Young children's use of a visual aid: an experimental study of the effectiveness of training

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We report an experiment concerning the use of a stand magnifier by young children with visual impairments (21 males, 12 females; mean age 4y 8mo [SD 11mo]). Children had a normative developmental level and a visual acuity of 0.4 or less (≤20/50 in Snellen's notation). To measure magnifier use objectively, we developed a task that closely resembled the dynamics of its real-life (pre-reading) use. Children had to follow trails visually, from a start location to an unseen end location. This could only be done successfully and reliably by proper use of the magnifier. In addition to this, we analyzed the effect of specific training with the magnifier by using a repeated-measures (before and after training) matched-groups (with respect to age and near-visual acuity) design. Results established both the task's efficacy as an instrument for measuring magnifier use in young children and the effectiveness of the training. Improvement in task performance after training was found in both groups, except for the youngest children (<3y 6mo). On average, 1.8 times as many paths were followed in both groups after training (p=0.001). The without-magnifier training group became 2.5 times as good at finding the correct end location, whereas the with-magnifier training group became 4.3 times as good (p=0.05).

Several studies recommend the use of low-vision aids for young children with a visual impairment.[1–4] Nonetheless, we still understand very little about the actual use of such aids in this group, from the scientific as well as from the clinical and applied point of view. Little is known, for example, about the relevant perceptual, motor, and cognitive factors that determine the successful and prolonged use of low-vision aids in a developmental context. Resulting from this is the lack of consensus among low-vision professionals and researchers on the minimum age at which it is sensible to introduce a low-vision aid to a child with a visual impairment. Moreover, we do not know exactly at what age and how children should be trained in order to use such an aid adequately. Nor do we know whether a training programme at an early age will improve a child's willingness to use the aid. From a social and economical perspective this situation is unsettling. Obviously, the number of successful (early) prescriptions of low-vision aids to children with visual impairments would significantly be increased by a resolution of these issues.

A measure of the effectiveness of a low-vision aid for young children

Related to the lack of knowledge, in our opinion, is the scarcity of clear-cut measures or evaluation procedures for the effectiveness of low-vision aids for children with visual impairments.[5–7] Clinical measures are often idiosyncratically tied to a specific low-vision professional and therefore not generally applicable or evidence-based. More objective measures almost always involve some ability that is directly related to reading, such as reading rate or comprehension rate. Although these are both functional and relevant, they are not appropriate for preschool children. For early prescription purposes, it would be important to have a measure that also applies to this group. A further point is that training programmes for low-vision aids are hardly ever

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described in detail in the literature, let alone evaluated (however, see Corn et al.[5] and Virgili and Acosta).[8]

As an exception, in an experiment by Ritchie et al.,[7] visually impaired children aged 18 months to 5 years had to name pictures and small objects with and without the help of a stand magnifier on two occasions. Results revealed an improvement in functional vision (i.e. ratio of correct responses) when using the magnifier, except for the children with the most severe visual disability. All children benefited from the magnifier after a trial period. The researchers reported that this improvement was independent of age, although their task required a developmental level of at least 2 years.

Two comments can be made with respect to that study.[7] First, the task was a static magnifier-aided naming task, which involved no manipulation of the magnifier. A task that would resemble more closely the actual movements involved in scanning or reading[9] would be more realistic and reliable. Second, the trial period with the magnifier is an uncontrolled factor in the experiment. In fact, specific training is likely to increase the size of the progress that might be achieved with the aid (e.g. see Corn et al.)[5] The effect of such training on performance task remains an empirical matter.

The present study

The work presented in this paper is motivated by the fundamental and practical need to address the issues that have been raised in the preceding sections. We developed a task and a related training programme that would encourage and help young children with visual impairments to develop their abilities in using a low-vision aid for near vision. At the same time, the task had to enable us to determine the effectiveness of the training programme and make individual assessments. That is, it must provide a reliable and objective quantitative measurement of the individual child's abilities in using the magnifier, as well as the changes resulting from the training. The task was designed to be appropriate for preschool children but still entailed the kind of motor behaviour (in particular magnifier movements) involved in reading and scanning. The stand magnifier was considered to be the most appropriate visual aid for our purposes because it offers a stable image and is easy to manipulate for children.[3]

METHOD

Participants

At the end of 2005, 57 children with a visual impairment were recruited from the patient files of the low-vision centres in the Netherlands. Of this group, 42 children agreed to participate. Children were selected on the basis of the following criteria: a visual acuity of 0.4 or less (≤20/50 in Snellen's notation) in the better eye after the best possible correction, no additional impairments, birth at term, and no previous experience with visual aids. Moreover, they had a normative developmental level, determined by the Reynell–Zinkin development scales for young visually impaired children,[10] for which Dutch age norms[11] were applied.

Five children did not complete the study, because of withdrawal (three children) or organizational problems (two children). Four more children were excluded from the analyses because reassessment of their near-visual acuity revealed that they received inappropriate stimulus material. The remaining group of 33 children contained 21 males and 12 females. The average age in this group at the start of the study was 4 years 8 months (SD 11mo).

Ophthalmological examination

In the research group, 12 children had albinism (10 with nystagmus), five had cataract (three with nystagmus), four had nystagmus only, three had retinoschisis (one with nystagmus), two had aniridia (both with nystagmus), and there were seven children with either high hypermetropia, Möbius syndrome, retinitis pigmentosa, congenital glaucoma, achromatopsia (with nystagmus), optic nerve atrophy (with nystagmus), or retinoblastoma. This distribution is representative of Dutch children with visual impairments.[12,13] Visual acuity was measured for the right eye, left eye and both eyes on 3m and 5m charts (LH-test[14,15] and E-chart[16] respectively) under controlled lighting conditions in an ophthalmological setting. Near-visual acuity was determined with the LH-test (line and single) for children, also for the right eye, left eye and both eyes, at a distance chosen by the child and at 40cm.[17]

A gross estimation of the visual field was obtained by confrontational techniques. Central scotomas could not be tested with perimetry in these young children. However, loss of function in the central area was observed when the child performed near-vision tasks.[14] Six children had visual-field defects; three of these had a normal central visual field and three probably had central scotomas. Indications for central scotomas were found in children with retinitis pigmentosa, retinoblastoma (after treatment), and congenital glaucoma.

Objective refraction was obtained after cycloplegia and if necessary the spectacle correction was prescribed or changed before the experiment started. Four children with afakia wore glasses, and one child had intraocular lenses. All children with glasses had to wear them during the entire study (high hypermetropia n=8, hypermetropia with astigmatism n=12, myopia n=2, no correction n=6).

Material

Stand magnifier

The visual aid used in the experiment is shown in Figure 1. It is a 23.0 diopter (aspheric-lens) stand magnifier (Eschenbach, Nuremberg, Germany) with a 6× standard magnification. It has an equivalent viewing distance (EVD) of 4.3cm.[18] The magnifier is 48mm high and its lens housing has a diameter of 52mm. These dimensions make it quite suitable for young children to manipulate. Because a stand magnifier rests on the surface of the underlying material, it provides a stable image and movements with the magnifier need to be made in only two dimensions.

Task

The stimulus materials used for the task were eight A3-sized (29.7 × 42cm) patterns, which were mounted on larger cardboards for stability (Fig. 2). Each pattern included four different trails, each consisting of one type of small optotypes (Lea symbols: apple, circle, house and square),[14,15] somewhat like an 'ant trail'. The trails all connected a start picture to a hidden finish picture. The task comprised a 'trace-following game': starting at an initial location pointed out by the experimenter, the children had to find the corresponding finish picture, by following the trail with the magnifier.

Several sets of patterns were available with trails in optotype sizes that varied across a large range of M-values. The M-values reflect a logMAR (minimal angle of resolution) visual-acuity scale, in which the angular size of the optotypes changes by a factor of 0.1 log units at each step. To be absolutely certain that children were not able to identify the optotypes without the use of the magnifier, we selected

Figure 1: The magnifier used in this study: Eschenbach aspheric-lens stand magnifier (23.0 dpt; 6× magnification). Dimensions: 48 mm high and 52 mm diameter.

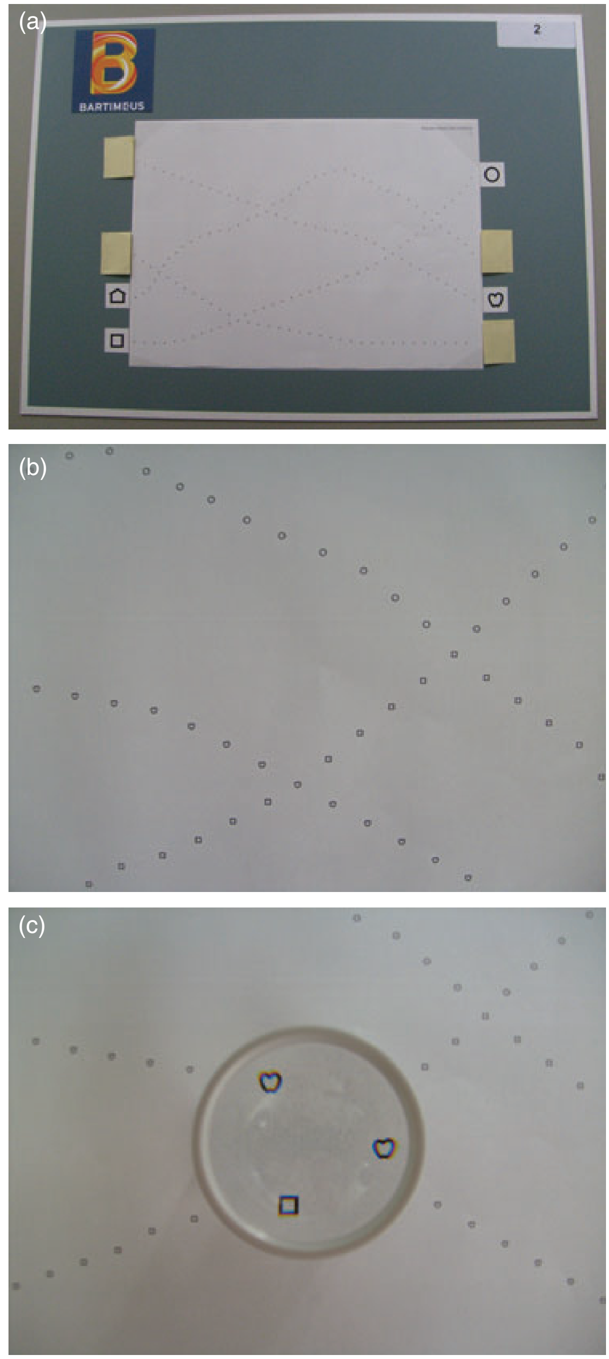

Figure 2: The stimulus material: (a) one of the horizontally orientated patterns; (b) a detail of this pattern in the neighbourhood of two crossings; (c) a detail of the pattern as partially seen through the magnifier.

a size that was three lines on the LH-chart[16] lower than the threshold M-value that a child had attained in the near-visual acuity test. As a result, children were still able to see the trails with their bare eyes, but for adequate task performance the magnifier was indispensable.

The distance between the optotypes was such that, when the magnifier was positioned on a trail, the image through the lens always contained at least two optotypes (of any kind) at once. Because of this, not only optotype information was available to the child, but the magnifier image also provided information on the movement orientation.

The patterns varied in orientation (horizontal, vertical, and circular) and type of crossings between the trails (interruption or continuation of the trail; see Fig. 2). These variations were included to attract across-pattern (scanning-like) movements and to increase the necessity to use the magnifier respectively.

Procedure

Before the start of the actual experiment, some simple example patterns in large optotypes (2.5M) were used to point out the correspondence between the start and finish picture, and to explain the ideas of trail following and crossings. These patterns were not yet done with the magnifier. A final introductory pattern with smaller optotypes was used to introduce the magnifier.

When the task was clear to the child, the first experimental pattern was introduced, which had to be performed with the magnifier. The experimenter placed the magnifier on the starting picture and asked the child to follow the trail. The patterns were presented in a random order. Only two trails had to be performed from each pattern before a new one was presented, resulting in a maximum number of 16 trails. When a child arrived at an incorrect end location, or somewhere during the trail indicated that a wrong turn was made, he or she was allowed to try one more time. If this second try also failed, a new trail was appointed. The experiment ended when all 16 trails were done or when the child refused to proceed. Finally, lighting conditions were controlled for by using task lighting that was directed onto the pattern by the experimenter (9000lux at close range to the patterns [10–15cm] and 1300lux at 40cm).

Training and post-test

To evaluate the effectiveness of the magnifier training in an objective way, two training groups were constructed. Half of the children were assigned to the group that trained with the magnifier (experimental group), the other half trained without the magnifier (control group). With this set-up it is possible to differentiate the effect of (mere) increased visual attention from the (additional) effect of the magnifier. The training groups were matched with respect to age and near-visual acuity. The without-magnifier training group (n=15, 9 males, 6 females) had an average age of 57 months (SD 12mo) and an average stimulus-material M-value of 0.35 (SD 0.13). The with-magnifier training group (n=18, 12 males, 6 females) had an average age of 55 months (SD 11mo) and an average stimulus-material M-value of 0.38 (SD 0.15).

Training started within 1 week after the pretest. Children were visited at home or at their school by an early interventionist for 12 half-hour sessions over 6 weeks. The material and the magnifier were not made available to the children outside the training sessions. During the training sessions, presentation of the different patterns was varied as much as possible. In the with-magnifier training group, the size of the optotypes was again three lines on the LH-chart lower than the near-visual acuity, and much attention was paid to improvement of magnifier use. In the without-magnifier training group, the size of the optotypes was equal to the near-visual acuity, and children used their finger to follow the trails.

Within 1 week after the last training session children performed the post-test. The set-up was the same as during the pretest. In particular, both training groups worked with the magnifier again, and the patterns and trails were presented to each child in the same order as during the pretest. The experimenters were not the same ones as during the pretest and were not informed whether the child had trained with or without the magnifier.

Data analysis

Task performance was analysed in terms of both quantity and quality. Quantity of performance refers to the number of trails followed, irrespective of whether the correct end location was found. Quality of performance refers to the number of correct end locations that were found among these trails. To indicate changes in this quality (caused by the training) several measures were used, all based on the *proportion correct*, given by the ratio of correct end locations to the number of trails that were tried. A proportion correct of 0 means that no trail that was started resulted in the correct end location being found, whereas a proportion correct of 1 means that all trails ended successfully. The distinction between these quantitative and qualitative aspects of task performance is meant to reflect that, by using the magnifier incorrectly or not at all, it is still possible to (partially) follow a trail, but it is not possible to reliably arrive at the correct end location.

Analysis of variance was performed on the relevant data for both types of task performance to compare the differences between training groups and age groups. All proportion scores were arcsine transformed before being entered into the analysis of variance to account for the fact that they are not normally distributed.

RESULTS

The characteristics and results of all 33 participants who completed the pre- and post-tests and all 12 training sessions are presented in Table I.

Task performance: quantitative

Generally, children in both training groups followed more trails in the post-test than in the pretest (Table I; note that the maximum number of trails was 16). The average number of trails for the without-magnifier training group was 7.3 (SD 3.4) in the pretest and 13.5 (SD 4.0) in the post-test. For the with-magnifier training group these numbers were 6.9 (SD 4.7) and 12.1 (SD 5.9) respectively. Thus the quantitative task performance increased from pre- to post-test by a factor of 1.8 in both groups. A paired-samples *t*-test comparing the pooled number of trails in the pretest

Table I: Raw scores in the pretest and post-test for the 33 participating children

				Pretest			Post-test		
Child	Age (mo)	Sex	NVA[a]	*n* of paths	*n* correct	Proportion correct	*n* of paths	*n* correct	Proportion correct
Training group without magnifier									
1	37	M	0.13	3	0	0.00	12	4	0.33
2	40	M	0.10	1	0	0.00	6	0	0.00
3	43	M	0.20	4	0	0.00	16	10	0.63
4	47	F	0.15	10	1	0.10	16	8	0.50
5	51	M	0.20	10	5	0.50	12	10	0.83
6	51	F	0.06	6	0	0.00	16	14	0.88
7	55	F	0.13	3	0	0.00	16	15	0.94
8	55	M	0.30	10	5	0.50	8	6	0.75
9	56	M	0.16	8	4	0.50	16	13	0.81
10	58	M	0.19	9	0	0.00	16	6	0.38
11	67	F	0.10	6	1	0.17	5	1	0.20
12	70	M	0.25	12	6	0.50	16	12	0.75
13	71	F	0.08	12	12	1.00	16	16	1.00
14	72	F	0.14	8	7	0.88	16	16	1.00
15	77	M	0.24	8	4	0.50	16	16	1.00
Training group with magnifier									
1	37	F	0.05	2	0	0.00	0	0	0.00
2	39	M	0.08	3	0	0.00	1	0	0.00
3	39	F	0.13	1	0	0.00	1	0	0.00
4	49	F	0.08	6	1	0.17	16	16	1.00
5	50	M	0.25	4	0	0.00	9	8	0.89
6	52	M	0.11	6	0	0.00	16	6	0.38
7	53	F	0.06	10	2	0.20	16	15	0.94
8	53	M	0.16	1	0	0.00	8	2	0.25
9	54	F	0.1	16	9	0.56	16	15	0.94
10	54	M	0.2	2	0	0.00	16	16	1.00
11	57	M	0.3	3	0	0.00	10	10	1.00
12	58	M	0.25	8	0	0.00	16	16	1.00
13	61	M	0.13	12	1	0.08	16	16	1.00
14	63	M	0.16	16	7	0.44	16	13	0.81
15	66	M	0.08	10	0	0.00	16	10	0.63
16	67	M	0.16	6	5	0.83	12	12	1.00
17	71	F	0.13	8	3	0.38	16	16	1.00
18	75	M	0.08	10	3	0.30	16	16	1.00

[a]Values represent children's NVA in decimal notation, as given by the following (standard) formula: NVA = distance ⁄ M-value, where the threshold M-value is determined by the LH-chart[12] at the shortest distance chosen by each child. The size of the optotypes on the stimulus material was taken three steps (i.e. three lines on the LH-chart) lower than the threshold M-value for each child. Two children (no. 8 in the without-magnifier training group and no. 11 in the with-magnifier training group) worked with stimulus material that was only two steps lower, because the smallest available optotype size was 0.20M. NVA, near-visual acuity.

and post-test showed that this increase is significant: $t_{(32)}=-7.46$, $p<0.001$ (two-tailed).

An analysis of covariance, with training group (with or without magnifier) as the intersubject factor and age and number of trails followed in the pretest as covariates, was performed on the number of trails followed in the post-test. This revealed that the number of trails followed before training was the only significant factor in determining post-test task performance: $F_{(1,33)}=5.63$, $p=0.02$. Age and training group were not significant.

Task performance: qualitative

Only five children did not improve their task performance qualitatively. One child in the without-magnifier training group already had a perfect score in the pretest and remained perfect in the post-test. Of the other four, one child was in the without-magnifier training group and three were in the group that trained with the magnifier. The number of correctly found end locations in the post-test was 0 for all four of these children. This means not only that there was no improvement, but also that their qualitative performance was the lowest possible. All of these children were younger than 3 years 6 months and, from the observations of their performance, it became clear that they had difficulties with the task. They either did not understand what was asked of them or were otherwise unable to meet the demands of the task. These four youngest children who did not progress were not included in the following analysis.

Table II presents several measures that reflect the quality of task performance for the two measurement times and the two training groups separately, all based on the proportion-correct scores for each individual child. Although the baseline scores appear to be different for the two training groups (0.20 with magnifier vs 0.28 without magnifier), a *t*-test on the arcsine-transformed proportion-correct data revealed that this difference was not significant: $t_{(26)}=0.73$, $p=0.48$ (two-tailed). The difference between the training groups in the post-test (0.86 with magnifier vs 0.69 without magnifier) was significant, however: $t_{(26)}=-2.06$, $p=0.05$ (two-tailed). This proved that both groups started out as equal, but that the with-magnifier training group performed better after the training period. The without-magnifier training group performed 2.5 times as well in the post-test as in the pretest (gain index 0.61), whereas the with-magnifier training group performed 4.3 times as well (gain index 0.84). Moreover, after this period more than half of the children in the with-magnifier training group attained a perfect score (53% vs 21% in the without-magnifier group).

To analyse the changes in qualitative task performance more thoroughly, an analysis of covariance, with training group (with or without magnifier) as intersubject factor and age and pretest proportion correct as covariates, was performed on the arcsine-transformed post-test proportion-correct data. This analysis revealed a main effect for training group after correcting for initial performance level or age: $F_{(1,27)}=5.23$, $p=0.03$.

DISCUSSION

We studied the effect of a low-vision aid, specifically a stand magnifier, used by young children with visual impairments and the effect of specific training for the use of this magnifier. In a repeated-measures matched-groups design, children were divided into two groups to be trained either with or without the magnifier. To enable us to measure magnifier use objectively before and after the training, we developed a task that met several criteria. Importantly, the task closely resembled the dynamics of most real-life magnifier use. That is, it was designed to evoke some of the magnifier movements involved in scanning pictures or drawings and reading. The task enabled us to compare the differences in progress between the training groups.

Results demonstrated that the task provides an objective and effective instrument that can be helpful for assessing magnifier use in young children. Moreover, the training

Table II: Measures reflecting the qualitative task performance at the group level

	Proportion correct[a]				Perfect scores[c]	
Training group	Pretest	Post-test	Ratio pre/post	Gain index[b]	Pretest	Post-test
Without magnifier (n=14)	0.28	0.69	2.5	0.61	1	3
With magnifier (n=15)	0.20	0.86	4.3	0.84	0	8

[a]The *proportion correct* is given by the ratio of the number of correct end locations and the number of trails that were tried (average of only the children who had improved after training). [b]The *gain index* is defined as $(y-x)/(1-x)$, where x is the proportion correct in the pretest and y is the proportion correct in the post-test. [c]A *perfect score* means that every trail that was tried resulted in the correct end location being found (i.e. proportion correct equals 1).

proved to have a positive effect on children's performance in the task, both quantitatively and qualitatively. Virtually all children followed a larger number of trails after the training; this was not the case, however, for the children younger than 3 years 6 months. In contrast to the number of paths followed, the quality of task performance differed significantly between the two training groups. Children who had trained with the magnifier became more effective in using it than the children who had trained without the magnifier. Both groups found a larger proportion of correct end locations, but in the with-magnifier training group this increase was about twice as large as in the without-magnifier training group.

From a clinical point of view, these are interesting results that can have important consequences for the prescription of low-vision aids to young children with a visual impairment, as well as for related training programmes. First of all, a basic finding of the present study is that our visual-attention training had a positive effect on children's performance in a demanding perceptuomotor task involving a visual aid. More specifically, this study shows that the training, which was based on the task, helps children to improve their capabilities in using the magnifier. We believe that, because of the close correspondence between the experimental task and the actual magnifier-demanding situations that children encounter, the increased effectiveness in using the magnifier can be extrapolated to their everyday practice. This study, therefore, supports the opinion that the prescription of a visual aid to children at a young age can be successful, provided that proper training is given. However, starting the present training before 3 years 6 months of age is not a good idea, although more study is needed to assess the factors that determine this minimum age.

Magnifier use

A stand magnifier enlarges the object under its lens and provides a stable image. Nonetheless, in general, a visual aid can be beneficial to its user only once he or she has learned how to use it adequately and has learned to interpret and use the enhanced flow of visual information. This is a matter not only of the properties of the visual aid itself but also of the characteristics of the task and the user. The task that was used in this study was developed such that it could be performed successfully only when the magnifier was used properly.

Handling a stand magnifier is particularly challenging for young children with a visual impairment. Studies (e.g. Reimers et al.)[19] have shown that children with visual impairments not only have a lower level of vision, but generally show an overall impediment in their motor development as well, compared with their age-matched peers. From a social and a research point of view, this poses an interesting issue. On the one hand, because of their lower level of vision, they might benefit from the use of a magnifier. On the other hand, their poorer motor skills might render the actual use of the device difficult. This study suggests that there is progress to be made in this area of children's rehabilitation.

Finally, in a dynamic magnifier-aided task such as the one used in this study, non-visual factors play an important role in determining task performance. The visual abilities and motor-control skills of a child have to combine into a task-specific behavioural organization that enables him or her to perform the task effectively and efficiently.[20] Such a perception–action organization is what low-vision professionals often label as *viewing behaviour*, a term as yet without a clear definition. The quality of the viewing behaviour is what ultimately determines a child's functional vision.[7] In conclusion, more insight into the perception–action organization that underlies viewing behaviour, and its development in young children with visual impairments, is necessary.

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