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Assessing handedness in pre-schoolers: Construction and initial validation of a hand preference test for 4-6-year-olds

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Abstract

The aim of this study was to develop and validate a test for measuring the handedness of pre-school children. The newly developed test consists of 14 activities for checking various aspects of hand preference and was administered to a Viennese sample of 120 children of the ages 4 to 6.5 (18 left-handed, 17 ambidextrous and 85 right-handed). For the purpose of validation, the handedness of the children was assessed via a questionnaire given to parents, observation of the hand used to draw and testing of visual-motor skills as well as general level of development using the Viennese Development Test (WET, Kastner-Koller & Deimann, 2002). The hand preference test proved to be reliable (α=0.97). The inter-correlations of the handedness measures gathered (parent's estimate as well as observation of drawing hand) with the hand preference test substantiates the concurrent validity of the procedure. Right-handers exhibited the most pronounced hand preference; while the hand use of left-handers was significantly less lateralized. Irrespective of the direction of handedness, children with a consistent hand preference had higher total development scores than children with inconsistent use, i.e. frequent changes in hand used for a specific activity. Compared to ambidextrous and right-handed children, left-handers achieved significantly lower scores in the field of visual-motor skills. The results highlight the necessity of a reliable method for differentiated measurement of handedness as early as pre-school.

Key words: Handedness, pre-school age, hand preference test

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1. Research goals

The importance of handedness of children comes into play within the context of the development of visual-motor skills and acquisition of cultural techniques. While half of all three-year-olds already show a clear preference for using either the right or left hand, this percentage rises to about 90 percent by the time children enter school (Öztürk, Durmazlar, Ural, Karaagaoglu, Yalaz & Anlar, 1999). Altogether, about 10 percent of all children show a preference for using the left hand, left-handedness is about 25 percent more common among boys than girls (Bryden & Steenhuis, 1997).

Correlations between lateral preference, spatial perception and fine and visual-motor skills have been empirically proved for pre-school children. Bryden and Steenhuis (1997) point out that distinctly developed handedness facilitates right-left differentiation and thus spatial orientation. Karapetsas and Vlachos (1997) were able to show that right-handers performed much better on the task of copying complex figures. They attributed this to the different speeds of brain development, the myelin coating of the corpus callosum and the lateralization of the hemispheres. Giagazoglu, Potiadou, Angelopoulou, Tsikoulas and Tsimaras (2001) compared the gross and fine motor skills of left and right-handed children and concluded that right-handers show significantly better fine motor skills. In both studies, left handed boys usually exhibited the lowest visual-motor and fine motor ability (Giagazoglu et al., 2001; Karapetsas & Vlachos, 1997).

Spatial orientation and visual-spatial intelligence develops through active handling of spatial conditions, especially grasping (Olsson & Rett, 1989). Perceptions of visual figures, directions and spatial relationships are an important pre-condition for learning to read and write. Perceptual differentiation of graphic symbols, such as e.g. letters, places demands on the perceptive and cognitive ability even of well-lateralized right-handed children entering school. Left-handed children have greater problems ascertaining the spatial position of letters and groups of letters, even if no switch in lateral preference has taken place. In a recent study carried out among 8-12-year-old pupils with writing difficulties, Bonoti, Vlachos and Metallidou (2005) found out that this group consisted almost exclusively of left-handers. As Olsson and Rett (1989) observed, left-handers do experience more difficulties learning cultural techniques than do right-handers, while left-handedness is not necessarily connected to dyslexia. In order to prevent learning difficulties among left-handed children and children without a distinct lateral preference, a diagnosis of laterality should be accomplished at preschool age.

In spite of the neuropsychological significance of handedness, the methods of assessment are open to debate. The easiest approach is to define handedness via the writing hand. The Hand-Dominanz-Test (Steingrüber & Lienert, 1976) for example, a handedness test for children from 6 to 10, is based on this approach. This procedure is often criticized, since using the right hand to write is suggested by culture (Bryden & Steenhuis, 1991). Generally, a distinction is made between two different ways of assessing handedness: lateral dominance tests check whether a task is easier to perform using the right or left hand (cf. Trolldenier, 1993, Annett, 1992, Tapley & Bryden, 1985). In contrast, tests which assess hand preference focus on the quality of the performance and spontaneous preference for a certain hand.

Reiss and Reiss (2000) distinguish among five diagnostic methods for ascertaining the preferred hand: in addition to determining the writing hand, the criteria used are self-

reporting, observation by and questioning of parents or caretakers, questionnaires and observation of children while performing certain tasks.

Beukelaar and Kroonenberg (1983) analyzed data on handedness gathered via questionnaires and found item clusters differing according to the muscle groups used in performing the activities. The first two clusters comprised activities involving the hand and wrist. The tasks in cluster three required the use of the entire arm (such as e.g. throwing a ball). The fourth cluster contained activities requiring precise finger movements and were more likely to be influenced by the environment than other activities (e.g., writing, drawing, sewing). The fifth cluster consisted of activities carried out using both hands while also tensing the back muscles (e.g. sweeping). According to the authors, interpreting the final two clusters proved to be difficult.

Steenhuis and Bryden (1989) also turned to musculature used in performing tasks when classifying the items for the Waterloo Handedness Questionnaire, but only made a dichotomous distinction into proximal and distal. Movements including the arm and shoulder or the axis of the body were termed proximal, while movements requiring only the use of the fingers and/or hand were designated as distal. Moreover, the authors distinguished between activities of picking up objects or manipulating objects. In their factor analysis, they could not identify any differences in hand preference related to movements of the proximal and distal musculature. Items for these two qualities were classified under the same factor. The two resulting factors differ mainly in that one factor comprised activities requiring skill, while another factor comprised automatic activities.

Questionnaires used to assess handedness, such as the Waterloo Handedness Questionnaire, are usually aimed at adult subjects. Using such questionnaires on children is of course subject to the usual limitations met in other diagnostic fields and is only possible when taking into account the level of verbal development, reading comprehension and self-perception. Adaptations for pre-school children have occasionally been used, providing for oral administration of items and requiring the child to provide a response by gesticulating (e.g. Karapetsas & Vlachos, 1997).

Krombholz (1993, cf. Tirosh, Stein & Harel, 1999) suggested an ethological approach for diagnosing handedness in children, based on video observations of play and everyday situations. Other authors have extended this approach to standardized observations (cf. Pryde, Bryden & Roy, 2000; Fagard & Marks, 2000).

Up to this point, there has been no test which enables a thorough assessment of handedness in pre-school children. The aim of this study was therefore to construct and carry out an initial validation of a hand preference test for kindergarten and pre-school children, which should fulfill the following requirements:

1. Assessment of hand preference irrespective of motor ability
2. Assessment of preference via standardized observations
3. Assessment of preference via an appealing test design which fosters motivation

2. Method

2.1 Construction of the hand preference test

Two selection criteria were utilized in the construction of items for assessing hand preference in children aged four to six. The aim was to develop tasks which can easily be carried out by children of this age group. Moreover, the content classification of the test items was based on Steenhuis and Bryden's (1989) idea of four components of movement types and musculature used and two qualities of execution. The movement components comprised (1) proximal movements involving arm and shoulder or the axis of the body, (2) distal movements involving the hand and/or fingers, (3) grasping objects and (4) manipulating objects. Each of these components was implemented in two stages of execution: (1) precise movements requiring skilled, often complementary use of the hands and (2) rapid, automatic movements. Table 1 relates the activities to components of movement and qualities of execution. Two activities were selected for each of these combinations, resulting in an item pool of 16 tasks. This ensured that the items covered as many aspects of handedness as possible.

To increase reliability (cf. Bryden and Steenhuis, 1997), each item was administered three times, which pre-supposed that one hand would be used in at least two out of three cases, thus making a preference obvious.

One major criterion of test development was the age-appropriate, appealing and motivating design of the testing conditions. To this end, the 48 tasks were integrated into the context of a treasure hunt. The test materials needed to accomplish the tasks were distributed all over the room in precisely determined positions (cf. example in Figure 1), explored with the child before the start of the test.

Table 1:
Hand preference test: Content classification of tasks

	Movements components			
Qualities of execution	**Proximal** (Movement of arm and shoulder and/or torso)	**Distal** (Movement of hand and/or fingers)	**Picking up**	**Manipulating**
precise	1) Throwing a ball 2) Sweeping the floor	5) Drawing 6) Rubber-stamping	9) Picking up a bead 10) Picking up a chain	13) Catching a fish using a magnet 14) Removing the lid of a can
automatic	3) Pointing to a dot 4) Waving	7) Counting the fingers of a hand 8) Rolling dice	11) Grasping candy 12) Grasping stickers	15) Turning a light switch on or off 16) Unzipping a zipper

The examiner then opened the treasure hunt with the following instructions: „Imagine you're an explorer on a voyage of adventure through this room. I have a tape here with a speaker asking you to perform some activities. At the end of the adventure you will hear where you can find a small treasure." An audio tape was used to provide the child with instructions against a music background. The child was to react to the instructions on the tape, receiving help from the examiner when necessary. The examiner also had the task of recording hand preference for every item on the observation sheet.

Figure 1:
Sample organization of test materials. The position of the child is labeled with x-marks on the floor, the examiner's observing position is right across from the child (chair)

2.2 Sample

120 Viennese kindergarten children of the ages 4.0 to 6.5 participated in the study, with 24 children in each half-year increment. These half-year groups included 12 girls and 12 boys each. The written consent form allowing the child to participate in the study included a question to the parents as to whether the child was left or right-handed (*global handedness*). After this initial rough assessment, the sample consisted of 85 right-handers and 35 left-handers, evenly distributed throughout the age groups.

6% of the mothers and twice as many fathers reported being left-handed themselves, but there was no family in which both parents were left-handed. There was no correlation between the handedness of the children and the fathers or mothers ($r_{Father/Child} = .07$, $p = .51$; $r_{Mother/Child} = .06$, $p = .55$). There was also no significant correlation between the occurrence of left-handedness in close relatives and the handedness of the child ($r = .11$, $p = .24$).

2.3 Measures

The newly developed hand preference test was administered to all the children (cf. Chap. 2.1). In order to carry out an initial validation, the handedness of the children was also assessed using two other methods, *parents' estimate* and *observation of the drawing hand*.

Parents' estimate: In addition to the global assessment of handedness within the context of the consent form, parents were also asked to fill out a short questionnaire. On a five-point scale („always left", „usually left", „no preference", „usually right" and „always right") they were asked to give an assessment of which hand the child used for five common everyday activities (drawing, throwing, cutting using scissors, holding a toothbrush when brushing teeth, holding a spoon when eating).

Observation of the drawing hand: While the child was taking the Vienna Developmental Test, the examiners observed which hand the child used for the drawings of the subtest *Nachzeichnen*.

Since left-handed children often exhibit problems with visual-motor skills, their developmental status was tested using the Vienna Developmental Test (WET, Kastner-Koller & Deimann, 2002).[2] The WET is a general developmental test for children aged 3 to 6. It is based on a social-ecological perspective of development pointing out the importance of social interaction for the acquisition of competences (e.g. scaffolding). Focussing on the enhancement of competences, the WET assesses the actual developmental level of a child in its entire scope. It provides a profile of strengths and weaknesses thus giving assistance in planning remedial interventions. In order to take into account the special needs of the age group three to six, the test material, tasks and test sequence were set up as a game. The WET consists of 13 subtests and a parent questionnaire, covering 6 functional areas of development (see table 2).

[2] Since 24 of the 120 children fell into the age group 6.0 – 6.5 year-olds the WET was not administered to them.

Table 2:
Vienna Developmental Test (WET): Areas of development, subtests and reliability coefficients

Area of development	Subtest	Number of items	Abilities	Split-half reliability coefficients
Motor development	"Turnen"	10	Gross motor skills	.84
	"Lernbär"	4	Fine motor skills	.72
Visual development/ Visual-motor coordination	"Nachzeichnen"	10	Drawing abilities	.84
	"Bilderlotto"	24	Spatial perception	.89
Memory	"Schatzkästchen"	6	Short-term memory-visual processing	.76
	"Zahlen Merken"	10	Short-term memory-verbal processing	.67
Cognitive development	"Muster Legen"	10	Analyzing patterns (block design)	.86
	"Bunte Formen"	10	Inductive reasoning	.91
	"Gegensätze"	15	Verbal reasoning by analogy	.84
	"Quiz"	11	Information and knowledge	.77
Language development	"Wörter Erkläre n"	10	Vocabulary, semantic development	.80
	"Puppenspiel"	13	Receptive language, syntactic development	.81
Psychosocial development	"Fotoalbum"	9	Interpreting emotional expressions, empathy	.81
	Parents Questionnaire	22	Autonomy, self-control	.90

An over-all developmental score (WET-total score) can be computed additionally (split-half reliability coefficient: .83).

After a thorough course of training, three examiners conducted the tests in Viennese Kindergartens. Two to three testing dates were needed for each child, and the test was administered in a quiet room.

3. Results

3.1. Item statistics and reliability coefficient

Within the context of the test, the hand preference of children was observed for 16 tasks, each of which was carried out three times. Thus, a total of 48 observations on hand use were available for each child. Tasks carried out using the right hand were marked with a 1, those with the left hand with a -1. A negative overall score thus indicated left-hand dominance, while a positive overall score indicated right-hand dominance.

An initial reliability analysis of all 48 observations resulted in an alpha of .96. Four observations showed item-total correlations lower than .3. All three trials of the item *Finger counting* as well as one trial of the item *Pointing to a dot* were concerned. Both items were removed from further analyses. Table 3 contains the item difficulties and item-total correlations before and after selection. The internal consistency of the reduced handedness scale with 42 items (14 tasks x 3 trials) amounts to a Cronbach's alpha of .97. The overall score ranges from -42 to +42, although the sample only achieved values of -40 to +42. Figure 2 shows the distribution of the total scores, which exhibits the J-shape typical of preference tests (cf. Bishop, 1990).

The consistency of hand use over all three trials was checked task per task. The codes were added up for each task. A value of –3 indicated that the corresponding activity was carried out with the left hand in all three runs. A value of +3 resulted if the right hand was used all three times. Children who attained a score of –3 or +3 consistently performed a task using the same hand. Table 4 clearly shows that at least 60% of the children accomplished the items consistently. The highest consistency was shown in the activity of *Drawing*. In this case, 119 out of 120 children always used the same hand. On average, the children performed 11 of the 14 activities consistently with one hand, so that it can be assumed that children of this age group already show a very clear preference for one hand.

Figure 2:
J-distribution of the total scores on the hand preference test (42 items)

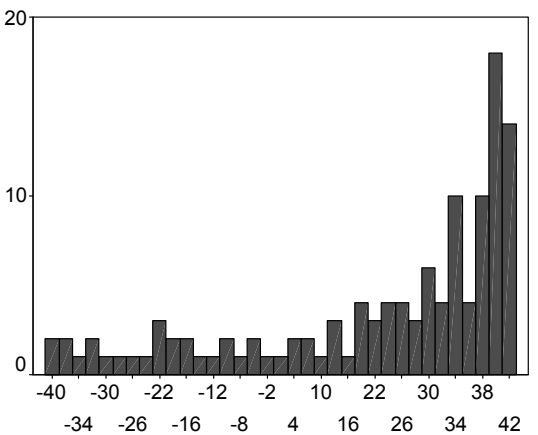

Table 3:
Hand preference test: Internal consistency und item-total correlations before and after selection of items with lower discriminatory power

Items		r_{it} **before**	r_{it} **after**	**Use of the**
Task	**trial**	**selection**	**selection**	**right hand (%)**
Throwing a ball	1	.66	.69	78.3
	2	.76	.78	77.5
	3	.59	.61	75.8
Sweeping the floor	1	.51	.53	67.5
	2	.65	.66	70.0
	3	.65	.67	70.0
Pointing to a dot	1	.35	---	64.2
	2	.08	---	64.2
	3	.42	---	72.5
Waving	1	.57	.55	82.5
	2	.65	.66	83.3
	3	.62	.64	80.0
Drawing	1	.81	.83	72.5
	2	.83	.85	73.3
	3	.83	.85	73.3
Rubber-stamping	1	.83	.85	75.8
	2	.81	.82	78.3
	3	.87	.87	75.8
Counting fingers	1	.07	---	27.5
	2	-.01	---	28.3
	3	.13	---	29.2
Rolling dice	1	.75	.75	81.7
	2	.70	.69	82.5
	3	.81	.81	75.8
Picking up beads	1	.59	.58	79.2
	2	.61	.60	75.8
	3	.74	.74	82.5
Catching a fish using a magnet	1	.73	.75	75.0
	2	.75	.76	75.0
	3	.70	.72	75.8
Picking up a chain	1	.61	.61	68.3
	2	.43	.44	69.2
	3	.56	.55	73.3
Grasping candy	1	.54	.54	65.8
	2	.57	.56	76.7
	3	.55	.54	72.5
Grasping stickers	1	.51	.51	74.2
	2	.58	.59	69.2
	3	.61	.61	73.3
Removing lid	1	.64	.63	68.3
	2	.67	.66	70.8
	3	.61	.60	69.2
Turning switch	1	.52	.52	76.6
	2	.66	.65	76.7
	3	.62	.61	69.2
Unzipping	1	.49	.49	71.7
	2	.53	.52	66.7
	3	.42	.41	65.0
Alpha (total scale)		**.96**	**.97**	

Table 4:
Hand consistency: Number of children with consistent hand use for each item (n = 120)

Item	***f***	**%**
Throwing ball	98	81.7
Sweeping floor	103	85.9
Waving	93	77.5
Drawing	119	99.2
Rubber-stamping	108	90.0
Rolling dice	102	85.0
Picking up a bead	97	80.9
Picking up a chain	74	61.7
Grasping candy	77	64.1
Grasping sticker	80	66.7
Fishing with a magnet	105	87.5
Removing the lid of a can	95	79.2
Turning light switch on/off	82	68.3
Unzipping a zipper	84	70.0

3.2 Validity

A whole host of information on the handedness and hand preference of the children was available from other sources for assessing the validity of the newly developed hand preference test. As was already mentioned, the parents had performed a global assessment on whether their child was left or right-handed when providing written consent (*Global handedness*). Moreover, a questionnaire was used to determine hand preference in five common every day activities, using a five-point rating scale (*Parents' estimate*) and a drawing assignment conducted independently of the hand preference test was observed by the test examiner (*Observation of drawing hand*). Table 5 provides the inter-correlations of these three variables and the hand preference test. The assessment of hand preference made by the parents was clearly based on their observations regarding which hand the child uses to draw. Thus, the global statement of whether the child is left or right-handed (*Global handedness*), corresponds precisely to the use of the *Drawing hand* observed within the course of testing. Even the more detailed *Parents' estimates* primarily report hand preference when drawing. In contrast to this, the inter-correlations of the three measures of handedness with the hand preference test do not only support the validity of the test, but also demonstrate that the hand preference test registers aspects of hand preference beyond those indicated by the drawing hand.

Table 5:
Inter-correlations of handedness measures

	Hand preference test	Observed drawing hand	Parents' estimate	Global handedness
Hand preference test	1.00 (n = 120)	.72 (n = 120) p = .000	.50 (n = 97) p = .000	.72 (n = 120) p = .000
Observed drawing hand		1.00 (n = 120)	.81 (n = 97) p = .000	1.00 (n = 97)
Parents' estimate			1.00 (n = 97)	.81 (n = 97) p = .000
Global handedness				1.00 (n = 120)

3.3 Hand preference and visual-motor skills

The overall score of the hand preference test was used to allocate the children to the groups left-handed, right-handed and ambidextrous. The range of values of the test goes from a possible raw score of -42 to +42. Children who performed more than two thirds of all tasks administered using one particular hand (left or right) were assigned to either the groups right-handers (RH) or left-handers (LH). For the left-handers this corresponded to scores of -42 to -15, and for the right-handers, a range of +15 to +42. Children attaining a total score of -14 to +14 were assigned to the group 'ambidextrous' – both hands (BH). The total sample comprised 18 left-handers, 17 ambidextrous and 85 right-handers (cf. Table 6). Test data concerning developmental status gathered using the Vienna Developmental Test was available for 96 children. The distribution of left, ambidextrous and right-handers in this sample is also shown in Table 6. The three groups differed significantly with respect to the consistency of hand preference. As expected, ambidextrous children tended to switch among the right and left hand most frequently, even when performing the same task. Right-handers exhibited the most prominent hand preference, while hand use was significantly less lateralized in the case of left-handers.

As previous empirical studies have shown, the visual-motor skills of left-handed children are less developed than those of right-handed children. For the sample at hand, we wanted to check whether left-handed, ambidextrous and right-handed children differed in terms of their overall level of development and whether left-handed children performed worse on visual-motor tasks. To this end, the children had to complete the subtest *Nachzeichnen* (a tracing task) which tests visual and graphic motor skills in a very narrowly defined sense. Furthermore a score out of all WET-subtests containing activities requiring visual-spatial and visual-motor skills was calculated. This *Visual-motor score* comprised the two subtests of the functional areas *Visual perception/Visual-motor-coordination (Bilderlotto* and *Nachzeichnen)*, as well as the subtest *Schatzkästchen* of the area *Learning and memory*, which tests

Table 6:
Hand preference test: Distribution of left-handed; ambidextrous and right-handed, medians of total scores and consistency of hand preference

Hand preference	*n* (total sample)	Hand preference test		*n* (WET-sample)	Hand preference test	
		Total score (Median)	Hand consistency (Median)		Total score (Median)	Hand consistency (Median)
LH	18	-27	10	15	-28	10
BH	17	2	8	14	0	8
RH	85	36	12	67	36	12
Kruskal-Wallis		$\chi^2 = 76.47$ $df = 2$ $p = .000$	$\chi^2 = 36.99$ $df = 2$ $p = .000$		$\chi^2 = 62.42$ $df = 2$ $p = .000$	$\chi^2 = 30.46$ $df = 2$ $p = .000$

visual-spatial memory and the subtest *Bunte Formen* of the area *Cognitive development*, which aside from placing demands on inductive reasoning, also entails processing of visual-spatial information. Moreover, the overall developmental score of the WET (*WET-Total*) was used as a measure of the child's general developmental level. Since left-handed, ambidextrous and right-handed children differed with respect to the consistency of their hand preference, this variable was used as a covariate in the analyses of covariance.

Table 7 shows the results of the univariate analyses of covariance with handedness as an independent variable, the total Centil values (*WET-Total*), the Centil value from the subtest *Nachzeichnen*, the *Visual-motor score* and the *Verbal score* as dependent variables, as well as *Hand consistency* as a covariate. The *Verbal score* comprised mainly tasks from the areas *Language*, *Psychosocial development* as well as the verbal subtests of the functional area *Cognitive development*. Level of type-1-error was set .05.

All four analyses of covariance yielded significant results, although hand preference and consistency of hand preference proved to have different effects. While hand preference had the largest effect on graphic-motor (subtest *Nachzeichnen*) as well as visual-motor and visual-spatial skills (*Visual-motor score*), consistency of hand preference influenced overall development (*WET-Total*, *Verbal score*, *Visual-motor score*).

The three hand preference groups did not differ significantly with respect to the total Centil values of the WET (*WET-total*). All three groups of children exhibited an average level of development (cf. Table 7). In contrast, the mean of the *Visual-motor score* of the group of left-handed children was significant below the mean of the ambidextrous and right-handed children. The lower visual-motor skills of left-handers especially came into play in the subtest *Nachzeichnen*. With an average Centil value of 3.67, the left-handed children were in need of remedial training concerning their graphic skills.

As described above, *Hand consistency* scores the amount of tasks required of the hand preference test that were performed using the same hand in all three runs. Children with high consistency scores always used either the left or right hand when performing a specific activity, but may have switched hands when changing to another activity (e.g. always drawing with the right hand, but throwing a ball with the left in all three runs). Children with low

Table 7:
Comparison of WET-results of left-handers, ambidextrous and right-handers – Means, standard deviations and results of univariate analyses of covariance

	Mean Centil values							
	WET-total		Subtest Nach-zeichnen		Visual-motor score		Verbal Score	
Hand preference	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
LH	4.73	2.19	3.67	1.63	4.80	1.08	4.97	1.69
BH	5.50	1.51	5.00	1.41	5.47	1.14	5.39	1.03
RH	5.91	1.74	4.84	1.61	5.59	1.10	5.71	1.46
total	5.67	1.82	4.68	1.63	5.45	1.13	5.54	1.45
Corrected Model								
F	4.76		2.85		4.72		3.31	
df	3		3		3		3	
p	.006		.042		.004		.024	
Factor: Hand preference								
F	1.83		3.52		3.83		1.05	
df	2		2		2		2	
p	.166		.034		.025		.356	
Co-variate: Consistency								
F	7.50		1.20		5.18		6.31	
df	1		1		1		1	
p	.007		.276		.025		.014	

consistency scores switched hands even within the three attempts of the same task (e.g. rubber-stamping twice using the right hand, and once with the left). Children with consistent hand preference generally exhibited higher scores in overall development than did children with inconsistent use, i.e. frequent changes of hand within an activity.

4. Discussion

The aim of this study was the construction of an objective, reliable, valid, but also age-appropriate preference test for analyzing handedness among four to six year old children. The assessment of preschoolers' handedness seems to be relevant since left-handed children often develop poor visual-motor skills which may further affect graphic and writing skills. Operationalization of the construct of handedness was intended to go beyond the oberservation of the drawing hand, a method common for this age group but often criticized. Therefore, items were developed according to the Steenhuis and Bryden's (1989) concept, which allows task analysis with regard to the movements involved and the quality of execution. Validation was based on information concerning handedness from independent sources: A global estimate of handedness and a detailed rating of hand preference when performing

everyday tasks were requested from the parents; the examiner was asked to observe the drawing hand outside the scope of the hand preference test.

The claim of developing an appealing age-appropriate and motivating hand preference test was realized by designing the test as an adventure and embedding the tasks within the context of a treasure hunt. Test objectivity was ensured in several ways: instructions were given via an audio cassette, and the positions of the test materials were pre-determined, as was the location of the child while performing the individual tasks. Since the examiner only had to record whether the child used its right or left hand, adequate objectivity can be assumed. As test analyses have shown, high internal consistency can be assigned to the hand preference test, item statistics were satisfactory throughout.

In order to ensure content validity, the hand preference test was designed as a preference test, thus eliminating the influence of fine motor skills on the test score. The medium to high correlations of the hand preference test to other measures of handedness underline the high concurrent validity of the test. Anyhow, the test does not merely assess hand preference with drawing but with a broader range of activities.

Estimates of handedness performed by the parents provided insight into their mental concept of the construct of handedness, which is obviously determined by the child's drawing hand. While the global estimate of the parents exhibited a relatively high correlation with the result of the hand preference test, the correlation was considerably lower when the parents tried to provide a detailed analysis. This is typical for the reliability of parents' estimates: they yield more precise estimates of their child's development and behavior when asked for a global assessment than for a detailed evaluation (cf. Deimann, Kastner-Koller, Benka, Kainz & Schmidt, 2005; Glascoe & Sandler, 1995).

As in other studies, left-handed children scored lower on visual-motor and visual-spatial tasks in this study (cf. Bonoti et al., 2005; Giagazoglu et al., 2001; Karapetsas & Vlachos, 1997; Olsson & Rett, 1989), even though they did not differ from right-handed or ambidextrous children in terms of other developmental domains. In tracing geometric figures such as an x-mark, circle or triangle (the subtest *Nachzeichnen* of the WET), left-handers scored so low as to indicate a need for remedial training. Although the administration of the hand preference test did not put left-handed children at a disadvantage, these children may still have experienced unfavorable conditions in an environment which is tailored to right-handers. From a social-ecological perspective such experiences might not have been conducive to the left-handers' previous visual-motor development (cf. also Gallo, Angioletti & Viviani, 2000).

Taking into account not only handedness but also consistency of hand use, a detailed view on the connection between hand preference and development of pre-school children emerges. Irrespective of lateral preference, children who tended to repeatedly perform a task with the same hand, were generally better developed than children whose use of hands was less consistent. Although ambidextrous children showed the least consistency and right-handers the greatest, as was expected, all three groups contained children with higher and lower levels of consistency. Thus, the consistent use of a particular hand to perform the tasks of the hand preference test can be seen as an indicator of lateralization. The pronounced lateralization of right-handers in comparison to ambidextrous or left-handers has been well-documented (cf. Polemikos & Papaeliou, 2000; Bishop, 1990).

The lower level of development of children with inconsistent handedness, which was especially apparent in the WET-subtests with verbal components, may be due to a less pro-

nounced functional specialization of the cerebral hemispheres. It is interesting to note, however, that the total score of the hand preference test does not suffice to identify differences in developmental level. This approach has been used in other studies, e.g. by classification into definite or less definite right-handers, also leading to differences in cognitive ability (cf. Papousek & Schulter, 1999). The importance of consistency is best shown when it comes to the ambidextrous: consistently ambidextrous children may use different hands when performing different tasks, but they have a clear preference when it comes to which hand they use for a particular activity. Those who are inconsistently ambidextrous neither have a clear preference in the case of specific tasks nor in general, leading to unfavorable overall development.

This connection between hand preference and hand consistency with pre-school development needs to be tested for clinical relevance, e.g. in children with developmental problems; a detailed analysis of lateral preference in this age group is crucial.

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