Psychology Science Quarterly, Volume 50, 2008 (2), pp. 134-146

Deficits in fine motor skill as an important factor in the identification of gifted underachievers in primary school

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Abstract

The underachievement of gifted students is one of the most disturbing and, simultaneously, most enduring problems for gifted education. Previously, the identification of underachievement has largely focused on discrepancies between achievement and cognitive abilities. This is partially due to the fact that, despite having detected some of the reasons for underachievement, current knowledge is still fragmentary and cannot fully explain the phenomenon. In particular the association with fine motor skills has not yet been adequately investigated. In a study with 4th grade students, it was demonstrated that achievement differences between gifted underachievers (n = 31) and achievers (n = 97) could best be explained by their fine motor skills and the interaction between fine motor skills and concentration. These results provide the first indications that deficits in fine motor skills can be predictors of under-achievement and, consequently, could well be integrated into the identification process in the future. The findings are discussed with regard to action regulation and in terms of educational implications.

Key words: Giftedness, Fine Motor Skills, School Age Children, Underachiever, Identification

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Definition and identification of gifted underachievers

In the pertinent literature, underachievers are designated as gifted pupils who, contrary to expectations, produce poor scholastic performances (Butler-Por, 1993). Apparently they are not capable of exhausting their total learning potential. This phenomenon has been long established and observed. It first came into investigative focus in the well-known longitudinal study by Terman, which began in 1921 and has still not yet been concluded. In his sample of gifted pupils, Terman found substantial inter-individual differences in scholastic performance and subsequent academic and occupational achievements (Terman & Oden, 1947). Similar discrepancies between cognitive abilities and scholastic or occupational achievement are reported in widely disparate studies, in which cognitive ability and achievement levels are correlated with one another (e.g. Khatena, 1992; Ziegler & Stoeger, 2006).

The actual proportion of underachievers among the gifted is widely disputed and differs in accordance with various definitions of giftedness and approaches to identification. Richert (1991) estimates this figure in the United States, where most investigations on underachievement took place, to be at least 50 %. Rimm (2003) agreed with this evaluation in a publication titled „Underachievement: A national epidemic“. In our own studies we were able to find comparable figures for Germany, when the data was based on the definitions of underachievement conventionally used in the United States (Stoeger & Ziegler, 2005; Ziegler & Stoeger, 2003). However, such definitions are highly arbitrary. Most are oriented on discrepancies between IQ and achievement measurements (for an overview refer to Peters, Grager-Loidl, & Supplee, 2000; Ziegler & Stoeger, 2003). For instance, Durr (1964), from the perspective of learning psychology, defined underachievement as a significant discrepancy between IQ and performance in the form of either scholastic achievement or the results of scholastic achievement tests. The cut-off points of such definitions are, however, completely random. Shaw (1964), for example, speaks of underachievement, when a child is among the top 25 % of his class with regard to intellectual abilities (IQ), but below class average with regard to performances. Similarly random is the definition used by Hanses and Rost (1998), whereby highly gifted underachievers are pupils with an IQ score of at least 96 and simultaneously, an achievement profile rating not higher than 50. In our own studies, we oriented our definition on the standard conventions, whereby one speaks of underachievement when the IQ is at least 130 and scholastic achievement is at least one standard deviation lower than the IQ measurement (Stoeger & Ziegler, 2005; Ziegler & Stoeger, 2003). Nevertheless, the lack of a consensus regarding a precise operational diagnosis of underachievement makes a standard diagnostic process next to impossible.

In addition to discrepancies between IQ and achievement, diagnoses often take into consideration various other potential causes for underachievement which have been discussed in the literature. These causes are widely varied and differ in accordance with the author (for an overview, please refer to Peters et al., 2000). Determinants considered in the research literature to be particularly interesting include motivational deficits, underdeveloped learning and work skills, inadequate control convictions, poor ability self-concepts, developmental factors, chance, personality parameters (e.g. poor attribution styles, detrimental success expectations and value systems as relevant motives for action decisions), environmental factors (e.g. occupational stereotypes, gender role convictions) or detrimental influences exercised by socialization agents such as parents, teachers and the media (see Ziegler & Stoeger, 2006).

Since Terman and Oden (1947), and, in particular, subsequent to the exceptionally influential publications by Rimm (1986, 2003) and Butler-Por (1993), insufficient motivation has been considered to be the most important risk factor for academic underachievement. In fact, this is not only consistent with empirical findings, but also correspondent with several models of giftedness (e.g. Gagné, 2004; Renzulli, 1986; Ziegler, 2005), which attach a high degree of significance to motivation. In contrast, the topic of fine motor skills has been consistently disregarded in previous empirical investigations.

The connection between fine motor skills and achievement, cognitive abilities, and underachievement

To our knowledge only one talent model exists in which fine motor skills are designated to be a discrete influential factor on the development of (scholastic) performance. Ziegler and Perleth (1997) in their *Dynamisches Münchner Begabungsmodell* [Munich Dynamic Model of Talent & Giftedness] see the influence of fine motor skills, in accordance with the work of Ackerman (e.g. 1987, 1992), as commencing relatively late, in other words shortly prior to the realization of an achievement asymptote in a specific talent domain. In the meantime, findings which support a much earlier influence of fine motor skills have been mounting up. However, with respect to the explanation of underachievement among gifted persons, deficits in fine motor skills have been fully neglected. In the following we will first, on the basis of our own conception of giftedness, form a theoretical explanation as to why motor deficits should be investigated in the identification of underachievers in primary schoolchildren. Subsequently, we will provide an overview on currently available empirical findings.

In our Actiotope Model of Giftedness (e.g. Ziegler, 2005; Ziegler & Stoeger, in this special issue) we focus on effective actions. We see the development of excellence as an expansion of the individual action repertoire to the point where outstanding actions are available. In taking a closer look at actions, it is clear that actions are always executed in parallel. When a pianist is performing a specific piece of work, he is not only screening the motoric movement of each individual finger, his arms, and his upper body. He is also reading notes from the music sheet before him, paying attention to the sounds being generated, controlling how he is hitting the keys, maintaining rhythm, ensuring correct interpretation etc. In the Actiotope Model complex coordinations of sub actions, as exemplified here, are realized in the subjective action space. Some partial processes are capacity-intense and compete for limited resources, in particular for attentional, perceptual and motoric resources. Among parallel actions, it is therefore important that several of the subactions are automatic. Under optimal conditions, their execution should be triggered as a result of calling up well known routines and will not necessitate detailed planning, monitoring and/or adjustment, or require the influx of extensive new information. The more capacity-reducing regulations and ad hoc decisions are necessary, the more likely it is that the actions taken will turn out faulty.

These considerations can also be applied to the consequences of fine motoric deficits. Should deficits in fine motor skills interfere with the effective execution of motoric movements when writing, attention will be focused on the supervision of this aspect of the action, whereby the effectiveness of other subactions can be impaired. For example, it could well be the case that a pupil, while taking a mathematics test, will have to allocate an over proportionally large degree of attention in his subjective action space to controlling his hand movements and will, therefore, have a lesser amount of capacity available for controlling mathematical operations or the coordination of these two subactions. Although scholastic performance is rather associated with cognitive abilities, there are several good reasons to expect an influence on performance through fine motor skills. A series of empirical findings support this hypothesis.

In the first place, fine motor skills have a significant meaning for the entire developmental process; and the attainment of various milestones in early childhood socialization is outright inconceivable without them. The fine coordination of small muscle groups, above all those in the hand, is essential for a number of activities (Cantell, Ahonen, & Smyth, 1994; Losse, Henderson, Elliman, Hall, Knight, & Jongmans, 1991), included here are getting dressed and undressed and tying shoelaces; using eating utensils properly; holding and using writing instruments, paintbrushes, rulers and scissors; turning the pages of books; and assembling puzzle pieces and building blocks. Should such competences not be obtained the result is often ridicule at the hands of peers and dependence on others along with all the well-documented negative effects these experiences have on self-esteem. In fact, Losse, Henderson, Elliman, Hall, Knight, & Jongmans (1991) were able to find evidence that children with fine motor skill deficits demonstrate significantly more manifest behavioral problems.

Fine motor skill deficits are, furthermore, consistently positively correlated with general as well as specific cognitive abilities. Relationships have been confirmed with optical differential abilities, reaction speed (e.g. Voelcker & Rehage, 2005) and intelligence (e.g. Baedke, 1980; Mozlin, Solan, & Rumpf, 1984; Wasserberg, Feron, Kessels, Hendriksen, Kalff, Kroes et. al., 2005). In accordance with expectations, positive relationships have also been shown for achievement. Vacc, Vacc, and Fogleman (1987) found, for example, that fine motor skills among pre-school aged children are among the best predictors of later performance on standardized achievement tests in the first grade. Further studies confirm correlations between fine motor skills and scholastic performance through to, at least, the end of primary school (e.g. Baedke, 1980; Li Beilei, Lin Lei, Dong Qi, & von Hofsten, 2002). However, many reasons can be found to assume that these relationships have a validity lasting beyond primary school. Most important here are: (1) Fine motor skills form the basis for several scholastic skills such as writing speed, quality and frequency of handwritten activities, the willingness to rework written assignments etc., which in no way or form lose their importance for scholastic progress over the entire course of scholastic education (Graham, 1990; Graham & Weintraub, 1996). (2) The quality of handwriting influences scholastic assessments made by teachers (Sweedler-Brown, 1992). Various studies have been able to confirm that (e.g. Briggs, 1980; Chase, 1986; Hughes, Keeling & Tuck, 1983), assignments which are identical with regard to content receive a more positive assessment if the handwriting is clean and legible rather than sloppy. Since teacher assessments of competence and achievement have a great deal of influence on scholastic self-concept, the quality of handwriting could mediate, through the mechanisms described here, an influence on one‘s ability self-concept (Sweedler-Brown, 1992), for which Piek, Grant, Baynam, & Barrett (2006) isolated the first indicators. (3) Furthermore, there are explicit correlations between fine motor skills and reading skills, which are indispensable for all scholastic subjects (Graham, 1990; Reno, 1995; Share, Jorm, Maclean, & Matthews, 1984). (4) Finally, deficits in fine motor skills have an emotional impact which is significant for scholastic motivation. For instance Losse, Henderson, Elliman, Hall, Knight, & Jongmans (1991) found increased dispositions towards irritated reactions and designative, depressive moods among schoolchildren with deficits in fine motor skills.

In our own investigations we were able to establish a first correlation between scholastic underachievement among gifted children and deficits in fine motor skills (Ziegler, Stoeger, & Martzog, 2008). In a study with 4th grade children it could be shown that underachievement could be predicted by concentration and the interaction of fine motor skills and concentration. Other variables which were observed, such as motivation, work habits or self-confidence, in contrast, were not able to contribute to the explanation of this phenomenon.

Investigative aims

The cursory overview of the literature was able to provide a wide array of theoretical and empirical cues to the importance of fine motor deficits in identifying underachievers. The study by Ziegler et al. (2008), although providing the most meaningful results along this line so far, has two weaknesses. First, concentration was assessed by teacher observation alone. Therefore, in the present study this drawback will be rectified with the application of the d2, a well established, standardized measuring instrument. The d2 is a concentration endurance test which necessitates the application of a complex coordination of visual and manual activities, and is therefore much better suited to assess concentration than teacher observations (Brickenkamp, 1962). Second, in the study conducted by Ziegler et al. pupil concentration was not observed differentially. The d2 permits for a differentiated observation of concentration. In addition to the total volume of actions executed which require a high degree of concentration, it also permits for an assessment of the errors made. Consistent with our theoretical model, the Actiotope Model of Giftedness (Ziegler, 2005; Ziegler & Stoeger, in this special issue), we assume that the error rate in the d2 is more useful for the prediction of underachievement than the total number of actions executed. The reasoning here is that problems in the coordination of parallel actions manifest themselves in the emergence of less effective actions, and therefore also in error rates.

Method

Participants

A total of 576 pupils in the 4th grade from 23 classes attending 15 different primary schools took part in the investigation. In order to assess cognitive abilities, each pupil completed a German version of the Culture Fair Intelligence Test (CFT). Reported here are the results obtained from those pupils who, according to Gordon and Bridglall (2005), can be considered gifted, i. e. those who, in accordance with the reference values of the CFT, were among the top 15 %.

In the following we will use the term underachiever to refer to those pupils whose average scholastic performances in the three subjects[3] Mathematics, German (native language),

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[3] The average of the grades obtained in these three subjects in the fourth grade determines whether a pupil will later be admitted to a Gymnasium (school for high achievers).

and Science were at least one standard deviation below their result on the intelligence test. Among the 128 gifted pupils identified, 31 were found to be underachievers according to these criteria, and of these 23 were male and eight female. Among the 97 achievers 48 were male and 49 female.

Measuring instruments

Cognitive abilities: The cognitive abilities of the pupils were assessed with the assistance of the German version (Weiss, 1987) of the Culture Fair Intelligence Test (Catell, 1960). The test consists of two parts. The similar construction of both parts allows using only the first part (form A) as an abridged test format which was done in the current study. The test consists of 4 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 test, which is presented in a paper and pencil format, takes about 30 minutes to complete and demands only minor verbal competence.

Fine motor skills: To assess fine motor skills, the pupils were given a standard sized (DIN A4) sheet of paper with a depiction of a labyrinth (curved parallel lines about 4mm. apart from one another), with illustrations of a car at the start and a house at the end. With the following instructions, the pupils were requested to use a pencil to „navigate“ as quickly as possible from the car to the house, without touching or crossing the borders: „On this page you see a doubled black line. Use a sharpened pencil to draw a line between the two black lines. Try to be as *fast* as possible. Also make sure that you don‘t touch the black lines with your pencil”.

Concentration: The concentration of the pupils was measured with the assistance of the “Aufmerksamkeits-Belastungs-Test” d2 (Brickenkamp, 1962), a timed test of selective attention. The test consists of 14 similar subtests with each 47 item stimuli that are aligned in rows. The subjects are asked to mark target stimuli (d with two strokes attached) and avoid distracter stimuli (e.g. d with only one stroke or p with one or two strokes) as fast as possible. After 20 seconds on the first row the tester instructs the subjects to continue marking the target stimuli in the next row. To capture quantitative and qualitative measures there are several indexes available. In the current study we used the total number of stimuli (target and distracter) that have been marked and the number of correctly marked stimuli as quantitative measures. The percentage of errors served as a qualitative measure of concentration.

Scholastic grades: The classroom teachers supplied us with their students‘ report card grades for the three subjects in question. Here one should note that the grade scale in Germany ranges from one to six, whereby one represents the best grade possible and six the poorest.

Data collection

The d2, the fine motor skills test and the CFT were administered to the pupils in the second semester of the school year, during regular classroom instruction. The survey, including a short introduction and a brief break following the d2, took about one and a half class hours to complete. The investigation was conducted by specially trained school psychologists.

Results

The first analytical step should provide evidence that underachievers can be statistically differentiated, not according to their intelligence, but rather in accordance with their scholastic achievement. In forming the group of underachievers we applied the criteria of one standard deviation between z-standardized intelligence scores and z-standardized scholastic performance. In the statistical analyses of the α - level was set at .05.

Figure 1 shows close to identical percentile rankings for the intelligence scores (Achiever: $\bar{x}$ = 93.00, s = 3.43; Underachiever: $\bar{x}$ = 93.84, s = 3.59), but significantly better average grades for the achievers (Achiever: $\bar{x}$ = 1.83, s = .33; Underachiever: $\bar{x}$ = 2.74, s = .52). As predicted, the difference in intelligence was not statistically significant (t (126) = 1.41, $p > 0.10$), however, this was quite evident for the difference in performance (t (126) = 11.28, p = .000). In accordance with the definition of these terms, the achievers and the underachievers in our investigation had equivalent levels of intelligence, and could be differentiated from one another solely on the basis of their scholastic performances.

In the second step of analysis, we wanted to determine whether achievers and underachievers could be differentiated in accordance with our explanatory variables. To test for statistical significance, t-tests were calculated. In accord with our hypotheses, clear differences in fine motor skills could be shown between underachievers ($\bar{x}$ = 12.23, s = 7.14) and achievers ($\bar{x}$ = 8.43, s = 7.98), which were indeed statistically significant (t (126) = 2.36, $p < 0.05$). In the fine motor skill test underachievers touched the borders more frequently than achievers. Figure 2 holds the mean values for fine motor skills for achievers and underachievers. With respect to concentration, no significant differences could be confirmed (Total score: Underachievers: $\bar{x}$ = 342.23, s = 62.92, Achievers: $\bar{x}$ = 343.46, s = 62.47, t(126) = 0.10, $p > .10$; Error rates: Underachievers: $\bar{x}$ = 12.61, s = 7.67; Achievers: $\bar{x}$ = 16.38, s = 21.78; t (126) = -1.45, $p > .10$; Total score minus errors: Underachievers: $\bar{x}$ = 330.52, s = 61.22, Achievers: $\bar{x}$ = 328.55, s = 57.90, t (126) = 0.16, $p > .10$).

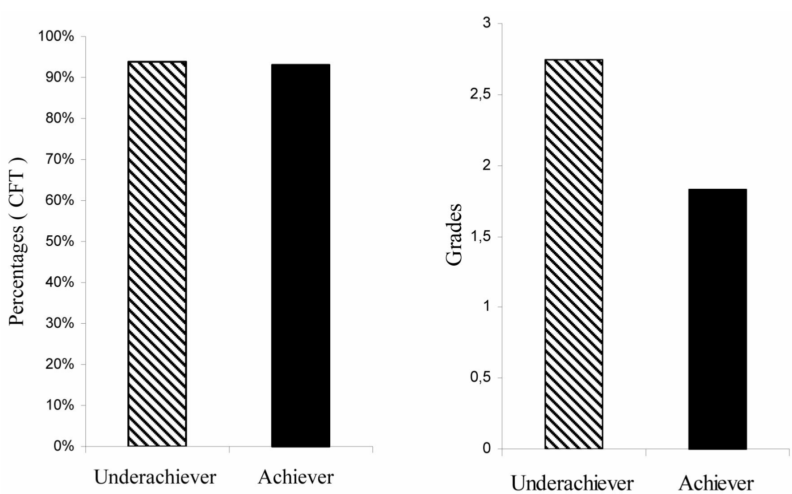

Figure 1:
Mean percentages and scholastic grades for gifted underachievers (n =31) and achievers (n = 97)

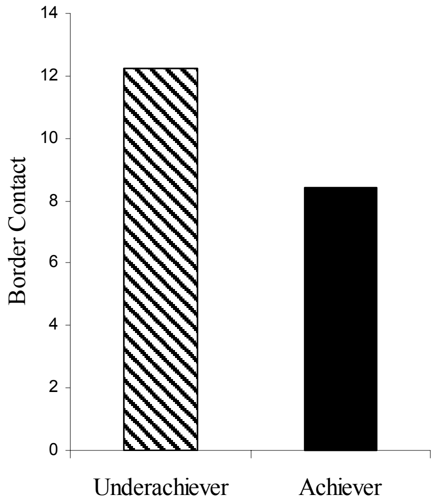

Figure 2:
Means for the variable fine motor skills (border contact) for gifted underachievers (n =31) and achievers (n = 97)

In the next analytical step, we were interested in isolating correlations among the variables we hypothesized would determine underachievement (see Table 1). The variable in prime focus, fine motor skills, was found to only have a significantly positive correlation with the number of errors made on the d2. Here one must pay close attention to the poling of the variables; pupils with deficits in fine motor skills make, on the average, more mistakes on the d2. Furthermore, the total score on the d2 correlated, as expected, positively with the number of errors and the difference between the total score and the errors.

In the final step of the analysis a logistic regression analysis was calculated (Method: Forward Wald, Pin: .05, Pout: .10). The dichotomous dependent variable was whether the subject was an underachiever or an achiever. The variables fine motor skills, total score in the d2, errors on the d2, difference between total score and errors on the d2 as well as the 2-way interactions between fine motor skills and the various d2 scores all served as predictor variables in the regression equation. Here the scale means were set to zero and afterwards the scales were multiplied. Statistically significant predictors turned out to be fine motor skills (β = -.11, *Wald* = 8.74, $p < 0.01$) as well as the interaction between fine motor skills and errors

Table 1:
Intercorrelations among the variables used to analyse underachievement

	1	2	3	4
1. Fine motor skills	-	.60	.34	-.03
2. Total score d2		-	.30	.96
3. Errors d2			-	.06
4. Total score minus error d2				-

on the concentration test d2 (β = .01, *Wald* = 2.64, $p < 0.05$). A more precise inspection of the interaction shows that among the underachievers, pupils with numerous errors and simultaneously fine motor deficits were over-represented. Among underachievers the proportion of such cases was 52 %, among achievers this rate was 21 %.

The proportion of variance explained by the model produced a Nagelkerke coefficient of R^2 = .12 and 73.4 % of the participants in the investigation could be allocated to the correct group on the basis of these two variables. The model fit was, according to the Hosmer Lemeshow test, satisfactory (χ^2 (8) = 5.55, p = .70), and the *Wald* coefficient for the constants was 26.93.

Discussion

The aim of this investigation centered on answering the question of whether, in the identification of gifted underachievers in primary school, deficits in fine motor skills should also be assessed. Theoretical considerations on the basis of the Actiotope Model of Giftedness (Ziegler, 2005) and previous empirical findings indicated that this could well be the case.

To clear up this question, a study was conducted in which differences in fine motor skills between underachievers and achievers were examined. In fact, it could be shown that gifted underachievers made more mistakes on a test of fine motor skills than achievers. In a further analytical step, the interaction between fine motor skills and concentration was examined. In a regression analysis it was shown that both fine motor skills and the interaction between fine motor skills and errors on a concentration endurance test were able to predict underachievement. This result not only appears to be theoretically plausible, but is also reasonable in light of various empirical investigations which have been able to demonstrate that deficits in fine motor skills impair performance because they divert excessive quantities of concentration efforts.

In a study, already considered a classic, Scardamalia, Bereiter, and Goleman (1982) diminished capacity demands during the production of texts among pupils in grades 4 through 6 by having the pupils dictate their texts orally instead writing them out. This kept attention capacities free which previously would have been occupied with controlling hand movements while writing. Indeed, this did have a beneficial effect on performance. In a replication study Graham (1990) was able to confirm this finding and, in addition, could prove that over and above the quantity of text production, the quality of the text produced was also significantly improved when capacity demands were diminished. A systematic research program in this field has been introduced by Christensen (2004, 2005). She assumes that much of scholastic performance is based on the interplay among domain-specific knowledge, orthographic knowledge and fine motor capacities. The orthographic-motor integration is particularly capacity intensive. One of the ways in which she is able to demonstrate this is through the existence of substantial correlations between orthographic-motor integration (writing out the alphabet as quickly as possible within a specific period of time) and written products with respect to creativity, the number of ideas, correct use of syntax and text coherence. Accordingly, well developed fine motor skills correlate well and positively with scholastic performance because the automation of basic fine motor functions, as for example writing, frees up capacity resources which can be used for higher order cognitive activities.

In the introduction several reasons were given as to why fine motor skills not only have a direct influence on scholastic performance, but also why secondary effects are to be expected. Expectations along these lines are also valid for the effects on fine motor deficits caused by capacity restrictions. For instance, it may well be the case that poor or illegible handwriting, due to fine motor deficits, may lead to an even poorer assessment of a class test by the grader (Sweedler-Brown, 1992), which in turn may lead to a collapse in one‘s confidence in scholastic abilities altogether (Dweck, 1999). Impairments in self-confidence can promote the development of test anxiety, the main effect of which is a reduction in attention capacity in test situations (see Ziegler & Stoeger, 2004), which then intensifies the attention capacity problem even further. Although the individual steps of these secondary effects have been established in the field, an empirical confirmation incorporating the overall relations and further potential secondary effects has yet to be submitted. This, however, was not the concern of our study, which had the ultimate goal of providing first evidence of the necessity for considering fine motor deficits in identifying underachievers in primary school.

We see a need for further research efforts in this direction, as both the present study and the study by Ziegler et al. (2008) found, in addition to consequences for the identification of underachievers, also clear indications of remedial and preventative ramifications. First of all, and by all means, it is clear that in an optimal configuration of learning processes underachievement should not surface at all. However, since ideal learning processes are now as ever an utopian ideal, in most cases the so-called correspondence principle (Ziegler, Dresel & Schober, 1999) is applied: The introduction of new procedures should focus on suppressing the causes which have been already established. In more precise terms, this means that, in the current case, an intervention should concentrate on the elimination of deficits in fine motor skills and the related coordination problems in the subjective action space. Also, preventative measures should adhere to the correspondence principle. Fine motor skills can, by all means, be trained. The best approach here is a systematic support program in pre-school ages. From a pedagogic perspective, it would be a tragedy if the attainment of a gifted person‘s learning potential were to fail due to a lack of fine motor skills.

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