences between the dyslexic and the garden-variety poor reader: the phonological-core variable-difference model. *Journal of Learning Disabilities, 21,* 590-603.

van Bon, W. H. J., Adriaansen, L., Gompel, M., & Kouwenberg, I. (2000). The reading and spelling performance of visually impaired Dutch elementary schoolchildren. *Visual Impairment Research 2* (1), 17-31.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 10,* 192-212.

Appendix A

Explanation of ophthalmological terms used in this thesis

Age related macula degeneration (AMD)	A degenerative condition of the macula (the central retina). It is the most common cause of vision loss in people over 50 years old. AMD is caused by hardening of the arteries that nourish the retina. This deprives the sensitive retinal tissue of oxygen and nutrients that it needs to function and thrive. As a result, the central vision deteriorates.
Albinism	A lack of pigment, either in the eye alone (ocular albinism), or in the eye, skin, and hair (oculocutane albinism). This lack of pigment in the eyes causes an underdevelopment of the fovea, which leads to decreased visual acuity and nystagmus.
Amaurosis congenita Leber	Leber's Congenital Amaurosis (LCA) is a rare genetic eye disorder. It is a specific form of retinitis pigmentosa. Affected infants are often blind at birth or lose their sight within the first few of years of life. Other symptoms may include nystagmus and photophobia.
Aniridia	Congenital partial or total absence of the iris. It is often accompanied by macular hypoplasia. Children with aniridia have a decreased visual acuity, nystagmus and photophobia.
Atrophy of the optic nerve	Optic nerve atrophy involves tissue death of the nerve that carries the information of vision from the eye to the brain. Optic nerve atrophy causes diminished visual acuity and reduction of the field of vision. Also color vision can be impaired.

Bardet Biedl syndrome

A complex disorder that affects many parts of the body including the retina. Individuals with Bardet-Biedl syndrome have a retinal degeneration similar to retinitis pigmentosa (RP). The first symptom of RP is night blindness. RP then causes progressive loss of peripheral (side) vision. Individuals with Bardet-Biedl syndrome also experience central vision loss during childhood or adolescence. RP symptoms progress rapidly and usually lead to severe visual impairment by early adulthood. In addition to RP, polydactyly (extra fingers and/or toes) and obesity are defining characteristics of Bardet-Biedl syndrome. Approximately half of all individuals with Bardet-Biedl syndrome experience developmental disabilities ranging from mildly impaired or delayed emotional development to mental retardation. The degree of mental retardation can range from mild cognitive disabilities to severe mental retardation.

Cataract

A cataract is a partial or total clouding of the lens of the eyes.

Choroid

The choroid lies between the retina and sclera. It is composed of layers of blood vessels that nourish the back of the eye.

Coloboma

A coloboma is a gap in part of the structures of the eye. This gap can occur in a range of areas and be large or small.
The most common form of gap is caused by an imperfect closure of a cleft, present in the womb but usually closed by birth date. This gap can occur in the eyelid, iris, lens, choroid, retina, or optic disc.
The effects of the condition can be quite mild or cause more visual problems if the back of the eye is affected. This will depend upon the extent and location of the gap, or incomplete closure.
In some cases, the eye may be reduced in size. This condition is called Microphthalmous, a condition which may arise without coloboma.
Coloboma of the iris may sometimes give the appearance of a keyhole in the pupil.
Central vision may be affected and may reflect the extent, location and shape of the gap.

Cone cells

A type of photoreceptor cells. Although cones are present throughout the retina, they densely populate the macula, the central portion of the retina. Cone cells are particularly important for color vision and discriminating fine visual detail.

Cornea

The cornea is the transparent, dome-shaped window covering the front of the eye. It is a powerful refracting surface, providing 2/3 of the eye’s focusing power.

Glaucoma

An increased intra-ocular pressure that causes damage to the optic nerve, which leads to progressive visual field loss.

Macula	The central portion of the retina. The macula contains a dense concentration of cone photoreceptor cells that help us see fine visual detail and color vision.
Microphthalmus	A disorder in which one or both eyes are abnormally small. This can lead to secondary problems, such as glaucoma.
Myopia	A refractive error also known as near-sightedness. Myopia, occurs when light entering the eye focuses in front of the retina instead of directly on it. This is caused by a cornea that is steeper, or an eye that is longer, than a normal eye.
Nystagmus	Involuntary, rapid movement of the eyes, up and down, side to side or rotational. Nystagmus can be a congenital motor problem or can be associated with other ocular problems.
Oculomotor apraxia	Ocular Motor Apraxia (OMA) is a visual condition where a child or person has difficulty in controlling horizontal eye movements.
Photophobia	Sensitivity to light.

Retina	The retina is a thin tissue at the back of the eye that contains several cell types that are similar to brain cells since they are all neurons. The cell types include photoreceptor neurons (rods and cones) and other types of neurons. The photoreceptor cells of the retina absorb light and convert this light to electrical signals. The electrical signals are transferred from the photoreceptors to secondary neurons, which then send the electrical signals to the visual cortex region of the brain for interpretation. The brain and retina constitute the Central Nervous System of the body.
Retinitis Pigmentosa (RP)	Retinitis pigmentosa, or progressive rod-cone dystrophy causes the progressive loss of photoreceptor cells in the retina. Patients have decreased peripheral vision, night blindness, and eventual total loss of vision can occur.
Retinoblastoma	Retinoblastoma is a tumor of the retina, and occurs in early childhood. There are both hereditary and non-hereditary forms of retinoblastoma. In the hereditary form, usually multiple tumors are found in both eyes, while in the non-hereditary form only one eye is affected and by only one tumor.
Retinopathy of prematurity (ROP)	Failure of the retinal blood supply to develop properly, seen in infants who are small at birth and require oxygen therapy. ROP is classified in 5 stages, depending on the extent of the disease. Progression of the disease to later stages can lead to the formation of scar tissue in the retina and complications such as: retinal detachment, vitreous hemorrhage, strabismus, and amblyopia. Many children with ROP develop nearsightedness.

Retinoschisis	Splitting of the retina into two layers. Juvenile retinoschisis usually affects the macula (central retina), visual acuity is typically reduced. There is often slow progression of the disorder until about 20 years of age. Thereafter, the condition is usually stable and most patients retain vision of approximately 20/70. Retinoschisis only affects boys.
Rod cells	A type of photoreceptor cell that is located throughout the retina but is more common outside of the central macular region of the retina, i.e. the periphery of the retina. The rod cell is particularly important for night vision, black and white vision, and side or peripheral vision. Rod cell loss leads to loss of peripheral vision (i.e., tunnel vision).
Stickler syndrome	Stickler syndrome is an inherited disease characterized by progressive arthropathy, high myopia, retinal detachment, degenerative joint changes, epiphyseal dysplasia, flat midface, and heart defects.Within a family, a great variability in expression of the syndrome can occur.
Strabismus	A problem caused by one or more improperly functioning eye muscles, resulting in a misalignment (squinting) of the eyes.
Tapetoretinal dystrophy (TRD)	Hereditary disorder of the retina mainly affecting photoreceptors and retinal pigment epithelium.

Summary

In the Netherlands, children are legally considered visually impaired if their functional vision is less than 3/10 and/or their visual field is less than 30^o. According to these criteria, 0.1 to 0.2 percent of the Dutch children are visually impaired. The causes of their visual impairment are very diverse, as are the consequences. Besides visually impaired children who are totally blind, there are also children who have low vision. Most of these children with low vision are able to read print and are not dependent on Braille reading. However, teachers of children with low vision often report that these students do not reach a reading level comparable to that of sighted children. There appear to be children with low vision, however, who are good or even excellent readers. These impressions raise the question how the reading skills of these chilren compare to those of their sighted peers, and which factors determine the variation in reading ability of children with low vision. Because reading and spelling ability are often related, we also were interested in their spelling performance. Answering these questions will add to the knowledge of the literacy performance and development of children with low vision in the age range of primary education.

In the study reported in Chapter 2, the central question was to what extent the development of reading and spelling skills of children with low vision differs from that of their sighted peers. Standardized tests for word decoding, reading comprehension and spelling were administered to a little over 400 children with low vision (which is about two third of the population of interest). The scores of the children with low vision were compared to the scores of a norm sample of sighted children.

The results of this study showed that on average children with low vision are behind in reading and spelling skills compared to sighted children. This conclusion, however, needs some qualification. A difference was found between children with low vision in regular primary schools and children with low vision in special schools (these were special schools for the visually impaired as well as other special schools). Children with low vision in special schools were behind in all aspects of literacy we studied (word decoding, reading comprehension and spelling), whereas children in regular schools were only behind in word decoding. Moreover, the children with low vision in special schools were more behind their sighted peers in decoding skills than were the children with low vision in regular schools. Subsequent analyses showed that the mean visual acuity means of the two groups of children with low vision appeared not to differ from each other. From information acquired through questionnaires it was found that the difference between children with low vision in the two school types was in general cognitive ability and in the prevalence of additional disorders, like hearing disabilities, learning disorders and behavior problems.

From these findings, it was concluded that spelling and reading comprehension are not affected by visual impairments, but word decoding is. Because there was a large number of children with low vision with extremely poor decoding skills who had excellent spelling and comprehension skills, it was further concluded that, for children with low vision, good decoding performance is not a prerequisite for good reading comprehension and spelling.

Because the population of children with low vision is very heterogeneous with respect to the causes and consequences of their eye anomalies, we also studied the impact of several different eye anomalies on literacy. To investigate this, the scores on the tests of several subgroups of children with low vision were compared. The only difference we found was between children with a visual field restriction and children with intact visual fields. On average, children with a visual field restriction were poorer decoders than were other children with low vision.

A first practical implication of the study reported in Chapter 2 is that teachers should be aware of the relatively high prevalence of additional disorders (such as learning disabilities) in children with low vision. Although it might be difficult to discriminate between reading difficulties that are a direct result of low vision and those that are not related to the eye condition, it is important to examine this carefully, so that remediating or compensating arrangements can be adapted to the specific needs of children.

A second implication comes from the result that children with visual field restrictions are at a higher risk to develop word decoding problems. These children might therefore need extra or different support in the education of literacy from the start on.

The findings of the study reported in Chapter 2 show that children with low vision, but no additional disorders, are not behind in spelling attainment. This seems to implicate that children with low vision, despite poorer decoding skills, have developed sufficient orthographic knowledge. Still they have word decoding problems. The main question of Chapter 3 is whether the word decoding problems of children with low vision are entirely explained by the degraded visual input, or whether there are other factors that cause these decoding problems. To investigate this, children with low vision and sighted children were presented with words, small line drawings and drawings of large geometrical shapes in three naming experiments. Naming words and naming small line drawings have two factors in common: visual recognition and naming speed. A difference between both tasks is that naming words requires orthographic knowledge, whereas naming pictures does not. Because of the size and simplicity of the large geometrical shapes, visual recognition of these shapes is not likely to be the discriminating factor between children with low vision and sighted children. If both groups of children differ from each other on this task, this must be representing a difference in naming speed.

The results of this study showed no difference between the groups in naming speed on the large geometrical shapes. This indicates that problems with rapid naming are not a cause of the poorer decoding skills of children with low vision. On both the word naming task and the naming task with the small line drawings, children with low vision had higher naming times than did sighted children. However, if naming speed on the line drawings was entered as a covariate, no difference was found between children with low vision and sighted children in word naming speed. This result indicates that the slower reading speed of children with low vision can be explained entirely by their slower identification of the small line drawings. Since both tasks have only visual recognition and naming speed in common, and the results of the task with large geometrical shapes show no difference in naming speed between the two groups, it was concluded that the visual input constraint is a sufficient explanation for the poorer decoding skills of children with low vision. The reading difficulties of children with low vision do not seem to result from any linguistic shortcoming.

A second question that was investigated in Chapter 3 was whether the poorer decoding skills of children with low vision were a result of a lower reading speed, a less accurate reading strategy, or a combination of both. This question was studied by comparing the error percentages of children with low vision and sighted children on the word naming task. No difference in error percentages between both groups was found. This indicates that children with low vision do not read less accurately than sighted children do, they only read more slowly.

Because the results of this study show that visual input is the only factor that decreases the word decoding speed of children with low vision, one may argue that lower decoding speed performances of children with low vision should not be considered and treated as a learning difficulty to be remediated by practicing orthography. To improve the reading of children with low vision, one should rather focus on adapting the visual input to the specific needs of the individual child with low vision.

Chapter 4 is concerned with text reading and understanding. Although the results of the study reported in Chapter 2 already showed that children with low vision comprehend texts just as well as sighted children do, time-on-task was not taken into account in that study. In the study reported in Chapter 4, we investigated whether children with low vision need more time to read and understand texts than do sighted children, and whether this difference between children with low vision and sighted children is larger than the difference in reading isolated words. A second question of this study was whether children with low vision compensate for their poorer decoding skills by a higher reliance on contextual information.

In the first experiment of this study, we compared scores and time needed of children with low vision and sighted children on a word reading task and on a reading comprehension task. The results of this experiment were in accordance with the findings reported in Chapter 2, with respect to the comprehension skills of the children. No difference was found between the scores on the reading comprehension task of both groups of children. The children with low vision, however, needed more time (about one and a half to two times as much) for reading and comprehending a text than did the sighted children. Moreover, this difference in time needed is larger than the difference we found between these groups in the word reading task.

The second experiment of this study was a word naming task, in which words were presented either with or without a meaningful context. The results of this experiment showed that all children read words presented with a meaningful context faster than words without a meaningful context. The facilitating effect of context, however, was larger for the children with low vision.

The results of this study show that, despite the facilitating effect of contextual information, the reading of text is more time demanding for children with low vision than the reading of isolated words is. For the education of children with low vision these results mean that teachers should give children with low vision ample time to study texts and for completing tests. If it is not possible to give extra time, teachers might consider the use of auditory aids, like spoken books or text-to-speech computer software. When given enough time, children with low vision comprehend understand what they read just as well as sighted children do.

The study reported in Chapter 5 is about word decoding again, and consists of two word naming experiments that addressed three aspects of word characteristics. In the first experiment, we investigated the visual processing and recognition of words, and the strategy used in word identification. In the second experiment, the processing of the information of letter order the topic of concern.

The visual recognition of words was studied in the first experiment by presenting children with nonwords, that were derived from existing words by changing one letter. We manipulated three word characteristics in this experiment: word length, visual similarity of the substituted letter with the replacing letter, and position of the substituted letter. The results showed that the effects of visual similarity and place of substitution on word naming speed in children with low vision did not differ from those in sighted children. The effect of word length was different for both groups of children. Children with low vision needed more time to read long words than to read short words. This difference was not found in sighted children of the same age, but was found in younger sighted children of the same reading level as the children with low vision. Our conclusion was that the visual characteristics manipulated in this experiment did not have a specific effect on the word recognition of children with low vision. The longer reading times we found in children with low vision on long words are more likely a consequence of the reading level of these children than a consequence of the visual impairment.

In this same experiment we also manipulated the frequency of the orthographic neighbors (the existing words the nonwords were derived from). It was found that the effect of the frequency of the orthographic neighbor was different for children with low vision than for sighted children. In children with low vision a high frequency neighbor had a facilitating effect on the naming speed on the nonwords. Such an effect was not found in sighted children (both of the same age and of the same reading level). This result is an indication that, in addition to a strategy based on grapheme/phoneme conversion rules, children with low vision also apply an analogy based reading strategy.

To study the processing of letter order information, in the second word naming experiment reported in Chapter 5, two types of words were presented: words in which the constituent letters can form one or more other words (anagrams), and words of which the constituent letters can form no other word (unique words). We found that children with low vision needed more time to read anagrams than to read unique words. This effect was not found in sighted children, which shows that children with low vision have more problems with letter order than do sighted children. Probably this effect can be explained by the fact that children with low vision need more time to identify the single letters in a word and consequently have to keep the identified letters longer in working memory. This might interfere with keeping track of the position of the letters they identified.

We expected this letter order effect also because some children with low vision have scotomas (blind spots). Children with central scotomas need to make more regressions while reading, because some letters of a word fall at the retina on the place of a scotoma and thus are not visible in a single fixation. However, an analysis in which the reading times of children with scotomas were compared to those of other children with low vision, showed that the effect of letter order was not different for both groups of children.

As we have seen in the first nonword reading experiment of this chapter, similarity on the one hand seems to help children with low vision to read words faster, when letter identity is the discriminating factor between one or more words. On the other hand, similarity can hinder the reading speed of these children when the letter order is the factor that makes the difference between two or more words. It seems as if children with low vision are aware of the necessity to cautiously identify the individual letters of a word, but are less aware of the importance of letter order. In order to overcome problems with letter order, teachers may help children to apply strategies, such as following words in the text and letters in the words with the finger or a ruler.

Although low vision obviously is a condition that hampers reading, a positive conclusion is drawn from the results of the studies in this thesis. Children with low vision, but no additional disorders do show lower achievement in reading comprehension, spelling and reading accuracy. The only problem they seem to have is with the reading speed. As long as they are given enough time, their reading skills are comparable with those of sighted children. This speed problem can be attributed solely to the decreased visual input. Despite the fact that these children read on average less often and on a lower level than do sighted children, the development of orthographic knowledge and other linguistic skills seems not to be affected. Remediation and compensation should thus focus on an optimal adaptation of the visual input.

A less positive finding is that a relatively large number of children with low vision have additional disorders like other physical disorders, learning disabilities, behavior problems or a lower general cognitive ability. This implies that it is important to be alert to the possibility of any additional disorders. In case of reading problems, one should carefully examine other possible causes before concluding that the reading problems are a direct consequence of the low vision.

Samenvatting

In Nederland ben je visueel beperkt als je functionele visus minder dan 3/10 is en/of als je gezichtsveld kleiner is dan 30°. Volgens deze criteria heeft ongeveer 0.1 tot 0.2 procent van de Nederlandse kinderen een visuele beperking. De oorzaken van de visuele handicap kunnen zeer divers zijn, evenals de gevolgen. Naast blinde kinderen, zijn er ook kinderen die slechtziend zijn. De meeste van die slechtziende kinderen zijn in staat zwartdruk te lezen en zijn dus niet op braille aangewezen. Wel wordt door leerkrachten van slechtziende kinderen vaak gezegd dat hun leerlingen over het algemeen niet tot hetzelfde leesniveau komen als hun normaalziende leeftijdgenoten. Er zijn echter ook slechtziende kinderen die goed of zelfs uitstekend lezen. Deze indrukken uit de praktijk hebben de vraag opgeworpen welke factoren de variatie in leesvaardigheid bepalen bij slechtziende kinderen. Omdat lezen en spellen vaardigheden zijn die met elkaar in verband staan, waren we ook geïnteresseerd in de spellingvaardigheid van slechtziende kinderen. Het doel van de onderzoeken die beschreven zijn in dit proefschrift was een bijdrage te leveren aan de kennis over de geletterdheid van slechtziende kinderen in de basisschoolleeftijd.

In het onderzoek dat beschreven staat in hoofdstuk 2, was de centrale vraag of en in welke mate de ontwikkeling van lees- en spellingvaardigheid van slechtziende kinderen afwijkt van die van hun normaalziende leeftijdsgenoten. In dit onderzoek zijn met betrekking tot lezen zowel decodeervaardigheden als leesbegrip onderzocht. Bij iets meer dan 400 slechtziende kinderen (dit is ongeveer twee derde van de populatie) zijn gestandaardiseerde tests voor technisch lezen, begrijpend lezen en spellen afgenomen. De scores van de slechtziende kinderen zijn vergeleken met de scores van een normgroep van normaalziende kinderen.

De resultaten van dit onderzoek toonden aan dat slechtziende kinderen gemiddeld minder goed lezen en spellen dan hun normaalziende leeftijdsgenoten. Nadere specificatie van dit resultaat toonde echter aan dat er een verschil is tussen slechtziende kinderen in het reguliere basisonderwijs en slechtziende kinderen in het speciaal onderwijs (zowel het speciaal onderwijs voor visueel gehandicapten als ander speciaal onderwijs). Slechtziende kinderen in het speciaal onderwijs bleken achter te lopen op alle aspecten van de geletterdheid die hier onderzocht zijn (decoderen, begrijpend lezen en spellen), terwijl de slechtziende kinderen in het reguliere onderwijs slechts achterliepen in het decoderen. Bovendien was de achterstand in decodeervaardigheid ten opzichte van normaalziende kinderen groter bij de slechtziende kinderen in het speciaal onderwijs dan bij de slechtziende kinderen in het reguliere onderwijs. De gemiddelde gezichtsscherpte van de twee groepen slechtziende kinderen bleek niet te verschillen. Wel is een verschil tussen de twee groepen slechtziende kinderen gevonden in algemene intelligentie en in de prevalentie van bijkomende stoornissen, zoals gehoorstoornissen en leer- en gedragsstoornissen.

De conclusie op grond van deze resultaten was dat slechtziendheid geen directe gevolgen heeft voor het leesbegrip en de spellingvaardigheid, maar wel voor de technische leesvaardigheid. Omdat er een aanzienlijk aantal slechtziende kinderen was met een zeer zwakke technische leesvaardigheid, maar uitstekende begripsvaardigheid was een volgende conclusie dat een goede technische leesvaardigheid voor slechtziende kinderen blijkbaar geen voorwaarde is voor een goed leesbegrip, mits de slechtziende kinderen voldoende tijd krijgen.

Omdat de populatie van slechtziende kinderen zeer heterogeen is met betrekking tot de oorzaken en de gevolgen van hun oogafwijkingen, is ook onderzocht wat de invloed van een aantal veel voorkomende oogafwijkingen is op de geletterdheid. Om dit te onderzoeken zijn de scores op de testen van subgroepen van slechtziende kinderen met elkaar vergeleken. Het enige verschil dat is gevonden is tussen slechtziende kinderen met een gezichtsveldbeperking en slechtziende kinderen met een intact visueel veld. De kinderen met een gezichtsveldbeperking waren gemiddeld zwakker in technisch lezen dan de kinderen zonder gezichtsveldbeperking.

Een eerste praktische implicatie van het onderzoek dat beschreven is in hoofdstuk 2 is dat leerkrachten zich realiseren dat er bij slechtziende kinderen relatief vaak sprake is van bijkomende stoornissen (zoals bijvoorbeeld leerstoornissen). Hoewel het moeilijk kan zijn een onderscheid te maken tussen leesproblemen die een direct gevolg zijn van de slechtziendheid en leesproblemen die daar los van staan, is het belangrijk dit nauwgezet te onderzoeken, zodat de remediërende of compenserende maatregelen afgestemd kunnen worden op de individuele behoeften van een leerling.

Een tweede implicatie komt voort uit de bevinding dat kinderen met een gezichtsveldbeperking een hoger risico lopen leesproblemen te ontwikkelen. Mogelijk zouden deze kinderen van het begin af aan extra of andere begeleiding nodig hebben bij het leesonderwijs.

De resultaten van het onderzoek dat beschreven is in hoofdstuk 2 laten zien dat slechtziende kinderen die geen bijkomende stoornisssen hebben gemiddeld niet achter zijn op het gebied van spelling. Dit lijkt te impliceren dat slechtziende kinderen, ondanks een zwakkere technische leesvaardigheid, voldoende orthografische kennis ontwikkelen.

De centrale vraag in hoofdstuk 3 is of het relatief lage technische leesniveau van slechtziende kinderen geheel verklaard kan worden door een verstoorde invoer of dat er ook andere factoren zijn die de decodeerproblemen kunnen verklaren. Om dit te onderzoeken is een benoemingsexperiment uitgevoerd waarin een groep slechtziende kinderen en een groep normaalziende kinderen woorden, kleine lijntekeningen en tekeningen van grote geometrische figuren aangeboden kregen. Het benoemen van woorden en van kleine tekeningen doen beiden een beroep of twee vaardigheden: visuele herkenning en benoemsnelheid. Een verschil tussen deze twee taken is dat bij het woordbenoemen orthografische kennis wel een rol speelt en bij het benoemen van tekeningen niet. Bij de taak van het benoemen van grote geometrische figuren kan de visuele herkenning geen discriminerende factor zijn tussen de slechtziende en de normaalziende kinderen, omdat de figuren dermate groot en simpel waren dat ze voor elk slechtziend kind goed te onderscheiden waren. Als er een verschil in responstijd tussen de twee groepen gevonden zou zijn op deze taak, zou dit wijzen op een verschil in benoemingssnelheid.

De resultaten van dit onderzoek laten zien dat de slechtziende kinderen niet van normaalziende kinderen verschillen in de snelheid van het benoemen van de grote geometrische figuren. Dit wijst er op dat problemen met snel benoemen geen oorzaak zijn van de zwakkere decodeervaardigheden van slechtziende kinderen. Op zowel de woordbenoemingstaak als de benoemingstaak met de kleine lijntekeningen hadden de slechtziende kinderen hogere benoemingstijden dan de normaalziende kinderen. Als het verschil in benoemingssnelheid op de lijntekeningen echter als covariaat werd ingevoerd in de analyse op de benoemingssnelheid op de woorden, was het verschil tussen slechtziende en normaalziende kinderen in woordbenoemingssnelheid verdwenen. Dit resultaat wijst erop dat de hogere benoemingstijd die slechtziende kinderen hebben op de woorden volledig verklaard kan worden door de hogere benoemingstijd op de lijntekeningen. Omdat de beide taken slechts visuele herkenning en benoemingssnelheid als gemeenschappelijke factor hebben, en omdat uit de resultaten van de taak met de geometrische figuren geen verschil tussen de twee groepen is gebleken, is de conclusie dat de verstoorde visuele invoer een afdoende verklaring is voor de zwakkere decodeervaardigheden van slechtziende kinderen. De leesproblemen van slechtziende kinderen lijken dus niet veroorzaakt te worden door linguïstische tekortkomingen.

Een tweede vraag die onderzocht is in hoofdstuk 3 is of de zwakkere decodeervaardigheid van slechtziende kinderen voornamelijk gekenmerkt wordt door een lager tempo, door een groter aantal fouten of door een combinatie van beiden. Dit is onderzocht door de foutenpercentages op de woordbenoemingstaak van de slechtziende en de normaalziende kinderen met elkaar te vergelijken. Er is geen verschil gevonden tussen de foutenpercentages van beide groepen. Dit betekent dat slechtziende kinderen niet minder accuraat lezen dan normaalziende kinderen, zij lezen slechts langzamer.

Omdat de resultaten van dit onderzoek aantonen dat de visuele invoerbeperking de enige factor is die de leessnelheid van slechtziende kinderen negatief beïnvloedt, kan men stellen dat de lagere leessnelheid van slechtziende kinderen niet beschouwd moet worden als een leerprobleem dat behandeld kan worden door het oefenen met de orthografie. Om de leessnelheid van slechtziende kinderen te verbeteren zou men zich moeten richten op de aanpassing van de visuele invoer aan de specifieke behoeften van het individuele slechtziende kind.

hoofdstuk 4 heeft betrekking op het lezen en begrijpen van teksten. Hoewel in hoofdstuk 2 al is aangetoond dat slechtziende kinderen geen problemen hebben met tekstbegrip, was in die studie geen rekening gehouden met de tijd die de kinderen nodig hadden om een tekst te lezen en te begrijpen. De eerste vraag van het onderzoek dat beschreven staat in hoofdstuk 4 is of slechtziende kinderen meer tijd nodig hebben voor het lezen en begrijpen van teksten dan normaalziende kinderen en of dit verschil tussen die kinderen groter is dan het verschil bij het lezen van losse woorden. De tweede vraag van dit onderzoek was of slechtziende kinderen meer gebruik maken van contextuele informatie ter compensatie van de zwakkere decodeervaardigheden.

In het eerste experiment van dit onderzoek, hebben we de scores en de leestijd van slechtziende kinderen vergeleken met die van normaalziende kinderen op een woordleestaak en op een leesbegriptaak. Overeenkomstig de resultaten die vermeld zijn in hoofdstuk 2, zijn ook hier geen verschillen tussen de twee groepen kinderen gevonden in scores op de leesbegriptaak. De slechtziende kinderen hadden echter wel meer tijd nodig voor het lezen en begrijpen van een tekst dan de normaalziende kinderen. Bovendien was dit verschil tussen de groepen in benodigde tijd groter dan het verschil dat we hebben gevonden op de woordleestaak.

Het tweede experiment van deze studie bestond uit een woordbenoemingstaak, waarin woorden met of zonder een betekenisvolle context werden aangeboden. Uit de resultaten bleek dat alle kinderen woorden die aangeboden werden met een betekenisvolle context sneller lazen dan woorden zonder betekenisvolle context. Dit faciliterende effect was echter groter bij de slechtziende kinderen dan bij hun normaalziende leeftijdgenoten.

De resultaten van dit onderzoek wijzen erop dat, ondanks het faciliterende effect van contextuele informatie, het lezen van tekst slechtziende kinderen relatief meer tijd kost dan het lezen van losse woorden. Voor het onderwijs aan slechtziende kinderen betekenen deze resultaten dat leerkrachten deze kinderen voldoende tijd moeten geven voor het maken van tests en het bestuderen van teksten. Als deze tijd niet beschikbaar is, zou het gebruik van auditieve hulpmiddelen, zoals gesproken boeken en tekst-naar-spraak software overwogen kunnen worden. Als zij maar genoeg tijd krijgen, begrijpen slechtziende kinderen teksten net zo goed als normaalziende kinderen.

Het onderzoek dat beschreven staat in hoofdstuk 5 heeft opnieuw het lezen van losse woorden als onderwerp. In dit onderzoek werden in twee woordbenoemings-experimenten drie aspecten van woordidentificatie onderzocht. In het eerste experiment zijn de visuele verwerking en herkenning van woorden en de strategie die daarbij gebruikt wordt onderzocht. In het tweede experiment is de verwerking van de informatie over de lettervolgorde onderzocht.

De visuele woordherkenning is in het eerste experiment onderzocht door nonwoorden aan te bieden die van bestaande woorden waren afgeleid door het vervangen van een letter. Drie kenmerken van de nonwoorden waren in dit experiment gemanipuleerd: woordlengte, visuele gelijkenis van de vervangende letter met de oorspronkelijke letter en de positie in het woord van de vervangen letter. Uit de resultaten bleek dat de effecten van visuele gelijkenis en positie van substitutie niet verschilden tussen slechtziende en normaalziende kinderen. Het effect van woordlengte was echter wel verschillend voor slechtziende en normaalziende kinderen. Slechtziende kinderen hadden meer tijd nodig voor het lezen van lange woorden dan voor het lezen van korte woorden. Dit verschil werd niet gevonden bij de normaalziende kinderen van dezelfde leeftijd, maar wel bij de jongere normaalziende kinderen van hetzelfde leesniveau als de slechtziende kinderen. Onze conclusie was dat de visuele kenmerken die in dit experiment onderzocht zijn geen specifiek effect hebben op de woordherkenning van slechtziende kinderen. De langere opleestijden op lange woorden die we vonden bij de slechtziende kinderen lijkt eerder een gevolg van het leesniveau van die kinderen dan een gevolg van hun visuele beperking.

In ditzelfde experiment is ook de frequentie van de orthografische buren (de bestaande woorden waar de nonwoorden van zijn afgeleid) van de nonwoorden gemanipuleerd. Uit de resultaten bleek dat het effect van de frequentie van de orthografische buur op de benoemingssnelheid verschillend was voor slechtziende kinderen en normaalziende kinderen. Slechtziende kinderen benoemden nonwoorden met een hoogfrequente buur sneller dan nonwoorden met een laagfrequente buur. Dit effect is noch bij de normaalziende kinderen van dezelfde leeftijd gevonden, noch bij de normaalziende kinderen van hetzelfde leesniveau. Dit resultaat lijkt erop te wijzen dat slechtziende kinderen bij het lezen van losse woorden, naast een strategie die gebaseerd is op grafeem/foneem conversieregels, ook gebruik maken van een strategie die gebaseerd is op de analogie tussen woorden.

Om de verwerking van lettervolgorde-informatie te onderzoeken zijn in het tweede experiment twee typen woorden aangeboden: woorden waarvan de letters in een andere volgorde een ander woord kunnen vormen (anagrammen) en woorden waarvan de letters in geen enkele andere volgorde een bestaand woord kunnen vormen (unieke woorden). Het bleek dat de slechtziende kinderen de anagrammen langzamer lazen dan de unieke woorden. Bij de normaalziende kinderen is dit effect niet gevonden. Dit resultaat wijst erop dat slechtziende kinderen meer moeite hebben met het verwerken van de lettervolgorde-informatie dan normaalziende kinderen. Dit effect kan mogelijk verklaard doordat slechtziende kinderen meer tijd nodig hebben voor het identificeren van de individuele letters van een woord. Hierdoor moeten zij de geïdentificeerde letters langer in het werkgeheugen vasthouden, waardoor de volgorde-informatie mogelijk in het gedrang komt. Bij de opzet van dit experiment was het gevonden volgorde-effect ook verwacht omdat sommige slechtziende kinderen centrale scotomen hebben. Kinderen met centrale scotomen moeten meer regressies maken bij het lezen, omdat de letters van een woord precies daar op het netvlies vallen waar zich een scotoom bevindt, daardoor zijn deze letters dus niet zichtbaar in een enkele fixatie. Echter, een analyse waarin de opleestijden van kinderen met scotomen was vergeleken met die van andere slechtziende kinderen toonde geen verschillen aan tussen beide groepen kinderen.

Aan de ene kant blijkt uit de resultaten dat het lezen van slechtziende kinderen gefaciliteerd wordt door analogieën. Dit is het geval wanneer de letters in een woord op één na hetzelfde zijn als de letters in een ander, bekend, woord (zoals in het eerste experiment). Aan de andere kant lijkt analogie de leessnelheid ook te hinderen. Dit is het geval bij woorden die dezelfde letters hebben als een ander woord, maar in een andere volgorde (zoals in het tweede experiment). Het lijkt erop dat slechtziende kinderen zich bewust zijn van het belang de afzonderlijke letters van een woord te identificeren, maar minder van het belang van de volgorde van die letters. Leerkrachten zouden deze kinderen kunnen helpen door hen aan te moedigen bij het lezen de woorden en de letters binnen de woorden te volgen met de vinger of een lineaal.

De conclusies die uit de resultaten van alle onderzoeken in dit proefschrift worden getrokken zijn redelijk positief. Slechtziende kinderen met geen andere beperkingen dan hun slechtziendheid hebben geen problemen met leesbegrip, spelling en accuratesse. Het enige probleem dat deze kinderen lijken te hebben bij het lezen is een tempoprobleem. Zolang deze kinderen genoeg tijd krijgen, is hun leesvaardigheid vergelijkbaar met die van normaalziende kinderen. Dit tempoprobleem kan volledig toegeschreven worden aan de beperkte visuele invoer. Ondanks het feit dat deze kinderen gemiddeld minder vaak en op een lager niveau lezen dan normaalziende kinderen, lijkt de ontwikkeling van orthografische kennis en andere linguïstische vaardigheden niet aangetast. Naast het geven van extra tijd, zouden remediatie en compensatie dan ook zoveel mogelijk gericht moeten zijn op een optimale aanpassing van de visuele invoer bijvoorbeeld door middel van een op de visuele beperking aangepast hulpmiddel of vergroting van de tekst.

Een minder positieve bevinding is dat bij een relatief groot aantal slechtziende kinderen bijkomende stoornissen of beperkingen, zoals andere fysieke beperkingen, leerstoornissen, aandachtsstoornissen en een lager algemeen cognitief niveau een oorzaak kunnen zijn van leesproblemen. Voor de praktijk betekent dit dat het belangrijk is hier alert op te zijn en goed te onderzoeken waar eventuele leesproblemen van slechtziende kinderen door veroorzaakt worden, zonder er meteen vanuit te gaan dat deze het directe gevolg zijn van de slechtziendheid.

Dankwoord

Met dit dankwoord sluit ik een belangrijke periode in mijn leven af. Ik doe dit met gemengde gevoelens, aan de ene kant ben ik blij dat het proefschrift af is en ook trots op het resultaat. Aan de andere kant heb ik het onderzoek met heel veel plezier uitgevoerd en betekent deze afronding een afscheid van een periode waar ik met plezier op terugkijk.

Veel mensen om mij heen zijn op de een of andere manier betrokken en behulpzaam geweest bij de totstandkoming van dit proefschrift, hen wil ik op deze plaats graag bedanken voor hun ondersteuning. Ongetwijfeld zal ik hierbij mensen vergeten te noemen. Bedenk dat dit niet ligt aan de onbelangrijkheid van hun bijdragen, maar aan mijn slechte geheugen.

In de eerste plaats natuurlijk mijn promotoren en begeleiders, Ludo Verhoeven, Wim van Bon, Rob Schreuder en Lia Adriaansen. Hen ben ik vooral dankbaar voor de kans die zij mij hebben gegeven dit onderzoek te doen. Van hen was Wim mijn eerste aanspreekpunt, en daardoor misschien ook wel degene die de ongenoegens die bij mij af en toe de kop opstaken als eerste over zich heen kreeg. Ook met Rob heb ik wel in de clinch gelegen. Graag wil ik hier mijn waardering uitspreken voor de manier waarop we na onze onenigheden toch weer verder konden gaan. Ook Ludo wil ik bedanken voor zijn bemiddelende rol hierin. Waardering heb ik ook voor de manier waarop Wim en Rob altijd klaar stonden. Wim is van het begin af aan zeer betrokken geweest bij het project, zelfs in periodes waarin hij wel andere dingen aan zijn hoofd had, kon ik altijd bij hem terecht. Ook Rob heeft een belangrijke rol gespeeld. Met name zijn bijdragen in de discussies over onderzoeksopzetten en verslaglegging waren waardevol.

Van Lia heb ik veel geleerd over wat het onderwijs aan slechtziende kinderen eigenlijk inhoudt. Bovendien heb ik in haar een hartelijk en gezellig mens leren kennen.

Eenzelfde hartelijkheid heb ik ervaren van de collega’s van OLO. Nooit heb ik me buitengesloten gevoeld door mijn mede-aio’s, ondanks het grote leeftijdsverschil. Van de vaste staf wil ik met name Anny noemen, die in Amsterdam al een grote bron van inspiratie was en dat nu nog steeds is.

De uitvoering van het onderzoek was niet mogelijk geweest zonder de hulp van de mensen van Sensis, Bartiméus en Visio. Liesbeth Luycks en later Yvonne Kruithof (Bartiméus), Els Vervaart (Visio) en Ineke van Dijk (Sensis) hebben mij (met name in het begin, toen de wereld van slechtziende kinderen voor mij nog een volstrekt onbekend terrein was) van veel nuttige informatie voorzien. Ook Hélène Verbunt (Sensis) is een grote hulp geweest, door altijd met veel geduld uitleg te geven over allerlei mogelijke oogafwijkingen bij kinderen. Bovendien heeft zij samen met Piet Rison (Bartiméus) bij een groot aantal kinderen een visueel functieonderzoek uitgevoerd.

De ambulant begeleiders, de leerkrachten en de remedial teachers zijn allemaal behulpzaam geweest bij het verspreiden, invullen en afnemen van de vragenlijsten en toetsen. Ook een groot aantal leerkrachten van reguliere basisscholen heeft hieraan meegewerkt. Het belangrijkst echter was natuurlijk de medewerking van alle kinderen, slechtziend en normaalziend, zonder hen was er geen onderzoek geweest. Voor de afname van de verschillende toetsen en experimenten is de hulp van Angela Mintjes, Liesbeth van Brenk, Neeltje Janssen, Esther Wittenburg en Jossie van den Beemt onontbeerlijk geweest. Dat de computergestuurde experimenten zo goed zijn verlopen, heb ik te danken aan Hubert Voogd die de programmering hiervan heeft gedaan.

Ook privé brengt zo'n proefschrift nogal wat veranderingen teweeg. Het hele gezin is voor mij meeverhuisd van Lelystad naar Nijmegen en Rob en Bas reizen daardoor bijna dagelijks heen en weer naar Hilversum en Yorick naar Utrecht. Dat iedereen het hier nu best naar z'n zin heeft en Yorick zelfs niet meer terug zou willen, doet niets af aan mijn waardering voor hun bereidheid mij te volgen.

De afstand naar vrienden wordt ook wat groter door zo'n verhuizing. Ook ontbrak het vaak aan tijd voor lange telefoongesprekken. Gelukkig is er tegenwoordig e-mail, waardoor Mirjam en ik elkaar toch op de hoogte kunnen houden van ons wel en wee. Manja, Hans, Daan, Hendrikje en Agnes, we zien en spreken elkaar wel niet zo vaak, maar als we elkaar spreken is het als vanouds. Ditzelfde geldt natuurlijk ook voor mijn moeder, zus, broer en schoonouders.

Last but not least, ben ik Leah, Juul, Chiva en Belle dankbaar voor de welkome afleiding en hun vermogen mijn aandacht zodanig op te eisen dat zoiets als een proefschrift ver naar de achtergrond werd verdrongen in mijn gedachten. Dankzij hen ook heb ik de afgelopen jaren toch mijn dagelijkse portie frisse lucht gehad.

Curriculum Vitae

Marjolein Gompel is geboren op 9 mei 1959 te Rotterdam. Na een afgebroken gymnasiumopleiding aan het Comenius College te Hilversum en een opleiding en carrière als kapster, is zij in 1987 na een colloquium doctum toegelaten tot de studie psychologie aan de Universiteit van Amsterdam. Deze studie heeft zij in 1995 afgerond met als afstudeerrichting ontwikkelingspsychologie.

Na haar afstuderen was zij gedurende enige tijd als onderzoeksassistent verbonden aan de Katholieke Universiteit Nijmegen, bij de vakgroep Orthopedagogiek. Dit betrof een onderzoek naar de ontwikkeling van de leesvaardigheid met betrekking tot consonantclusters.

In 1998 is zij als aio aan de Katholieke Universiteit Nijmegen begonnen met het onderzoek dat in dit proefschrift staat beschreven. Daarnaast is zij aan diezelfde universiteit (waarvan de naam onlangs is gewijzigd in Radboud Universiteit) vanaf 2000 werkzaam als docent. Vanaf 2003 werkt zij tevens mee aan de inhoudelijke ontwikkeling van “Dyslexpert”, een expertsysteem voor de signalering en behandeling van dyslexie.