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Relationship Between Visual-Motor Integration, Eye-Hand Coordination, and Quality of Handwriting

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If the influence of visual-motor integration (copying forms) on the quality of handwriting has been widely investigated, the influence of eye-hand coordination (tracing item) has been less well analyzed. The Concise Assessment Scale for Children's Handwriting *(BHK), the* Developmental Test of Visual Perception *(DTVP-2), and the section "Manual Dexterity" of the* Movement Assessment Battery for Children *(M-ABC) were administered to a group of second grade children (N = 75; 8.1-year-olds). The association of visual-motor integration and eye-hand coordination are predictive of the quality of handwriting (p < . 001). These two skills should be taken into consideration when children are referred to occupational therapy for difficulties in handwriting.*

Keywords Visual motor coordination, motor skills, pediatrics, school

Children with non-proficient handwriting are often referred for occupational therapy (Cornhill & Case-Smith, 1996). Treatment varies according to the causes of non-proficient handwriting, which can result from inappropriate extrinsic factors such as biomechanical or environmental components (Rosenblum, Goldstand, & Parush, 2006) and/or from intrinsic factors such as poor performance in perceptual and motor skills (Feder & Majnemer, 2007). The relationship between perceptual-motor skills and handwriting has been investigated from two different but complementary theoretical frameworks: (1) the developmental perspective with regard to the question of readiness for handwriting (Beery, 1989) or to the identification of difficulties of handwriting and (2) the hierarchical model of motor control wherein visual and kinesthetic feedback information is required to perform handwriting (Maeland, 1992; Smits-Engelsman, Niemeijer, & Van Galen, 2001).

From these two theoretical frameworks, many studies have investigated the relationship between the quality of handwriting and visual-motor integration although no consensus concerning the definition of visual-motor integration exists. Beery (2004) defined it as the coordination between visual perception and movement of fingers, which is measured by a

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copying forms task in the *Beery-Buktenica Developmental Test of Visual-Motor Integration* (VMI; Beery, 2004). These authors differentiated the visual-motor integration from the motor coordination that is evaluated by a tracing task (capacity of drawing a line between two lines or on a large line). Conversely, the tracing item of the *Motor Accuracy Test* (MAC) included in the *Sensory Integration and Praxis Test* (SIPT; Ayres, 1989) measured eye-hand coordination. Regardless of how those tracing items are named, they are differentiated from visual-motor integration that requires more visual perception than eye-hand coordination. The latter needs more visual control. In this study, we retained "eye-hand coordination" instead of motor coordination.

Contrary to Beery (2004), Hammill, Pearson, and Voress (1993) had a larger comprehension of visual-motor integration than Beery. They included both tracing and copying tasks with two other items (spatial relations and visual-motor speed) in *Visual-Motor Integration* subscore of the *Developmental Test of Visual Perception-2* (DTVP-2; Hammill et al., 1993). In this test, the tracing item is named "eye-hand coordination."

There are three differences between the tracing items of these three tests (MAC, DTVP-2, and VMI). First is the size of the circuits; there is large loop-hold on a double page in the MAC, whereas the sizes of the shapes of the VMI and in the DTVP-2 are smaller in the subtest. Second is the complexity of the forms; there are large curves in the MAC and angles in the DTVP-2 and very complex figures in the VMI. Finaly, the width of the tracing space is bigger in the VMI than in the MAC and than in most of items of the eye-hand coordination in the DTVP-2.

The relationship between handwriting and visual-motor integration such as defined by Beery (2004) was investigated with children without any known disorder and also with children who present an identified disorder. In a developmental perspective, visual-motor integration has been investigated as a prerequisite skill before learning handwriting. Studies (Daly, Kelley, & Krauss, 2003; Marr, Windsor, & Cermark, 2001; Weil & Cunningham Amundson, 1994) were conducted with kindergarten children and used the *Scale of Children's Readiness in PrinTing* (SCRIPT; Weil & Cunningham Amundson, 1994) and the VMI (Beery, 1989). Significant correlations were measured: $r = .39$ ($p < .05$) in the study of Marr, Windsor, and Cermark (2001); $r = .47$ ($p < .01$) in the study of Weil and Cunningham Amundson, 1994); and $r = .64$ ($p < .05$) in the one of Daly et al. (2003). For older children, Tseng and Murray (1994) used a copy of text and the VMI in a study among a group of children including proficient and non-proficient handwriters in grades 3 to 5. They found a significant relationship ($r = .55$; $p < .05$). Cornhill and Case-Smith (1996), who administered *the Minnesota Handwriting Test* (Reisman, 1993) to children of the mean age of 7.3 years, identified a significant relationship with the VMI ($r = .60$; $p < .05$). Karlsdottir and Stefansson (2003) found that the correlation between the results of the VMI and the quality of handwriting tend to decrease with age.

Other studies have been carried out among samples of children with identified disorders. Within a group of children (10 year-olds) composed of clumsy children and of dysgraphic children, Maeland (1992) investigated the relationship between the VMI and the quality of handwriting based on a dictation. For the dysgraphic group, this relationship was not significant ($r = -.02$). For the clumsy children, the correlation was significant ($r = 40$; $p < .05$) and in the study by Malloy-Miller, Polatajko, Ansett (1995) who administered the VMI and the *Handwriting Evaluation Scale* (Malloy-Miller, 1985) to children with mild motor difficulties ($r = .37$; $p < .05$). Volman, van Schendel, and Jongmans (2006) confirmed a significant relationship ($r = .48$; $p < .01$) between visual-motor integration and the quality of handwriting with children who present developmental coordination disorder (American Psychiatric Association [APA], 1994). They administered the VMI and the *Concise Assessment Method for Children's Handwriting* (BHK; Hamstra-Bletz, Bie, & Brinker, 1987). In contrast, in a group of preterm children aged 6 to 7 years, Feder Najemer, Bourbonnais, Platt, Blayney, and Synnes (2005) did not measure a significant relationship between the *Evaluation Tool of Children's Handwriting-Manuscript* (Amundson, 1995) and the VMI.

The predictive value of visual-motor integration of the quality of handwriting is considered positive in some studies (Cornhill & Case-Smith, 1996; Maki, Voeten, Vauras, & Poskiparta, 2001; Weintraub & Graham, 2000) but not in others. Marr and Cermark (2002) did not find that the results of the VMI at kindergarten were predictive of non-proficient handwriting at first grade. Moreover, Goyen and Duff (2005) reported a low sensitivity rate of 34% for the VMI (Beery, 2004) to identify poor performance in handwriting. These two studies present a difference of method; the one by Goyen and Duff has been based on results of tests administered at the same period, whereas the study by Marr and Cermark included the prediction of the quality of handwriting in time (after 1 year).

For eye-hand coordination measured with the MAC (Ayres, 1989), the relationship between tracing scores and the quality of handwriting differed from one study to another. Among regular school children, Tseng and Murray (1994) and Cornhill and Case-Smith (1996) found a significant correlation and, respectively, $r = .47$ ($p < .01$) and $r = .59$ ($p < .01$). Karlsdottir and Stefansson (2002) measured a significant correlation only in the case of boys.

Among preterm children, Feder et al. (2005) found a significant correlation ($r = .34$; $p < .01$) between the results of the MAC (Ayres, 1989) and the quality of handwriting as did Volman et al. (2006), who found a significant correlation between the sub-score *Motor Coordination* of the VMI and the total score of the BHK among a group of children with non-proficient handwriting. These similar results must be interpreted with caution because the test differs.

Conversely, Maeland (1992) did not find any significant relationship between the quality of handwriting and the MAC. Tseng and Murray (1994) found that the MAC was a predictor of the quality of handwriting in second position after the VMI. In contrast, Cornhill and Case-Smith (1996) and Karlsdottir & Stefansson (2002) did not measure that the MAC had a predictive value of the quality of handwriting.

To our knowledge, no research has discussed the lack of consistency of tracing items measuring eye-hand coordination or motor coordination. No study has analyzed the differences between two different tracing tests (DTVP-2 and M-ABC). The predictive value of eye-hand coordination has been less investigated than visual-motor integration. No study discussed the differences between the conception of visual-motor integration of Beery (1989) and the one of Hammill et al. (1993) and addressed the predictive value of the sub-score *Visual-Motor Integration* from the DTVP-2. Among a sample of second-grade children ages 8 years, few studies have investigated the relationship between visual-motor integration, eye-hand coordination, and quality of handwriting. This age and this grade are interesting because the children should have mastered handwriting.

Apart from the study by Volman et al. (2006), which administered the entire VMI, no other study has used the same test to measure visual-motor integration and eye-hand coordination. The use of the same test ensures the same normative procedures and gives a better point of comparison. Moreover, for clinical practice, it appears important to identify the skills that could relate non-proficient handwriting to effective treatment.

This study aims to (1) analyze the relationship between the quality of handwriting and the items of *Visual-Motor Integration* of the DTVP-2, (2) investigate the differences of correlation between tracing item (as measured in the DTVP-2) and the quality of handwriting versus tracing item (as measured in the M-ABC) and the quality of handwriting, (3) analyze the predictive value of the four items of the *Visual-Motor Integration* of the

DTVP-2, and (4) of analyze the predictive value of the composite score *Visual-Motor Integration* of the DTVP-2.

Method

Participants

Seventy-five children (N = 75; mean age = 8.1 years; standard deviation [SD] = 0.37), second-graders from a regular public school in the French part of Switzerland, took part in the study. They were from 10 multilevel classes, and they have no identified developmental disorder. This sample was chosen on the basis of the different results of a test of handwriting that was the French version of the BHK (Charles, Soppelsa, & Albaret, 2003). Three types of results were retained: <1 SD (n = 19), <2 SD (n = 21), and >0 to 2 SD (n = 35). The sample was composed of 52 boys and 23 girls. No significant difference in quality and speed was found between girls and boys in this sample. They were all fluent French speakers.

Procedure

The project research was accepted by the Swiss National Fund Research and by the direction of the Department of Public Education subject to agreement on certain ethical considerations. The school volunteered to be part of the project. Parents gave first written agreement for the administration of the French BHK. Then, the parents of the 75 children retained gave their written consent. They were informed that they could withdraw their child at any time during the study.

Two weeks after the administration of the BHK, the children (N = 75) were tested individually during school time by the first author or by students who were trained and supervised by her. The children were assessed using the French version of the *Movement Assessment Battery for Children* (M-ABC; Henderson, & Sugden, 1992; Soppelsa & Albaret, 2004) and the entire DTVP-2 (Hammill et al., 1993).

Measures

The French version of the BHK (Charles et al., 2003) measures the quality and the speed of handwriting. In this test, the child was asked to copy a text for 5 minutes. The first five lines are considered in the assessment process, which is based on 13 criteria: (1) letter size, (2) left margin widening, (3) poor word alignment, (4) insufficient word spacing, (5) acute turns in connecting letters or too long joining (chaotic writing), (6) irregularities in joining strokes, (7) collision of letters, (8) inconsistent letter size, (9) incorrect relative height of letters, (10) letter distortion, (11) ambiguous letter forms, (12) correction of letter forms, and (13) unsteady writing trace. For overall quality of handwriting, the minimal score in this test is zero and the maximal score is 65. A score of less than 20 means “no difficulty,” between 21 to 28 means “poor handwriting,” and a score at or above 29 means “very poor handwriting” (Hamstra-Bletz, & Blöte, 1993). The inter-rater reliability for this assessment is .90, and the concurrent validity with a teacher’s judgment is 0.68 (p < .01; Charles et al., 2003). Speed is measured by counting the number of letters written in five minutes.

The French version of the *Movement Assessment Battery for Children* (Henderson & Sugden, 1992; Soppelsa & Albaret, 2004) measures manual dexterity, ball skills, and balance. The test is composed of four age bands (4–6; 7–8; 9–10; and 11–12 years) with test items varying from one age band to another. The items of manual dexterity include a tracing item that was retained to analyze the eye-hand coordination. The test-retest reliability coefficient is 0.75, and the inter-rater reliability is 0.70 to 0.89 (Henderson & Sugden, 1992).

The DTVP-2 (Hammill et al., 1993) measures *Visual-Motor Integration* and *Visual Perception* for children between 4 and 10 years of age. Four visual-motor integration items (eye-hand coordination, copying forms, spatial relations, visual motor speed) alternate with four visual perception items (position in space, figure-ground, form completion, form consistency). A total score and two sub-scores (visual motor and visual perception) are related to quotients, age equivalence, and percentiles. Test-retest reliability is above .80 for all ages. Inter-rater reliability is high, with correlations between .92 and .99.

Data Analysis

Tracing items of the M-ABC and of the DTVP-2 were used to measure eye-hand coordination, whereas visual-motor integration was represented by performance in copying forms item of the DTVP-2.

A Pearson product-moment correlation analysis examined the relationship between the quality of handwriting and (1) visual-motor integration, (2) eye-hand coordination, and (3) composite score of DTVP-2. An alpha level of .05 was used. Stepwise linear regression analysis was performed to investigate predictors of the quality of handwriting.

Results

A significant relationship was found between the quality of handwriting and all the items composing the VMI subscore of the DTVP-2 (Table 1). Copying and tracing items have a stronger relationship than the other items. The tracing item from the DTVP-2 ($r = .36$, $p < .01$) had a stronger relationship with the quality of handwriting than the tracing item from the M-ABC ($r = .22$, $p < .05$). Then an analysis of correlation between items of the BHK indicated that only the items that measure more specifically

Table 1

Correlation between quality of handwriting, tracing item of M-ABC, and visual-motor integration items of DTVP-2

	M-ABC, TR	DTVP-2, TR	DTVP-2, CO	DTVP-2, SR	DTVP-2, VMS	DTVP-2, VMI
BHK-Quality	.22*	.36**	.37**	.23*	.25*	.45**
M-ABC, TR	–	.29**	.38**	.05	.20	.22*
DTVP-2, TR	–	–	.40**	.25*	.32*	.75**
DTVP-2, CO	–	–	–	.31**	.33**	.71**
DTVP-2, SR	–	–	–	–	.01	.54**
DTVP-2, VMS	–	–	–	–	–	.62**
DTVP-2, VMI	–	–	–	–	–	–

TR = tracing; CO = copying; SR = spatial relations; VMS = visual-motor speed; VMI = *Visual-Motor Integration* sub-score.

$*p \le .05$, $**p \le .01$.

Table 2
Correlation between items of BHK that measure the quality of trace and form of the letters and tracing and copying form items of the DTVP-2

	DTVP-2, CO	BHK, C. HWR	BHK, U. Trace	BHK, C. L. F.
DTVP-2, TR	.40**	.32**	.33**	.26*
DTVP-2, CO	–	.40**	.40**	.37**
BHK, C. HWR	–	–	.62**	.31**
BHK, U. Trace	–	–	–	.37**
BHK, C. L. F.	–	–	–	–

CO = copying; C. HWR = chaotic handwriting; correct.; U. Trace = unsteady trace; C. L. F. = correction of letter forms.
$*p \leq .05$, $**p \leq .01$.

the quality of trace (acute turns in connecting letters or too long joining, unsteady trace) were significantly related to the score of tracing items of the DTVP-2 (Table 2). The item "copying" of the DTVP-2 had also a significant relationship with the item "correction of letter forms." If the four items of the visual-motor integration are introduced in the model, the association of the copying and tracing items are significantly predictive ($R^2 = .19$; $F = 8.65$; $p < .001$). A stepwise regression analysis with the subscore of *Visual-Motor Integration* indicated a predictive value ($R^2 = .21$; $F = 19.48$; $p < .001$).

Discussion

The results of the item of copying forms from the DTVP-2 showed a significant relationship with the quality of handwriting that confirmed the results of other studies (Cornhill & Case-Smith, 1996; Karlsdottir & Stefansson, 2002; Tseng & Murray, 1994). These studies used the VMI (Beery, 2004) and a copy of text to measure the quality of handwriting. In our study, the value of the Pearson correlation ($r = .37$) is the same as that of Karlsdottir and Stefansson among a sample of 8-year-old children. The study of Cornhill and Case-Smith presented a higher value of the Pearson correlation ($r = .60$) but was realized with younger children (7.3 years old). Tseng and Murray also found a higher correlation ($r = .55$) but, if the grade is known (3–5), the age of the children was not stated.

The relationship between the results of the tracing item of the DTVP-2 and quality of handwriting and the relationship between items of the BHK that measured the quality of the trace are significant. These results confirmed those of previous studies (Cornhill & Case-Smith, 1996; Maeland, 1992; Tseng & Murray, 1994). The test used in our study was different from the MAC (Ayres, 1989). The MAC is timed and requires large movement of the arm, whereas the items of the DTVP-2 need to be realized with more digital movements than the MAC. Fine-motor control is needed especially when the circuits are small and the space between lines is thin. The child has to anticipate the change of curve and the need to stop or to slow his or her movement more often and more quickly. The trace must be precise and regular such as in a handwriting task. Irregularities in tracing letters could be related to difficulties in visual control of a movement or in motor control. Smits-Engelsman and Van Galen (1997) suggested a neuromotor noise that produces unsteady traces during handwriting.

The tracing item of the M-ABC had a weaker relationship with the quality of handwriting than the tracing items of the DTVP-2. Composed of four tracing tasks, the DTVP-2 has a better capacity of measuring eye-hand coordination skill than the item of the M-ABC, which has only one task.

The predictive value of the association of tracing (eye-hand coordination) and of copying forms items (visual-motor integration) found in our study is quite similar to that of Tseng and Murray (1994). This research showed that they found these two skills to be predictive of the quality of handwriting. Visual-motor integration as defined by Beery (copying item) was not alone a predictor of the quality of handwriting. These results differed from those of Cornhill and Case-Smith (1996), who found that the VMI was the predictor of the quality of handwriting. They used the MHT and the VMI among younger children (7.3 years old), which could be one explanation for this difference.

If the visual-motor integration related to Beery's conception is not a predictor alone, visual-motor integration as defined by Hammill et al. (1993) with four paper and pencil items has a predictive value. It includes different tasks such as tracing, copying forms, relying dots to reproduce a shape (spatial relations), and drawing cross in square and two horizontal lines in a circle without exceeding the limits (visual-motor speed). The item "spatial relations" measures the capacity of aiming, which is required in baseline orientation of the letters on the line. The item "visual-motor speed" evaluates the capacity of stopping a trace in a limit such as in handwriting to form the letter or joint between the letters.

From our results, if a child presents weak results at a handwriting test, the occupational therapist should consider at least two measures: copying and tracing items. For children 8 years old, the administration of the DTVP-2 could give more informations on visual-motor integration skills.

Limitations and Conclusion

This research was carried out among a group of children whose mean age was 8.1 years. The results cannot be applied to older children because the relationship decreased with age as showed by Karlsodttir and Stefansson (2002). Another test measuring visual motor integration should have been administered to sustain these results. Speed and legibility of handwriting have not been considered in this research, although quality interferes in legibility. The result of the composite score "visual perception" of the DTVP-2 was not presented in this study because of the lack of significant results.

Most of the studies on handwriting measured only visual-motor integration with the test VMI of Beery (Daly et al., 2003; Malloy-Miller et al., 1995; Marr et al., 2001; Weil & Amundson Cunningham, 1994). As we have shown, eye-hand coordination associated with visual-motor integration is a predictor of the quality of handwriting. Instead of separating these different but similar paper-and-pencil tasks to measure in fact the coordination of motor and visual controls, visual-motor integration should be considered as a whole, including tracing items and copying form items or using the larger conception of Hammill et al. (2003). Our study has investigated the differences of relationship of different skills measured by the same test and to our knowledge, apart from Volman et al. (2006), no study have done this.

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