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Development of an Age Band on the ManuVis for 3-Year-Old Children with Visual Impairments

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ABSTRACT. *Aim:* To compare fine motor performance of 3-year-old children with visual impairment with peers having normal vision, to provide reference scores for 3-year-old children with visual impairment on the ManuVis, and to assess inter-rater reliability. *Method:* 26 children with visual impairment (mean age: 3 years 7 months (SD 3 months); 17 boys) and 28 children with normal vision (mean age: 3 years 7 months (SD 4 months); 14 boys) participated in the study. The ManuVis age band for 3-year-old children comprised two one-handed tasks, two two-handed tasks, and a pre-writing task. *Results:* Children with visual impairment needed more time on all tasks ($p < .01$) and performed the pre-writing task less accurately than children with normal vision ($p < .001$). Children aged 42–47 months performed significantly faster on two tasks and had better total scores than children aged 36–41 months ($p < .05$). Inter-rater reliability was excellent (Intra-class Correlation Coefficient = 0.96–0.99). *Conclusions:* The ManuVis age band for 3-year-old children is appropriate to assess fine motor skills, and is sensitive to differences between children with visual impairment and normal vision and between half-year age groups. Reference scores are provided for 3-year-old children with visual impairment to identify delayed fine motor development.

KEYWORDS. Children, fine motor skills, ManuVis, motor development, pre-writing skills, visual impairment

Fine motor skills allow us to successfully interact with our physical and social environment by providing the possibility to manipulate objects. Young children develop these skills, among other ways, by playing with toys. These experiences

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prepare them to engage in daily life, which contribute to their independence and increase their self-esteem as they grow older. Vision is essential for the development and performance of fine motor tasks, so differences in fine motor skills between children with visual impairment and children with normal vision are to be expected. However, inter-individual differences in motor skills between children with visual impairment are large (Reimer et al., 2015) and not related to the degree of visual impairment (Houwen et al., 2008). Apparently, these inter-individual differences are at least partly due to differences in motor skill learning in daily life. To detect delays in motor skill learning as early as possible, insight in typical development in children with visual impairment is necessary.

Brambling (2006) proposed that vision is essential for increasingly efficient ways of attuning to (i.e., detecting and using) relevant information for action. Vision facilitates motor control, as do other senses, in the context of a specific task as well as in response to an ever-changing environment. Specific sub-functions entail responding to and anticipating upcoming events, monitoring task performance, and providing feedback on the execution of goal-directed movements. Secondary functions of vision related to motor learning include the observation and imitation of the movements of others (e.g., peers or parents) as well as picking up on and responding to the encouragements of caregivers, which are mostly expressed nonverbally through gestures and facial expressions.

Motor skill learning is also influenced by the expectations of social environment, which are often lower for children with visual impairment than for children with normal vision (Warren, 1994). In 2005, the prevalence of low vision in children aged between 0 and 14 years in the Netherlands was estimated at 0.6/1,000 (Limburg, 2007). Research has demonstrated that children with visual impairment have poorer motor skills (Hatton et al., 1997; Houwen et al., 2008; Liebrand-Schurink et al., 2015), delays in functional play (Lewis et al., 2000), and reach motor milestones later than their peers with normal vision (Celeste, 2002). It has been suggested that developmental delays related to motor skills observed in children with visual impairment could be caused by less opportunities and poorer experience, rather than an inability to acquire these motor skills (see e.g., Haibach et al., 2014; Schneekloth, 1989).

The developmental trajectory of children with visual impairment often differs from that of children with normal vision. For this reason, the motor capabilities of a child with visual impairment should not be expected to match with those of a child of the same age with normal vision. To determine whether a child with visual impairment exhibits developmental delays, motor skills need to be assessed relative to those of peers with visual impairment. Since children with visual impairment are at greater risk of less-than-optimal development of manual dexterity (Smits-Engelsman et al., 2003), an objective and reliable measure is needed to monitor fine motor development of young children with visual impairment.

In a previous study, we developed the ManuVis, a test specifically developed to measure fine motor skills of children aged 4–11 years with visual impairment (Reimer et al., 1999, 2011, 2015). We observed that there were major differences between children with visual impairment and children with normal vision at the age of 4 years than between groups of older children. This was reported earlier by Brambling (2001), who emphasized the relevance of these findings in terms of readiness to start in school. Assessment of fine motor skills at the age of 3 years

would allow for earlier intervention and advice, even before children start going to school (in the Netherlands). This prompted the decision to extend the ManuVis age band for 3-year-old children.

Several tests are available to measure fine motor skills in 3-year-old children with normal vision. The Bayley Scales of Infant and Toddler Development (BSID) assess a broad development range for children from 1 to 42 months of age (Bayley, 2006); the Mullen Scales of Early Learning (Mullen, 1995) are tailored for children aged up to 68 months; and the Manual Dexterity Scale of the Movement Assessment Battery for Children-2 (MABC-2) (Henderson et al., 2007) is available to test fine motor skills in children aged 3 to 16 years.

Although all these tests are appropriate to assess fine motor skills in 3-year-old children with normal vision, none of the tests fulfills the requirements of being suitable for 3-year-old children with visual impairment, nor do they allow for monitoring development over time. Both the Mullen Scales and the BSID are specifically designed for young children. For BSID-III, an adapted version for children with motor and/or visual impairments exists (Visser et al., 2014); however, it is not suitable for children aged more than 42 months. The advantage of MAB-2 is the wider age range; however, even for 3-year-old children with normal vision, certain manual dexterity items are difficult to execute (Smits-Engelsman et al., 2011).

Therefore, we decided to carry out this study to provide a suitable instrument for clinical practice to measure fine motor skills in 3-year-old children with visual impairment and decided that a 3-year age band of the ManuVis (Reimer et al., 1999, 2011, 2015) would allow for early intervention and longitudinal follow-up of the development in individual children. The ManuVis (4–11 years) consists of six different fine motor tasks (two one-handed tasks, three two-handed tasks, and a *pre-writing task*). See the Method section and Table 1 for an overview of the ManuVis items used in the age band for 3-year-old children and the adaptations made for these children in more detail. Test–retest and inter-rater reliability of the ManuVis is moderate to excellent, with Intra-class Correlation Coefficient (ICC) score ranging from 0.58 to 0.89 and from 0.98 to 1.00, respectively. Moreover, the test items were valid to discriminate between age bands. A more extensive description of the chosen items of the ManuVis (for 4–11-year-old children) and the validation are described by Reimer et al. (2015).

The aims of this study were to develop and evaluate an age band on the ManuVis for 3-year-old children with visual impairment by (1) comparing fine motor skill development of 3-year-old children with visual impairment and normal vision; (2) providing norm reference scores for 3-year-old children with visual impairment; and (3) investigating inter-rater reliability. We hypothesized that children with visual impairment would be slower in performing the fine motor tasks and would have more problems with accuracy in the pre-writing task. We also hypothesized that children aged 42–47 months would perform better than children aged 36–41 months in both visual impairment and normal vision groups.

METHOD

Design

This prospective cohort study is embedded in a larger study focusing on interventions for children with visual impairment. Baseline data were used for this study.

TABLE 1. Description of all Tasks and Corresponding Procedures of the ManuVis for 3-Year-Old Children Compared with the ManuVis for 4–11 Years

One-handed tasks

1. Putting coins in a money box

In the 'putting coins in a money box' task, the target position for the coins is known because the other hand feels the position and can remain there to provide a reference point. The 10 plastic coins are in an open container so that their starting position is relatively fixed. The box is placed with the long side facing the child. The task is carried out with both left and right hand, starting with the child's preferred hand. Start timing is when the hand is lifted to move, and stop timing is when the last coin strikes the bottom. Each hand is scored separately, and the scores in seconds from both hands are summarized to an item score.

In the ManuVis (4–11 years), the same material and procedure are used.

2. Putting rings on rods

This task introduces an additional spatial factor: changing starting positions and target positions. Eight wooden rings must be placed on two vertical rods. The eight rings are initially in a fixed position in front of the rods on a wooden board in two rows of four rings. The task is to place the first ring on the first rod, the next ring on the second rod, and so on. The rings may be picked up in any order. If a child makes a procedural error (i.e., places two consecutive rings on the same rod), the child is reminded of the instructions once; subsequent errors are scored.

To categorize procedural errors, four categories were described: (1) Correct execution; (2) Equal number of rings on the two rods, but there were procedural errors; (3) Unequal number of rings on the two rods; (4) All rings were placed on one rod.

The task is performed with both left and right hand, starting with the child's preferred hand. Start timing is when the hand is lifted to move, and stop timing is when the last ring is on the rod. Each hand is scored separately, and the scores in seconds from both hands are summarized to an item score.

In the ManuVis (4–11 years), there are three rods and 12 rings for each hand.

(Continued on next page)

TABLE 1. Description of all Tasks and Corresponding Procedures of the ManuVis for 3-Year-Old Children Compared with the ManuVis for 4–11 Years (Continued)

Two-handed tasks

3. *Screwing a nut onto a bolt*

This task includes an additional manual dexterity factor. A nut (35 mm) must be placed on a bolt (M 13 mm) using a counter-movement and then screwed on using fingers and thumb. In terms of positioning of objects in space, this task is easier because the child starts with a nut in one hand and the bolt in the other and these must then be brought together. The nut and bolt are placed in an open container. Start timing when the hands are lifted to move and stop when the nut is screwed until the end.

In the ManuVis (4–11 years), there are two nuts (19 mm), and the size of the bolt is M 10 mm.

4. *Threading beads*

Six cubic beads (each side 27 mm) are placed in an open container with the holes facing up. These must be threaded onto a piece of cord. One hand manipulates the bead and feels for the hole, and the other hand threads the cord through. Start timing is when the hands are lifted to move, and stop timing is when the last bead has slit past the stiff part of the lace.

In the ManuVis (4–11 years), there are six smaller beads ($h = 16\text{ mm}/w = 12\text{ mm}/d = 4\text{ mm}$) and the lace is thinner and the stiff end is shorter.

5. *Threading lace*

This task is not part of the ManuVis for 3-year-old children because of the degree of difficulty.

6. *Pre-writing task*

The pre-writing items are comparable with those in BSID-II. The task requires children to copy three geometrical objects (circle, plus sign, and square) and they have to draw a trace between two boundary lines of a circle, square, and diamond. The score is the amount of correct executions.

The ManuVis (4–11 years) has a different writing task.

The entire research study was approved by the Medical Ethics Committee (CMO 2010/037 Arnhem Nijmegen/NTR = 2494), and was conducted in accordance with the Declaration of Helsinki. All parents of the participants gave written informed consent.

Participants

Fifty-four 3-year-old children participated in this study, 26 children with visual impairment (mean age 3 years 7 months (SD 3 months); 17 boys and 9 girls) and 28

children with normal vision (mean age: 3 years 7 months (SD 4 months); 14 boys and 14 girls). The children were divided into two groups based on age. One group consisted of children aged 36–41 months (nine with visual impairment and 11 with normal vision). The other group consisted of children aged 42–47 months (17 with visual impairment and 17 with normal vision).

Visually impaired children were selected from the databases of the institutions for visual rehabilitation in the Netherlands. The inclusion criteria for children with visual impairment in this study were as follows: visual acuity of at least 0.05 and ≤ 0.3 , no known comorbidity and/or cognitive impairment, birth at term (i.e., ≥ 36 weeks of gestation), and normal birth weight. Children born prematurely were excluded because they are known to have a higher risk of motor performance deficits and other comorbidities (Feder et al., 2005; Goyen et al., 2006). The ManuVis (Reimer et al., 2015) had the same exclusion criteria. The children had to be able to cooperate and understand the tasks of the ManuVis age band for 3-year-old children. The parents of the children selected for inclusion received an invitation letter, and were also contacted by telephone. If they were willing to participate and written informed consent was received, an appointment was made for the measurements. The clinical data of the children with visual impairment are described in Table 2.

Children with normal vision were living in the neighborhood of the Dutch city of Utrecht and were recruited from three local kindergartens ($n = 15$) and through a social network of other children with normal vision ($n = 13$) who had participated. Parents of 3-year-old children with normal vision received an invitation letter, and were also contacted by telephone. If they were willing to participate and written informed consent was received, an appointment was made for the measurements.

Adaptation of ManuVis Materials

The materials of the original ManuVis were adapted to make the items suitable and more attractive for 3-year-old children. All components of the version for 3-year-old children and corresponding procedures are described in Table 1, including the differences with the original ManuVis items in the age band for 4–11 years. The extension of the ManuVis comprised two one-handed tasks (*putting coins in a moneybox*, and *putting rings on rods*), two two-handed tasks (*screwing a nut onto a bolt*, and *threading beads*), and a pre-writing task with age-related forms and figures. Test-retest reliability (ICC score between 0.58 and 0.89) and inter-rater reliability (ICC score between 0.98 and 1.00) for the test items and total scores of the ManuVis are moderate to excellent (Reimer et al., 2015).

Procedure

Testing was always done in a quiet and well-lighted room without interruptions.

All testers had experience in testing children with visual impairment. The performance of each child was recorded on videotape. The video camera was placed opposite the child.

Children were instructed to work as quickly as possible during one- and two-handed tasks and as accurately as possible during pre-writing task. The time necessary to complete the one- and two-handed tasks was measured in seconds, and the score of the pre-writing task was the amount of correct executions. If a procedural mistake occurred, the tester interrupted the attempt immediately, after which

TABLE 2. Descriptive Data for Children with Visual Impairment ($n = 26$)

	Sex M/F	Age (months)	Diagnosis	VA (Snellen equivalent)	Strabismus	Refraction
1.	M	37	Congenital stationary night-blindness (CSNB 2)	20/130	+	OD S-2/OS S-2
2.	M	38	Albinism	20/125	+	-
3.	F	39	Congenital nystagmus	20/100	-	-
4.	M	39	Congenital nystagmus	20/160	-	OD S-2/OS S-2
5.	M	39	Albinism	20/200	-	OD S+2/OS S+2
6.	F	41	Hyperopia ^a	20/80	-	OD S+3/OS S+2.75
7.	F	41	Albinism	20/200	+/-	OD S-4/OS S-4
8.	M	41	Cone dystrophy	20/130	+/-	OD S-4/OS S-4
9.	M	41	Albinism	20/67	+	-
10.	F	42	Macular hypoplasia	20/500	+	-
11.	M	42	Congenital stationary night-blindness (CSNB 2)	20/100	-	OD S-8/ OS S-7.75
12.	F	43	Retinal coloboma ^a	20/130	-	OD S-7/OS S-5
13.	F	44	Aniridia	20/80	-	OD S+2.5/OS S+2.5
14.	M	44	Congenital nystagmus	20/125	-	-
15.	M	44	Albinism	20/100	-	-
16.	M	45	Glaucoma (aphakia) ^a	20/67	+	OD S+18.75/OD S+18
17.	M	45	Aniridia	20/160	-	OD S+2.75/OS S+5
18.	M	45	Albinism	20/200	-	OD S+5/OS S+5
19.	M	45	Albinism	20/160	+	OD S-1.25/OS S-1.25
20.	F	46	Albinism	20/67	-	-
21.	F	47	Unknown	20/67	+	-
22.	F	47	Albinism ^b	20/80	+	OD S+4.75/OS S+7.25
23.	M	47	Congenital nystagmus	20/160	-	OD S+2/OS S+3.5
24.	M	47	Albinism	20/67	+	OD S+4/OS S+4.75
25.	M	47	Albinism	20/160	-	-
26.	M	47	Albinism	20/125	-	-

^aThe visual field is not completely intact.^bNystagmus is absent.

corrective instructions and/or demonstration of the task were given before the child started again. A procedural mistake in putting coins in a moneybox occurred when a child picked up two coins at the same time, and in putting rings on rods when a child placed two consecutive rings on the same rod. Furthermore, for both one-handed items, a procedural error occurred when a child changed hands or used both hands, and for the two-handed tasks, when a child picked up more than one bead at a time. Two new attempts were allowed. For the item putting rings on rods, the children were allowed to continue during the third attempt even in the occurrence of errors; however, these procedural errors were counted. Total testing took between 15 and 20 min.

It is known that children with visual impairment use fewer fingers and exhibit less variation in grip than children with normal vision (Smits-Engelsman et al., 2003), which might influence their performance on pre-writing skills. Therefore, pencil grip was observed and categorized as (1) primitive grips, (2) transitional grips, or (3) mature grips, based on the classification system by Schneck & Henderson (1990). Two pediatric physical therapists (A. M. Reimer (AR)/A. Overvelde (AO)), who were experienced with this type of grip categorization, independently scored the grip from video. The highest level of the observed pencil grip was scored. Inter-rater reliability was calculated between the two observers. For further analysis, consensus on the final category was reached when the two researchers had different initial scores.

One child with normal vision and another with impaired vision were unable to perform any of the tasks, and were excluded from the analysis. Three children with visual impairment, aged 36–41 months, failed to execute the items of screwing a nut onto a bolt and threading beads, and two children with visual impairment, aged 36–41 months, failed to execute the item of threading beads. There was no video recording available for administration of pencil grip of one girl with normal vision.

Data Analysis

Task scores for one- and two-handed tasks were based on the performance time in seconds, and total score was the sum of task scores 1–4. For the calculation of total score in case of a missing item, when a child could not complete the task, the lowest score in the same age category and group was used. Excluding these children from the analysis would have biased the results. In addition, for the item, putting rings on rods, procedural errors (e.g., placing two consecutive rings on the same rod) were reported. The score of pre-writing task was based on the number of correct executions (from 0 to 6). Scores belonging to the 5th and the 15th percentile were calculated for use as reference values in clinical settings.

The scores of children with visual impairment and normal vision were approximately normally distributed. Therefore, six univariate analyses of variance (ANOVA) with age (36–41 months and 42–47 months) and group (children with visual impairment and children with normal vision) as between-subject factors were conducted on each task score as well as the total score. Chi-square tests were performed to compare procedural errors on the item putting rings on rods between groups (visual impairment and normal vision) and age categories. To determine whether pencil grip and the total score of the pre-writing task were correlated, non-parametric Spearman's rho was calculated.

In order to determine inter-rater reliability, the performance of 12 children (five children with visual impairment and seven with normal vision) was scored twice. One tester (Karlijn Oude Wolbers/Janne van Essen) scored the items of five children with visual impairment during testing, whereas the second scorer (AR) scored later from video recordings. Seven children with normal vision who were scored during testing by Annemieke Gerrits and were later scored by AR from video recordings were also included. Inter-rater reliability was calculated using ICC and standard error of measurement (SEM) for each item separately as well as the total score. ICC score was interpreted using the following criteria: 0.00–0.49 is poor; 0.50–0.74 is moderate, and 0.75–1.00 is excellent (Portney & Watkins, 2000). For each ICC, the 95% Confidence Interval (CI) was calculated. The SEM describes the error in interpreting an individual's test score and is computed as follows: $SEM = SD \times \sqrt{1 - ICC}$, with SD as the standard deviation. The inter-rater reliability for the score of pencil grip was determined using the Kappa statistic.

All data were analyzed using IBM SPSS (version 21.0). A significance level (alpha) of 0.05 was applied throughout.

RESULTS

Scores on the ManuVis are presented in Table 3. Univariate ANOVA score revealed significant differences between scores of children with visual impairment and normal vision for all tasks. Children with visual impairment needed on average 17 s more for putting coins in a moneybox ($F(1.50) = 26.44$; $p < .001$) and putting rings on rods ($F(1.50) = 19.44$; $p < .001$), 14 s more on screwing nut onto a bolt ($F(1.50) = 23.70$; $p < .001$), and 18 s more on threading beads ($F(1.50) = 10.80$; $p = .002$). The mean group difference in total score was 66 s, a difference that was significant ($F(1.50) = 32.34$; $p < .001$). Furthermore, children with visual impairment were less able to perform the pre-writing task ($F(1.50) = 16.95$; $p < .001$). In addition, ANOVA score showed a significant main effect between children aged 36–41 months and 42–47 months. Older children were faster at putting coins in a moneybox ($F(1.50) = 6.46$; $p = .014$), screwing a nut onto a bolt ($F(1.50) = 6.38$, $p = .015$), and had a better total score ($F(1.50) = 4.92$; $p = .031$). No significant interactions were found.

A Chi-square test revealed no significant differences between children with visual impairment and normal vision, or between younger and older children on procedural errors in the item putting rings on rods. Six children with normal vision and three children with visual impairment were able to execute the task in correct order, 13 children with visual impairment and nine children with normal vision placed consecutive rings on the same rod, eight children with visual impairment and nine children with normal vision ended with unequal numbers of rings on each rod, and one child with normal vision placed all the rings on one rod.

Spearman's rho revealed no significant correlation between pencil grip and performance on the pre-writing task. All children used primitive or transitional grips during the pre-writing task. Half of the children with visual impairment used the primitive grasp with extended fingers. For the children with normal vision, the most

TABLE 3. ManuVis Outcomes per Task and per Age Group for Children with Visual Impairment (VI) and Children with Normal Vision (NV). Mean Scores, 15th and 5th Percentiles as well as the Range per Group and Age Category Are Reported Along with the Results on the Inter-Rater Reliability per Item

Item	Group	Age category (months)	Mean (SD)	P15	P5 ^a	Range	ICC	95% CI	SEM
1. Putting coins in a moneybox (s)	NV	36–41	61 (7)	66	77	46–77	0.96	0.86–0.99	2.78
		42–48	51 (11)	64		36–77			
	VI	36–41	75 (14)	91	92	53–93			
2. Putting rings on rods (s)		42–48	69 (14)	87		47–90			
	NV	36–41	46 (12)	61	64	28–67	0.99	0.96–0.99	2.47
		42–48	36 (7)	46		26–49			
	VI	36–41	59 (20)	91	87	27–86			
		42–48	57 (16)	81		41–87			
3. Screwing a nut onto a bolt (s)	NV	36–41	20 (10)	35	36	7–37	0.99	0.96–0.99	2.75
		42–48	13 (5)	19		6–26			
	VI	36–41	35 (10)	43	55	19–43			
		42–48	26 (15)	47		6–57			
	NV	36–41	48 (11)	60	70	29–63	0.99	0.99–0.99	3.25
4. Threading beads (s)		42–48	43 (13)	57		28–76			
	VI	36–41	66 (20)	86	123	39–86			
		42–48	62 (30)	112		33–127			
	NV	36–41	3.2 (1.8)	0	0.5	0–5	0.99	0.96–0.99	0.38
5. Pre-writing task (n)		42–48	3.5 (1.6)	1.6		1–6			
	VI	36–41	1.1 (1.9)	0	0	0–6			
		42–48	1.7 (1.6)	0		0–5			
	NV	36–41	174 (26)	212	212	117–213	0.99	0.96–0.99	5.57
		42–48	143 (28)	174		108–206			
Total item score 1–4 (s)	VI	36–41	235 (56)	302	315	155–303			
		42–48	214 (54)	284		148–321			

Note: The scores for items 1–4 and the total item score 1–4 are in seconds (s), the score for the pre-writing task is the number (n; between 0 and 6) of correct trials.
^aFor calculation of 5th percentile, data of the two age groups were combined because of the sample size.

frequently used grip was the transitional static quadripod grip: seven children applied this grip.

Inter-Rater Reliability

The intra-class correlation coefficient scores of each item were excellent, ranging from 0.96 to 0.99. SEM scores were below 5.57 (see Table 3). In addition, the inter-rater reliability for the assessment of pencil grip, expressed with the Kappa coefficient, was sufficient ($\kappa = 0.68$, $n = 53$).

DISCUSSION

This study demonstrates that 3-year-old children with visual impairment on average have lower scores on the ManuVis age band for 3-year-old children compared with their peers with normal vision. Three-year-old children with visual impairment needed more time to complete all fine motor tasks and they had more difficulty with the accuracy of the pre-writing task. The inter-rater reliability of the ManuVis for 3-year-old children was excellent for all items. Inter-rater reliability for the assessment of the pencil grip was sufficient.

The item screwing a nut onto a bolt was difficult for the children with visual impairment; five of the 11 children with visual impairment aged 36–41 months could not complete this task. In addition, two of these children were also unable to perform the item threading beads. For the analysis, these missing values were replaced with the lowest value on that item for children within the same group and age category. This decision was based on the observation during testing that the motor skills of these children were insufficient to execute these tasks, which was confirmed by inspection of the data: they were also slow performers on the tasks that they were able to execute. Excluding them from the analysis would have led to the overestimation of results of the remaining children with visual impairment. We recommend using a similar approach in clinical practice to be able to compute a total score in the case of missing item. Letting children struggle with a task when they are clearly unable to perform it would presumably take longer, and therefore taking the lowest value is a conservative estimate.

For the task screwing a nut onto a bolt, minimal visual inspection is required; the task can be guided through haptic sensory information provided by the materials. Therefore, we expected that children with visual impairment would be able to perform this task. However, not all children with visual impairment executed this task adequately. In contrast, all children with normal vision were able to perform this task, which is consistent with the norms for a similar task in the Mullen scales for children aged 20–26 months (Mullen, 1995). Considerable difficulties children with visual impairment seemed to have with screwing a nut onto a bolt and threading beads might be caused by a lack of experience with such tasks (cf. Haibach et al., 2014; Schneekloth, 1989).

Children with and without visual impairment had difficulties in executing the item putting rings on rods, specifically with the correct order of the rings. The majority of children placed consecutive rings on the same rod. This seems to reflect problems with understanding where to place the ring, rather than problems with performing the movements. It is unlikely that this affected the execution time on

this task, since children still placed rings on one of the rods, although not necessarily on the correct one.

Pencil grip and scores on the pre-writing task were not correlated. This is in line with research of the effect of pencil grip on speed and legibility of handwriting (Schwellnus et al., 2012). The grip patterns were immature in both groups, but half of the children with visual impairment used a primitive grip with extended fingers whereas more children with normal vision were using the more mature transitional quadripod grips. Although we did not find a relationship between the ability to write and the type of grip in the pre-writing task, we advocate the correction of immature grip in young children to stimulate learning to write with a dynamic pen grip (De Vries et al., 2015).

Previous research on the development of fine motor skills in children with visual impairment and normal vision aged 4–11 years has shown an age-related decrease in execution time and an increase in the accuracy of writing tasks (Reimer et al., 2015). The item putting coins in a moneybox was also used in the original version of the ManuVis for 4 years, which allows comparison of the scores of the 3-year-old children with visual impairment with the scores of older children with visual impairment. The results of the present study with the ManuVis support the trend shown in the previous study with the ManuVis: Older children with visual impairment are faster at performing the task putting coins in a moneybox than younger children with visual impairment (mean scores at: 3 years = 72 s, 4 years = 54 s, 5 years = 46 s, 6 years = 44 s; Reimer et al., 2015). Four-year-old children with visual impairment in our previous study performed the task putting coins in a moneybox at a similar level as done by 3-year-old children with normal vision in the present study, which demonstrates a possible delay in children with visual impairment.

The evaluation of fine motor skills in children with visual impairment is important. Identifying a child with motor deficits can prompt caregivers to employ motor tasks and play material that strengthen fine motor skills. For parents, it is difficult to estimate what a child can or cannot see, and this may lead to over- or under-estimation of their capabilities. It is important for parents of children with visual impairment to enable them to engage in activities focusing on fine motor skills and to encourage practicing fine motor tasks. At this young age, there is an important role for positive parent–child interactions (Dale & Salt, 2007). It is recommended to refer children to a developmental center as soon as severe visual impairment is suspected (Sonksen et al., 1991).

The main limitation of this study is the number of children included. This mostly affects the normative values for the ManuVis age band for 3-year-old children with visual impairment. Further research with more children is recommended to provide more valid reference scores. The sample was representative of 3-year-old children with visual impairment in the Netherlands. Although the number of children in each group was small, differences between the groups were significant. To reduce the possibility that delays in fine motor skills of children were caused by preterm birth rather than visual impairment, we excluded prematurely born children. We know from earlier studies that a preterm birth is a risk factor for brain damage and cerebral palsy. Even in the population of premature children without known deficits, the percentage of children with abnormal motor development is high. This ranges from 45% at the age of 2 years to about 37% at the age of 5 years (Feder

et al., 2005; Goyen et al., 2006; Janssen et al., 2008, 2011; Jongbloed-Pereboom et al., 2012).

Another limitation is that the design was cross-sectional. It would be advisable to monitor children with visual impairment and children with normal vision longitudinally to determine differences in individual developmental trajectories.

CONCLUSIONS

This study found excellent inter-rater reliability for the ManuVis age band for 3-year-old children while measurement error was acceptable. Moreover, the test was sensitive to differences between children with and without visual impairment, and between age categories. The ManuVis can be used to assess the development of fine motor skills of children with visual impairment (in the age range of 3–11 years) by comparing their performance with peers with (and without) visual impairment. Early identification of fine motor delay in children with visual impairment is encouraged to initiate coaching and preventive interventions as soon as possible (Reimer et al., 2011). Stimulating development of fine motor skills is recommended before children need these skills at school (Jongmans, 2005).

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