Psychological Test and Assessment Modeling, Volume 55, 2013 (3), 274-288

Identifying the causes of underachievement: A plea for the inclusion of fine motor skills

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Abstract

Underachievers are children who show academic performance that is lower than what would be expected for their IQ. Previous research has investigated a number of variables that might explain underachievement and recently fine motor skills (FMS) have been implicated as playing an important role. We extend this work by exploring the influence of FMS and attention on underachievement and achievement. Fourth-grade children in Germany (n = 357, age = 10.8) were tested on measures of intelligence, attention, and FMS, and teachers were asked to report grades in mathematics. Amongst other findings, analyses indicated that underachievers had lower attention and FMS and that attention mediated the relation between FMS and maths achievement. Overall, the current findings contribute to the growing body of evidence that FMS play an important role in underachievement and are, therefore, a candidate for inclusion in the identification processes.

Keywords: fine motor skills; underachievement; giftedness; academic achievement; attention

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Underachievers are pupils for whom measures of academic performance or achievement remain considerably lower than expected based on their cognitive or intellectual ability (Butler-Por, 1987; Peters, Grager-Loidl, & Supplee, 2000; Reis & McCoach, 2000). Consequently, understanding the causes of underachievement is of paramount importance to giftedness research, which may explain the increasing popularity of investigating influences on underachievement.

In the hunt for explanatory variables clarifying the causes of underachievement, researchers have discussed numerous individual and environmental variables, such as motivational deficits, underdeveloped learning skills, poor ability concepts, developmental factors, and personality parameters in addition to, on the environmental side, the influence of parents, peers, and media. Qualitative clinical or single-subject studies have reported in detail some of these influences (for an overview cf. Peters et al., 2000; Peterson & Colangelo, 1996; Reis & McCoach, 2000). However, only a small number of studies report quantitative investigations of whether such explanatory variables actually differentiate between achievers and underachievers.

In one such study, McCoach and Siegle (2003) empirically examined variables thought to play a role in underachievement. Specifically, they showed that achievers and underachievers differed according to general academic self-perceptions, attitudes towards school and teachers, motivation, self-regulation, and goal valuation, and were able to predict achievement status based on these variables. It is important to extend the work in this study by investigating additional underlying cognitive and developmental variables playing a role in underachievement.

Investigating the role of what could be considered more underlying cognitive factors, Stoeger, Ziegler, and Martzog (2008) investigated the role of various variables in achievement in a sample of 576 fourth graders. They demonstrated that achievement and underachievement could be best predicted by fine motor skills (FMS) and the interaction between fine motor skills and attention. In this study, we seek to build on the unique findings of Stoeger and colleagues (2008) and will examine the connection between FMS and underachievement in more detail. We will firstly seek to replicate previous work and test whether FMS differentiate between achievers and underachievers. Second, with the aim of examining the causes of underachievement in more detail, we examine the interplay between FMS and attention and their influence on performance and underachievement.

Fine motor skills and cognition

Numerous empirical studies have examined the relationship between FMS and cognitive abilities on the one hand and between FMS and academic achievement on the other hand. Overall, evidence for links between FMS and both general and specific cognitive abilities is particularly clear for preschool-aged children (Davis, Pitchford, & Limback, 2011; Dellatolas et al., 2003; Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010).

Specifically, cross-sectional work has established links between FMS and the embedded figures test and semantic fluency (Dellatolas et al., 2003) as well as between FMS and crystalline intelligence, memory, and fluid reasoning (Davis et al., 2011). Recently, in longitudinal studies, Martzog and Stoeger (2011) found links between FMS and cognitive processing skills one year later; and Grissmer and colleagues (2010) found links between FMS and cognitive processing skills such as receptive vocabulary and attention skills. Overall, it appears that links between FMS and cognitive abilities are stronger for young children and weaken as children age (Martzog & Stoeger, 2011).

Fine motor skills and academic achievement

In terms of academic skills, numerous studies, some of which were longitudinal, have identified connections between FMS and mathematics achievement as well as between FMS and reading achievement (Grissmer et al., 2010; Luo, Jose, Huntsinger, & Pigott, 2007; Pagani, Fitzpatrick, Archambault, & Janosz, 2010; Tramontana, Hooper, & Selzer, 1988). Moreover, FMS measured in early childhood continue to have some predictive relevance for academic achievement through to fourth grade at least. Overall, studies show that the links between FMS and mathematics achievement are considerably stronger than those for FMS and reading. In light of these predictive relations across the entire primary-school period, it seems plausible that deficits in FMS could also play a role in underachievement during primary school.

Research on FMS and underachievement

By and large, the growing number of studies indicating links between achievement and FMS has been largely overlooked in giftedness research. However, exceptions exist. Ziegler and Stoeger (2010) examined the influence of FMS in the identification of gifted achievers and underachievers from 788 fourth-graders. They demonstrated that an IQ test placing low demands on FMS led to the identification of more underachievers than an IQ test with higher FMS demands. Although this result may at first seem counterintuitive, it makes sense when one differentiates between IQ-test underachievement and underachievement as it is usually defined in giftedness research. Specifically, giftedness researchers typically define underachievement as an unexpectedly low level of achievement by a gifted person with respect to her or his IQ. As such, when gifted pupils are to be identified via an IQ test that places considerable FMS demands upon them, FMS deficits will prevent some pupils from being identified as gifted. These pupils can also not be identified as gifted underachievers, therefore, simply because FMS were not adequately taken into account. In short, IQ tests that place lower demands on FMS make it possible for pupils with FMS deficits to achieve high scores that are presumably more reflective of their cognitive abilities.

In addition to disadvantaging estimates of IQ, FMS deficits are known to negatively affect scholastic achievement. Thus, as we now review, gifted pupils with FMS deficits are more likely to be gifted underachievers because these deficits hinder their academic performance and render them more likely to have a greater IQ-achievement discrepancy.

In support of this notion, Stoeger et al. (2008) showed in their study of around 1200 fourth-grade pupils that 31 gifted underachievers and 97 gifted achievers differed in their FMS. Using a logistical regression analysis, the authors then correctly categorized 84 percent of participants as to their status as either gifted achievers or gifted underachievers based on their FMS and attention. In a further study of 15 fourth-grade gifted underachievers and 38 fourth-grade gifted achievers, Stoeger and Ziegler (2013) could again differentiate between gifted achievers and gifted underachievers according to FMS. Moreover, they also showed that differences in persistence between gifted underachievers and gifted achievers reflect, at least in part, FMS deficits of the first group.

Attention as a mediator between FMS and achievement?

Building on findings showing that attention, FMS, and achievement relate to one another, we now explore in detail the possibility that attention mediates the relation between FMS and achievement. First we note that Stoeger et al. (2008) used a logistic regression analysis to show that the interaction term between FMS and attention predicted whether participants were achievers or underachievers. Among underachievers, the proportion of students with FMS deficits *and* low attention scores was 52%, among achievers this rate was 21%. However, Stoeger et al. (2008) did not examine the nature of the interaction between FMS and attention in more detail and test whether attention mediates between FMS and achievement. Theoretically, it is plausible that pupils with FMS deficits achieve lower grades because they are more distracted during classroom instruction and homework by the manual aspects involved in copying information from the board, taking notes, completing homework, and underlining. Accordingly, pupils with FMS deficits ought to have less attention capacity available for high-level cognitive functions such as following instructions or executing learning tasks. Indeed, various studies show that diminished attention capacity demands during the production of texts (e.g., when pupils are to write down what a teacher reads aloud) lead to a decline in the quantity and quality of text production (Christensen, 2004, 2005; Graham, 1990; Scardamalia, Bereiter, & Goleman, 1982). Clearly, however, more research is needed to test the roles that FMS and attention play in achievement, especially with regard to the possible mediating role of attention.

Aims of the study and hypotheses

In the current study, we seek to build upon these pioneering studies that were the first to explore the interplay between various explanatory variables of underachievement while also considering FMS. Here we seek to more closely examine the interaction of FMS and attention in underachievement. Crucially, attention may mediate the relation between

FMS and cognitive and academic skills, as has been suggested in previous work (e.g., Grissmer et al. 2010; Pagani et al., 2010; Stoeger et al., 2008).

Our first goal was to replicate the results of Stoeger and colleagues (2008) and Stoeger and Ziegler (2013) on how gifted achievers and underachievers were differentiated according to FMS. To this end we used two different FMS tests, differing on whether they were closely related to the kind of academic tasks required to achieve academically. In one test, which closely represents the demands children are expected to meet in academic environments, participants were required to copy Greek letters (cf. Stoeger & Ziegler, 2013); and, in a second task, a less inherently academic labyrinth test was used (cf. Stoeger & Ziegler, 2013). Our second goal was to more closely examine the interplay of the two key explanatory variables of FMS and attention (Stoeger et al., 2008) in underachievement. Therefore, our first step was to create two groups of children, namely gifted achievers and underachievers, based on a discrepancy of one standard deviation between their maths grades and IQ scores (Butler-Por, 1987; Peters et al., 2000; Reis & McCoach, 2000). Consistent with previous research, (i.e., Stoeger et al., 2008; Stoeger & Ziegler, 2013), we hypothesize that gifted underachievers will obtain lower scores on tests of FMS and attention than gifted achievers.

Finally, we turned to examining more causal hypotheses on the relations between FMS, attention, and gifted underachievement. Thus, we tested whether attention mediates the relations between FMS and achievement, hypothesizing that after controlling for attention, the relation between FMS and academic achievement will decrease. If this meditational role of attention is supported, then we can assume that underachievers' attention levels will drop particularly when they are confronted with tasks with high sensory-motor demands, as such tasks will demand a greater amount of both FMS and attention. Examples of such tasks include those in which participants must focus their attention on using motor skills to indentify or classify target items in short succession. Accordingly, on such tasks, underachievers should show stronger decreases in attention than achievers because of the extra strain caused by their weaker FMS. We test this idea in our study by manipulating the extent to which students complete attention tasks with either high or low sensory-motor demands. Here, we hypothesize that increasing sensory-motor demands will decrease the attention performance of underachievers more than of achievers. Moreover, it was expected that statistically controlling for FMS would reduce or eliminate this interaction between achievement status and sensory-motor demands on attention.

Method

Participants

A total of 357 fourth-graders from 17 classes attending 8 different primary schools took part in the study. The mean age of the participants was 10.8 years (*SD* = 0.52 years, range 9.4 to 12.3). There was no significant age difference between girls and boys. To assess cognitive abilities, each pupil completed the German version of the Culture Fair

Intelligence Test (CFT). Reported here are the results obtained for those pupils who, according to Gordon and Bridglall (2005), can be considered gifted, that is those who, in accordance with the reference values of the CFT, were ranked among the top 15%. In the following we use the term underachiever to refer to those pupils whose z-standardized average scholastic performances in mathematics were at least one standard deviation below their *z*-standardized score on the intelligence test. Among the 73 gifted pupils identified, 36 were found to be underachievers according to these criteria, and of these 28 were male and eight female. Among the 37 achievers 11 were male and 26 female.

Measures

Cognitive abilities. We assessed the cognitive abilities of the pupils with the German version (Weiss, 2006) of the Culture Fair Intelligence Test (Cattell, 1960). The test consists of two parts. As both parts are similar in design, the first part (form A) can be used as an abridged test format, which we utilized. The test consists of four subtests: series (12 items), classifications (14 items), matrices (12 items), and topological reasoning (8 items). Each subtest is timed and the items increase in difficulty. The paper-and-pencil test takes about 30 minutes to complete and places only low demand on participants' verbal skills. Raw scores are used in the analyses and percentiles were used to identify giftedness.

Fine motor skills (FMS). We assessed FMS with two tests. The first was a line-tracing task and the second was a symbol copying task.

Line tracing task. In the first test, participants received a sharpened pencil and a sheet of paper (DIN A4) on which a drawing of a labyrinth was printed. The labyrinth consisted of two curved parallel lines separated from one another at an average distance of about 4mm. At one end of the lines there was a drawing of a car and at the other end a drawing of a house. Pupils were instructed to "navigate" with their pencil along the route indicated by the parallel lines from the car to the house by drawing a line (between the two parallel lines) without touching or crossing the lines. The FMS score from this task was obtained by counting the number of instances in which each pupil's line touched or crossed one of the two printed lines. Accordingly, a greater score reflects more errors and therewith a lesser task performance.

Symbol copying. In the second test, participants were asked to copy a series of Greek letters. Participants received a one-page text containing 102 Greek symbols presented in six rows of 17 letters and an empty sheet of paper. The sheet of paper with the text was placed with the printed side down to prevent pupils from reading the text before the test started. The experimenters instructed the pupils to copy as many as possible within three minutes, one at a time, and to do this as quickly and accurately as possible. The following scores were derived: total number of copied Greek letters; number of incorrectly copied Greek letters; the difference between the total number of copied letters and the number of incorrectly copied letters; and the penmanship quality of the copied Greek letters (1 being very high and 3 being poor). The inter-rater reliability calculated for assessment of penmanship resulted in a Kappa of .76, which is satisfactory.

Attention (high sensory-motor demands). We measured pupils' attention with the "Aufmerksamkeits-Belastungs-Test" [Attention Stress Test] d2 (Brickenkamp, 1962), a timed test of selective attention. The test consists of 14 similar subtests with each containing 47 items presented in rows. The subjects were asked to mark target stimuli (always a letter 'd' with two strokes attached to it) and to avoid distracter stimuli (e.g., a 'd' with only one stroke or a 'p' with one or two strokes) as quickly as possible. After working for 20 seconds on the first row, the experimenter instructed the participants to continue marking the target stimuli in the next row. The total score constituted the difference between the total number of stimuli (targets and distracters) that were correctly marked and the number of incorrectly marked stimuli.

Attention (low sensory-motor demands). To allow for experimental manipulation of the sensory-motor demands during completion of the attention test, we used a second attention task. In this variant, instead of placing a line through the target stimuli, participants were asked to circle the target stimuli. Although placing a single circle around a target item places greater demands on motor skills than simply placing a line through the target stimuli, in a timed task we reasoned that placing a line would mean that the total strain on sensory-motor processing, which results from the interaction of the attention and motor components, would be greater. Specifically, the participants in the "cross" condition would then be expected to move more rapidly onto the next items, which diverts more resources away from the motor to the attention component – in short, children with lesser FMS ought to fare comparatively worse on the high-sensory-motor attention task. Thus, the interaction between the task demands in total makes this condition the low sensory-motor task.

Academic achievement. The classroom teachers provided us with their students' report-card grades in mathematics. In Germany, grades range from one to six, with one representing the best grade possible and six the poorest.

Procedure

The attention, FMS, and CFT tests were administered to the pupils during regular classroom instruction in the second term of the school year. The study took about two class hours to complete, including a short introduction and a brief pause following completion of the attention tests. The tests were carried out by specially trained school psychologists. Additionally, to investigate the role of FMS in attention, a random sample of half of the pupils received the low sensory-motor attention task.

Results

First, we calculated the descriptive statistics as a function of achievement and these are presented in Table 1. In Table 2 we present the correlation coefficients between the performance indicators in Table 1. Despite a vastly restricted variance (as only gifted stu-

Table 1:
Descriptive statistics for gifted achievers and underachievers on fine motor skills, attention, IQ, and academic achievement.

Performance indicator	Gifted achievers		Gifted underachievers		Total sample	
	M	*SD*	*M*	*SD*	*M*	*SD*
(1) Intelligence (raw scores on the CFT)					35.26	2.06
(2) FMS line tracing	6.51	5.63	12.31	8.13	9.37	7.52
(3) FMS symbol copying (total correct)	57.86	16.04	49.00	13.14	53.49	15.25
(4) FMS symbol copying (errors)	.50	.70	1.15	1.26	.81	1.05
(5) FMS symbol copying (total)	57.56	16.13	47.47	12.78	52.66	15.36
(6) FMS (penmanship quality of copied syllables)	1.73	.56	2.11	.40	1.71	.54
(7) Attention (both low- and high-sensory-motor demands)	144.60	29.36	131.94	21.17	124.36	28.54
(8) Mathematics grade in last report card	1.87	.41	2.25	.57	2.03	.63

Note. N = 146, but for low sensory-motor attention n = 73 and for high sensory-motor attention n = 73. Grades, line tracing, and penmanship quality are scaled inversely, such that lower scores represent greater achievement/higher quality.

Table 2:
Correlations coefficients between fine motor skills, attention, IQ, and academic achievement.

	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Intelligence (raw scores)	.11	-.01	-.26*	-.01	-.17	.17	-.28*
(2) FMS line tracing		-.04	.16	-.06	.33**	-.04	.16
(3) FMS symbol copying (total correct)			.18	.99**	-.01	.36**	-.24*
(4) FMS symbol copying (errors)				.12	.18	.19	.14
(5) FMS (total)					-.02	.36**	-.25*
(6) FMS (quality of copied symbols)						-.09	.13
(7) Attention (both low- and high-sensory-motor)							-.08
(8) Mathematics grade in last report card							

Note. N = 146, but for low sensory-motor attention n = 73 and for high sensory-motor attention n = 73. Grades, line tracing, and quality of copied symbols are scaled inversely, such that lower scores represent greater achievement. * = p <.05, ** = p <.01

dents were included), FMS correlated with symbol copying, IQ, attention, and academic achievement. In accordance with the definition of underachievement, the achievers and the underachievers in our investigation had equivalent levels of intelligence and could be differentiated from one another on the basis of their academic performance.

Consistent with the hypotheses, gifted achievers and underachievers differed with regard to their FMS and attention. Specifically, underachievers in the sample performed lower on all FMS measures. In the tracing task, underachievers made more errors, $t(71) = 3.55$, $p < .01$. The underachievers also scored lower than the achievers on the second FMS test. In copying the Greek letters, underachievers copied fewer letters in the allotted three minutes, $t(71) = -2.58$, $p < .05$, copied more letters incorrectly, $t(71) = 2.68$, $p < .01$, achieved a lower number of correctly copied letters, $t(71) = -2.89$, $p < .01$, and received lower penmanship scores, $t(71) = -3.36$, $p < .01$. Furthermore, measures of attention were somewhat lower for the underachievers in our sample. As expected, compared to the achievers, the underachievers correctly identified marginally fewer target items (difference between the sum of all marked items in the attention test minus the number of wrongly identified items, $t(71) = -1.52$, $p < .10$).

Attention mediates the influence of fine motor skills on math achievement

A mediation analysis tested whether attention mediated the relation between FMS and mathematics achievement. This analysis included only pupils ($n = 161$) who completed the low-sensory-motor attention task. The FMS task in this analysis was the performance on the line tracing task because we assume that this task is less confounded with reading skill, and therewith academic achievement, because tracing is less intrinsically linked to handwriting than copying Greek letters. All variables were grand mean centered.

To test for mediation, we conducted four separate regression analyses (Baron & Kenny, 1986; Holmbeck, 1997; Judd & Kenny, 1981). First, we conducted an analysis to determine if FMS predicted math achievement, which was confirmed, $\beta = .22$, $t(160) = 4.08$, $p < .001$. Second, we established that fine motor skills predicted attention, $\beta = -.13$, $t(160) = -2.39$, $p < .05$. Third, we examined whether attention (the potential mediator) predicted math achievement when controlling for the effect of FMS. Results confirmed that attention did in fact predict math achievement, $\beta = -.23$, $t(160) = -4.27$, $p < .001$. Fourth and most crucially, we examined whether attention actually mediated the effect of FMS on math achievement. The amount of mediation is defined as the amount of reduction in the effect of FMS on math achievement when controlling for attention. When attention was controlled for in the analysis, the effect of FMS on math achievement dropped, from $\beta = .22$, $t(160) = 4.08$, $p < .001$, to $\beta = .19$, $t(160) = 3.62$, $p < .001$. A Sobel test verified that this degree of mediation was indeed significant ($Z = 2.08$, $p < .05$).

High versus low sensory-motor demands and their effect on attention skill of gifted achievers and underachievers

Next we tested the hypothesis that an increase in sensory-motor demands will lead to a greater decrease in the attention performance of underachievers than of achievers. As mentioned above, this hypothesis was tested by using a feature of our study in which a random sample of participants received the low- versus high-sensory-motor attention task.

A two-way between-subjects analysis of variance (ANOVA) was conducted, which did not find a main effect for achievement status, M = 120.92, SD = 20.56 for underachievers and achievers, M = 127.70, SD = 34.57, after partialling out the number of completed target items in the attention test ($F(1) = 0.67$, $p > .10$, $\eta^2 = .01$). However, we found a main effect for the version of the attention test, $F(1) = 25.12$, $p < .001$, $\eta^2 = .27$, with participants who completed the high-sensory-motor version achieving higher scores, M = 138.78, SD = 26.36, than participants who completed the low-SMD version, M = 109.53, SD = 22.69. As hypothesized, the interaction between the version of the attention test and the participant's status as achiever or underachiever, was marginally significant, $F(1) = 1.92$, $p < .10$, $\eta^2 = .03$. The underachievers scored lower in the high-sensory-motor attention task. In the case of the low-sensory-motor attention task, underachievers and achievers showed almost no difference in their scores (high sensory-motor: underachievers: M = 131.94, SD = 21.17, achievers: M = 144.69, SD = 29.36; low-sensory-motor: underachievers: M = 111.05, SD = 14.34, achievers: M = 107.82, SD = 29.81). These results are depicted in Figure 1.

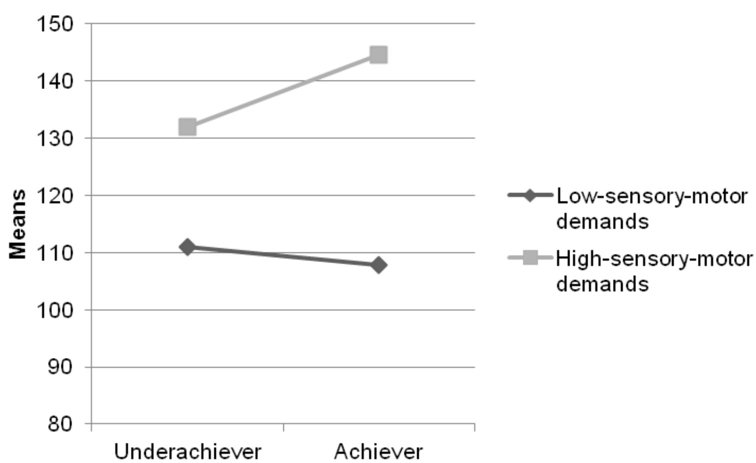

Figure 1:
Interaction between performance on the high-sensory-motor demands versus low-sensory-motor attention task as a function of being a gifted achiever versus a gifted underachiever.

Finally, we tested the hypothesis that the significant interaction between ability (achievers versus underachievers) and version of the attention test will lessen or disappear when we control statistically for FMS. Before partialling out FMS, the interaction effect between the version of the attention test and ability (achievers vs. underachievers) was marginally significant ($F(1) = 1.92$, $p < .10$, $\eta^2 = .03$). However, once we partialled out FMS tracing, the interaction effect lost its statistical significance ($F(1) = 1.45$, $p > .10$, $\eta^2 = .02$).

Discussion

The overall aim of this paper was to investigate the pedagogically and scientifically relevant question of the role that FMS play in gifted underachievement. Specifically, we were first interested in whether gifted underachievers would exhibit lower FMS than gifted achievers and whether underachievers would also have lesser attention skills. Consistent with previous research (e.g., Stoeger et al., 2008; Stoeger & Ziegler, 2013), both of these hypotheses were supported. Next we investigated whether attention mediated the relations between FMS and mathematics achievement and found that the relation between FMS and mathematics decreased once attention was controlled for. This finding provides further evidence for the idea that at least some of the influence of FMS on achievement is due to tying up of attention resources.

Additionally, we explored whether placing greater demands on sensory-motor processing reduced performance on a measure of attention and whether FMS explained, in part, this reduction in performance as a function of achievement status. Importantly, we found evidence to suggest that the gifted achievers showed better performance on the attention task than gifted underachievers when sensory-motor demands were greater. Moreover, once the influence of FMS was accounted for, achievement status did not interact with sensory-motor demands. This finding borders on demonstrating experimentally that greater demands on FMS particularly affect the attention skills of underachievers, thus extending previous correlational research (e.g., Grissmer et al., 2010). Finally, to verify that it was indeed the greater FMS demands that resulted in the decreased performance on the attention task, we then controlled for FMS and the previously significant FMS x Achievement interaction became no longer statistically significant.

In conducting this study, we adhered to typical procedures in research on achievement in determining underachievement based on a discrepancy between academic performance and IQ. However, we also note that there are problems with this definition that have been comprehensively documented elsewhere and will not be repeated here (see Phillipson, 2008; Reis & McCoach, 2000). In the context of the current study, it is possible that a kind of regression to the mean effect operated for FMS and attention skills, whereby underachievers by chance overachieved on the IQ measure in comparison to their grades but that their performance was more normal on the FMS and attention measures.

Additionally, achievement was defined using grades in mathematics, which has two interesting implications. First, school grades are influenced by a number of factors other than actual academic achievement in a given subject, such as teacher perception, classroom behavior, neatness of handwriting (e.g., Helmke & Schrader, 2010; Helmke & Weinert, 1996). In such a scenario, the extent of gifted underachievers might have been inflated and thereby led to an underestimation of the effects reported here. Such a contamination of the estimate of achievement might best be avoided by employing researcher-administered measures to partial out non-academic influences in grade assignment. Second, previous research indicates that FMS and mathematics achievement are linked (Grissmer et al., 2010; Luo et al., 2007; Pagani et al., 2010; Tramontana et al., 1988). Therefore, the role that FMS plays in math-defined underachievement might be greater than that in a subject where FMS play a smaller role.

Relatedly, hand writing skill is clearly important for academic achievement (e.g., during note taking, legibility of writing), particularly in humanities subjects where more extensive note taking is required than in mathematics. Given the inherent role that FMS plays in handwriting, it would be reasonable to hypothesize that still greater effects than those found here would be obtained in investigation of underachievement in English or history, for example. Here also the mechanism might be similar, in that children with poor handwriting fluency would need to direct greater attention away from the content of the lesson to take notes and complete written tasks.

Finally, we divided children into two groups and gave them two different forms of the attention task that varied in the FMS demands required for a greater score. Although statistically significant, we observed a comparatively small effect given the large size of our sample. Additionally, although we reasoned that the circle version of the attention task resulted in lesser sensory-motor demands, we acknowledge that further research is needed to fully test this assumption. Future research might better manipulate sensory-motor and fine motor demands, using a within-subjects design and perhaps utilize altogether a different strategy to investigate experimentally the effect of increasing FMS demands on attention. Possibilities include experimental manipulations of FMS task difficulty while requiring children to simultaneously attend to a stimulus that is only intermittently activated.

Similarly, one of our FMS measures (line tracing) tapped only the number of errors made and not the time taken to complete the task, which might have provided a more stringent test of FMS skill. Interestingly, the FMS measure that did have a time limit (letter copying) correlated significantly with attention and maths grades, whereas the line tracing task did not (see Table 1).

Taken together, the current findings add to the emerging body of evidence that FMS cannot be overlooked when considering children’s school underachievement, even in children in the fourth grade of school. Furthermore, FMS appear to play a role in children’s mathematics achievement, with the worrying consequence that gifted children in terms of having a high IQ run the risk of not being identified as such because of their FMS difficulties. Moreover, evidence was presented suggesting that having lower FMS placed greater demands on attention skills, thus providing preliminary evidence of a mechanism through which FMS may affect achievement. Specifically, if children need to divert more of their attention towards tasks requiring FMS such as writing, they have less attention remaining to attend to the content of instruction.

In summary, although work in this direction is at a beginning, we tentatively propose that FMS be added to the list of factors found to be important ingredients of underachievement and its identification (e.g., Peters et al., 2000; Peterson & Colangelo, 1996; Reis & McCoach, 2000). Future research would do well to further compare and explore the influence of FMS in comparison to other motivational, developmental, and environmental influences, perhaps through longitudinal designs. However, as we attempted to do in the second part of our study, we encourage the development of more experimental paradigms to more exactly isolate and manipulate the role that FMS play in academic achievement. Such a line of work would have clear implications for the diagnosis, prevention, and remediation of underachievement.

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