Behavioral Executive Functions among Adolescents with Mathematics Difficulties

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Abstract

This study investigates behavioral executive functions (EFs) in the mathematics classroom context among adolescents with different mathematics performance levels. The EF problems were assessed by teachers using a behavioral rating inventory. Using cutoff scores on a standardized mathematics assessment, groups with mathematics difficulties (MD; $n = 124$), low mathematics performance (LA; $n = 140$), and average or higher scores (AC; $n = 355$) were identified. Results showed that the MD group had more problems with distractibility, directing attention, shifting attention, initiative, execution of action, planning, and evaluation than the LA group, whereas the differences in hyperactivity, impulsivity, and sustaining attention were not significant. Compared to the AC group, the MD group showed more problems with all behavioral EFs except hyperactivity and impulsivity, while the LA group showed more problems only with shifting attention. Male adolescents showed more behavioral EF problems than female adolescents, but this gender difference was negligible within the MD group. The practical implications of the results are discussed.

Keywords: adolescents, behavioral executive functions, mathematics difficulties

Behavioral Executive Functions among Adolescents with Mathematics Difficulties

Cognitive testing has often been used to examine executive functions (EFs) among students with mathematics difficulties (MD; Cai, Li, & Deng, 2013; Passolunghi & Mammarella, 2012). As EFs might be hard to detect in controlled testing situations, researchers suggested measuring these functions in the everyday context (Gioia & Isquith, 2004). An understanding of EFs in the everyday context might help generate educational support (Gioia & Isquith, 2004; Klenberg, Jämsä, Häyrinen, Lahti-Nuuttila, & Korkman, 2010). Adults with MD reported that their EF problems were not understood in the school context (Desoete, 2009). Mathematics teachers reported that they do not get enough information about adolescents' EF problems during professional training (Gilmore & Cragg, 2014). Adolescents who face behavioral problems, academic failure, and school dropout (Eccles, 1999) need their behavioral EFs to be understood and supported. Adolescents with MD (Hakkarainen, Holopainen, & Savolainen, 2015) or who demonstrate a decrease in behavioral EFs around 15 years of age (Archambault, Janosz, Morizot, & Pagani, 2009) are at risk of dropping out of school. Therefore, this study investigates behavioral EF problems in the mathematics classroom context among adolescents with MD and low mathematics performance.

EFs

While a unified theory of EFs has not been established, it is agreed that EFs consist of several components, such as working memory (Gioia & Isquith, 2004; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003), inhibition, shifting attention (Garcia-Barrera, Kamphaus, & Bandalos, 2011; Gioia & Isquith, 2004; Klenberg et al., 2010; Miyake et al., 2000), directing attention, sustaining attention, and goal-directed behaviors (Garcia-Barrera et al., 2011; Klenberg et al., 2010).

Barkley (1997) identified three processes of behavioral inhibition: *inhibiting prepotent responses* refers to impulsivity, *stopping an ongoing response* refers to hyperactivity, and *controlling interference* refers to distractibility. Students with inhibition problems might be unable to wait for their turn (i.e., impulsivity) or to stay seated (i.e., hyperactivity) and are interrupted by external stimuli (i.e., distractibility; Klenberg et al., 2010). Attention functions involve directing attention to a certain stimulus, sustaining attention for an extended period, and shifting attention from one aspect of a stimulus to another (Mirsky, Pascualvaca, Duncan, & French, 1999). Students with attention problems have difficulty focusing on instructions (i.e., directing attention), working for long time (i.e., sustaining attention), and shifting from one activity to another (i.e., shifting attention; Klenberg et al., 2010). EFs include the abilities needed for goal-directed behaviors, such as initiation, planning, execution, and evaluation of actions (Garcia-Barrera et al., 2011; Gioia & Isquith, 2004; Klenberg et al., 2010). Individuals with problems in goal-directed behaviors may be unable to start working without help (i.e., initiative), plan their actions in advance (i.e., planning), perform activities efficiently (i.e., execution of action), or judge their own performance (i.e., evaluation; Klenberg et al., 2010).

We use *behavioral EFs* to describe EFs measured with rating scales for behaviors at home or school (Garcia-Barrera et al., 2011; Gioia & Isquith, 2004; Klenberg et al., 2010) and *cognitive EFs* to describe the EFs measured with cognitive tests (Lehto et al., 2003; Miyake et al., 2000). Although tests can provide reliable information about cognitive aspects of EFs, such as working memory (i.e., controlling and storing information; Lehto et al., 2003), these tests are often structured and administered in nondistracting settings that do not reflect the complexity of everyday situations and where the examiners may offer guidance that influences the test takers' performance (Gioia & Isquith, 2004; Jurado & Rosselli, 2007). Therefore, rating scales completed by parents and teachers have been developed to analyze behavioral EFs at home and school (Garcia-Barrera et al., 2011; Gioia & Isquith, 2004; Klenberg et al., 2010).

EFs and Mathematics Performance

Although a growing body of literature indicates that adolescents with MD have problems working with rational numbers (Mazzocco & Devlin, 2008; Siegler & Pyke, 2013) and approximating numbers (Mazzocco, Feigenson, & Halberda, 2011), show shame about mathematics (Holm, Hannula, & Björn, 2017), and have cognitive EF deficits (Cai et al., 2013), behavioral EFs among adolescents with MD are not understood. To support adolescents with MD, it is crucial to develop a comprehensive understanding of their EFs in the classroom context. However, studies have often investigated cognitive EFs among young children rather than adolescents (Peng, Congying, Beilei, & Sha, 2012; Reimann, Gut, Frischknecht, & Grob, 2013).

Behavioral EFs. Although researchers have shown that adolescents (Swanson, 2012) and primary school children (Martin et al., 2012; Raghubar et al., 2009; Wu, Willcutt, Escovar, & Menon, 2014) with MD have more problems with teacher- and parent-rated attention behaviors than their peers with average or higher mathematics scores, other behavioral EFs among students with MD are not understood. Significant relations between parent- (Wu et al., 2014) and teacher-rated (Fuchs et al., 2006; Martin et al., 2012; Raghubar et al., 2009) attention behaviors and mathematics performance were found but only in primary school. However, an insignificant difference in self-reported attention problems between adolescents with MD and low mathematics performance was found (McGlaughlin, Knoop, & Holliday, 2005), while significant differences were found between these groups in primary school when teachers (Raghubar et al., 2009) and parents (Wu et al., 2014) rated these problems. McGlaughlin et al. (2005) defined attention problems to include hyperactivity and impulsivity. As hyperactivity and/or impulsivity are not as critical as inattention in mathematics performance (Merrell & Tymms, 2001), these behaviors should be studied separately. Although students with MD have attention problems, students with low mathematics performance do not differ in teacher-rated inattention from students with average or higher mathematics scores, at least in primary school (Wu et al., 2014).

Although it is unclear whether adolescents with MD have specific attention and goal-directed behavior problems, adults with MD have reported planning and evaluation problems during interviews (Desoete, 2009). Primary school children's initiative (Finn, Pannozzo, & Voelkl, 1995) and preschool children's initiative (Dobbs, Doctoroff, Fisher, & Arnold, 2006) and planning (Clark, Pritchard, & Woodward, 2010) behaviors rated by teachers are associated with their mathematics performance. However, preschool children's shifting-attention behaviors rated by teachers are not related to their mathematics performance (Clark et al., 2010). Although teacher-rated hyperactivity and/or impulsivity behaviors are associated more weakly with mathematics performance than inattention among primary (Merrell & Tymms, 2001) and preschool children (Sims, Purpura, & Lonigan, 2016), this association is unclear among adolescents with MD. Clark et al. (2010) even showed that teacher-rated hyperactivity and/or impulsivity behaviors of preschool children are related to their mathematics performance.

Cognitive EFs. Studies investigating cognitive EFs among students with MD rarely focus on adolescents (Cai et al., 2013; Swanson, 2012). These studies showed that adolescents with MD have problems with cognitive tasks requiring planning (Cai et al., 2013), inhibiting responses (referring to impulsivity; Cai et al., 2013; Swanson, 2012), and inhibiting numerical information (referring to distractibility; Cai et al., 2013). Mathematics performance is related more strongly to cognitive tasks that require the ability to inhibit irrelevant information in a numerical relative to a nonnumerical context among adolescents and adults (Gilmore, Keeble, Richardson, & Cragg, 2015). Similarly, primary school children with MD have problems with tasks that require planning (Kroesbergen, Van Luit, & Naglieri, 2003), inhibiting responses (Szűcs, Devine, Soltesz, Nobes, & Gabriel, 2013), and inhibiting irrelevant numerical information (Peng et al., 2012; Szűcs et al., 2013) instead of verbal (Peng et al., 2012) or spatial information (Toll, Van der Ven, Kroesbergen, & Van Luit, 2011). Primary school children with MD also have problems with cognitive tasks requiring directing to certain stimuli (Reimann et al., 2013) and shifting between schemas (McLean & Hitch, 1999; van der Sluis, de Jong, & van der Leij, 2004) but not with tasks requiring shifting between rules or responses (Toll et al., 2011; van der Sluis et al., 2004) or simple mathematical operations (Raghubar et al., 2009).

Gender. Males tend to have more problems with several behavioral EFs rated by parents (Huizinga & Smidts, 2011) and classroom (Dobbs et al., 2006; Merrell & Tymms, 2001) and subject teachers (Klenberg et al., 2010) throughout the age range. Male adolescents reported more problems with goal-directed behavior in mathematics than female adolescents (Cleary & Chen, 2009; Kenney-Benson, Pomerantz, Ryan, & Patrick, 2006). Some studies showed that males perform more poorly than females on cognitive tasks requiring planning, attention (Naglieri & Rojahn, 2001), and sustaining attention (Sussman & Tasso, 2013) throughout the age range, while other studies found no significant gender differences in tasks requiring planning, attention, and inhibiting responses and irrelevant stimulus among adolescents (Cai et al., 2013).

The Present Study

Previous studies have shown that students with MD who score below the 11th percentile on a mathematics test differ in EFs, such as attention behavior (Wu et al., 2014), working memory (Geary, Hoard, Nugent, & Byrd-Craven, 2008; Passolunghi & Mammarella, 2012), and other components (e.g., number sense; Mazzocco et al., 2011; Wong, Ho, & Tang, 2017), from those with low mathematics performance (between the 11th and 25th percentiles) and with average or higher mathematics scores. However, the two latter groups did not differ in these components. Thus, students in MD and low-performing groups should be analyzed separately to avoid reducing the effects that may be more significant in one group (Mazzocco, 2008). As correlational analyses would not inform the problems among students with MD, we selected a categorical approach to investigate EFs among adolescents with MD, low mathematics performance, and average or higher mathematics scores.

Previous studies have investigated cognitive EFs and attention behavior among students with MD, gender differences in several behavioral EFs rated by parents and teachers in general, and gender differences in self-reported goal-directed behaviors in mathematics among adolescents. To our knowledge, no previous study has examined various behavioral EFs among adolescents with MD or gender differences in various behavioral EFs in mathematics. Thus, this study investigated the differences in several teacher-rated behavioral EFs among adolescents with MD, low mathematics performance, and average or higher mathematics scores and gender differences in these functions in the mathematics classroom context. As a normative study found significant gender differences in all behavioral EFs explored in our study and suggested that these EFs should be considered separately by gender (Klenberg et al., 2010), we investigated the interaction between gender and mathematics performance groups in these behavioral EFs. The following two hypotheses were proposed:

On the basis of previous studies (Martin et al., 2012; Raghubar et al., 2009; Swanson, 2012; Wu et al., 2014), we hypothesized that adolescents with MD had more problems with attention behaviors than students with average or higher mathematics scores (Hypothesis 1).

Other hypotheses regarding EFs among adolescents with different mathematics performance levels could not be proposed due to the limited theoretical background. On the basis of previous studies (Cleary & Chen, 2009; Dobbs et al., 2006; Huizinga & Smidts, 2011; Kenney-Benson et al., 2006; Klenberg et al., 2010; Merrell & Tymms, 2001), we propose that male adolescents have more problems with behavioral EFs in mathematics than female adolescents (Hypothesis 2).

Method

Participants

The participants were 619 eighth graders (14–15 years old) with low and average mathematics performance at 27 compulsory schools. A geographically representative sample of the schools in five Finnish provinces was compiled (southern Finland, eight schools; central Finland, nine schools; eastern Finland, four schools; Oulu, three schools; Lapland, three schools), including municipalities and cities of different sizes. The school sizes varied, from small (*n* = 65 students) to large (*n* = 658 students). The inclusion criterion was that the participants’ mathematics grades were average or low (7 or less; grading in Finland ranges from 4 [fail] to 10 [excellent]). All participants were from Finnish-speaking schools. Finland is a relatively ethnically and socioeconomically homogeneous country. The Finnish educational system consists of 6 years of primary school and 3 years of lower secondary school; most children begin school the year they turn 7. In Finland, the educational system is an equal, publicly funded, comprehensive system, and the socioeconomic and school variances in mathematics performance are negligible (Kupiainen, Hautamäki, & Karjalainen, 2009).

We classified adolescents into groups with MD (MD group), low mathematics performance (LA group), and average or higher mathematics scores (AC group). The cutoff scores were based on a representative sample of Finnish eight graders (Holm et al., 2017). The cutoff score was 12 or below (below the 11th percentile) for the MD group, between 13 and 16 (between the 11th and 25th percentiles) for the LA group, and above 17 (maximum 40; above the 25th percentile) for the AC group on a standardized mathematics assessment (Räsänen & Leino, 2005). Of the participants, 124 met the criterion for MD, 140 for low mathematics performance, and 355 for average or higher mathematics scores. Table 1 shows the demographic and screening data for the groups; students were broadly scattered among the MD, LA, and AC groups across the sample schools.

Table 1. Demographic and Screening Data Across Mathematics Performance Groups.

	Group		
Variable	MD	LA	AC
Total, *n*	124	140	355
Females, *n*	67	73	141
Males, *n*	57	67	214
Mathematics test, *M* (*SD*)	9.45 (2.57)	14.74 (1.10)	22.06 (3.80)
Scatter of sample schools, %	89	93	100

Note. MD = mathematics difficulties; LA = low mathematics performance; AC = average or higher mathematics scores.

Measures

Mathematics performance was determined based on the KTLT test, a standardized Finnish assessment (Räsänen & Leino, 2005). It focuses on core mathematics skills in Grades 7 through 9, including arithmetic (e.g., addition, subtraction, multiplication, and division), word problems (e.g., solving the tax rate), algebra (e.g., equation solving), geometry (e.g., solving the surface area), and unit conversion (e.g., rounding a large number to the nearest hundred). This test, developed to screen students with MD (Räsänen & Leino, 2005), is widely used in Finland (e.g., Kyttälä, 2008). The KTLT is a paper-and-pencil test consisting of 40 items, with 1 point for a correct answer and 0 points for an incorrect answer. Test scores range from 0 to 40. Of the four versions (A, B, C, and D), version B was chosen for this study as it showed the highest internal reliability (.90; Räsänen & Leino, 2005). The test correlated significantly with other measures of mathematical skill ($r = .61 – .78$, $p < .001$; Räsänen & Leino, 2005).

Behavioral EFs were examined using the *Attention and Executive Functions Rating Inventory* (ATTEX; Klenberg et al., 2010). The ATTEX is a rating inventory used by teachers that consists of 55 items grouped into 10 scales: Distractibility (four items; e.g., activities are interrupted by external stimuli), Impulsivity (nine items; e.g., waiting for turns), Hyperactivity (seven items; e.g., staying in one's seat), Directing Attention (five items; e.g., focusing on instructions), Sustaining Attention (six items; e.g., working a long time), Shifting Attention (four items; e.g., changing from one activity to another), Initiative (five items; e.g., starting tasks without help), Planning (four items; e.g., planning tasks before starting), Execution of Action (eight items; e.g., completing tasks), and Evaluation (three items; e.g., evaluating own performance). The English version of the ATTEX is available as an appendix in Klenberg et al. (2010). Teachers rate students' behavior on a 3-point scale (*not*, *sometimes*, and *often a problem*). The ATTEX showed good internal reliability for each scale (Cronbach's alpha range = .73 – .92) and good criterion validity (correlations range = .76 – .95) with another behavioral rating scale (DuPaul, Power, Anastopoulos, & Reid, 1998) for a sample of 7- to 15-year-old Finnish students (Klenberg et al., 2010). The mean scores of the ATTEX scales were used as dependent variables in our study.

Procedure

The eight graders in this study completed the assessment in the spring of 2010. We followed Finnish ethical principles of research in the humanities and social and behavioral sciences (National Advisory Board on Research Ethics, 2009). The permission for the study was obtained from the municipal education departments and the head teachers, and informed consent was gathered from the participants' parents. The study material was sent to the schools by regular mail. Mathematics teachers were asked to evaluate students' behavioral EFs by choosing the alternative that best corresponded to the student's typical behavior in the classroom context. The students had 40 min to complete the KTLT test, and we recommended that all students at the school take the test at the same time. The teachers collected the materials and returned them to the researchers by regular mail.

Preliminary and Data Analysis

Missing data for the ATTEX items (0.08%) were not imputed. The reliability of the ATTEX scales was estimated using Cronbach's alpha (α) coefficients and ranged from good ($.8 \leq \alpha < .9$) to excellent ($\alpha \geq .9$). The reliability of the mathematics test was good (Cronbach's $\alpha = .83$). Although some Pearson's product-moment correlations between the ATTEX scales were quite high (between .41 and .79), they were always lower than the magnitude of the validity coefficient ($r_{ab} < \sqrt{\alpha_a \cdot \alpha_b}$, where r_{ab} is the correlation between two scales (a, b) and α is the reliabilities of these scales), indicating discriminant validity (McCoach, Gable, & Madura, 2013).

A two-way MANOVA was performed to test the main effects of the mathematics performance groups, gender, and Group × Gender interaction on the ATTEX. The ANOVA analyses were conducted to investigate the effects of the mathematics performance groups, gender, and Gender × Group interaction on each ATTEX scale. In these analyses, the dependent variables were all the ATTEX scales and the independent variables were the mathematics performance groups and gender as well as the Group × Gender interaction. Scheffe post hoc tests were used to compare the means of the mathematics performance groups on each ATTEX scale. Effect sizes were reported as partial eta-squared (η_p^2: small $\geq .01$, medium $\geq .06$, large $\geq .14$) for the MANOVA and ANOVA and in terms of Cohen's *d* (*d*: small $\geq .2$, medium $\geq .5$, large $\geq .8$)

for the post hoc tests (Cohen, 1988). When statistical differences were found, the percentages of students with scores on the ATTEX scales higher than +1 standard deviation were presented. The criterion (+1 standard deviation) was determined based on a Finnish normative sample that presented typical EF problems in the classroom context in Finland (Klenberg et al., 2010). This comparison indicated the clinical perspective of the behavioral EFs among the MD group.

Results

The main effects of the mathematics performance groups, $F(20, 1190) = 3.52$, $p < .001$, Wilks' lambda = .89, $\eta_p^2 = .056$, and gender, $F(10, 595) = 3.72$, $p < .001$, Wilks' lambda = .94, $\eta_p^2 = .059$, were significant on the ATTEX. The main effect of the Group × Gender interaction, $F(20, 1190) = .98$, $p = .486$, Wilks' lambda = .97, $\eta_p^2 = .016$, was not significant on the ATTEX.

Table 2. Gender Differences and Differences Among Mathematics Performance Groups on the ATTEX Scales.

	Gender Differences (IVs)						Mathematics Performance Groups (IVs)							
	Female		Male				MD		LA		AC			
DVs	*M*	*SD*	*M*	*SD*	*F*	η_p^2	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	η_p^2
Distractibility	.54	.56	.75	.59	14.98***	.02	.83	.63	.59	.55	.62	.57	8.65***	.03
Impulsivity	.44	.58	.65	.67	9.11**	.02	.64	.66	.46	.57	.56	.65	2.80	.01
Hyperactivity	.18	.36	.38	.53	19.17***	.03	.30	.44	.24	.43	.31	.50	.63	.00
Directing	.63	.59	.79	.60	8.56**	.01	.94	.63	.67	.58	.65	.58	12.68***	.04
Sustaining	.58	.61	.80	.64	15.82***	.03	.87	.67	.68	.63	.65	.61	7.16**	.02
Shifting	.76	.66	.89	.69	6.19*	.01	1.12	.67	.89	.67	.71	.65	19.63***	.06
Initiative	.69	.57	.88	.59	18.99***	.03	1.03	.62	.78	.55	.72	.57	16.09***	.05
Planning	.64	.60	.78	.64	9.24**	.02	.95	.67	.75	.58	.62	.61	15.44***	.05
Execution	.53	.48	.72	.53	20.58***	.03	.82	.51	.64	.47	.57	.52	14.03***	.04
Evaluation	.51	.62	.68	.63	11.95**	.02	.82	.69	.62	.59	.53	.60	12.16***	.04

Note. The descriptive statistics are the mean scores for the *Attention and Executive Functions Rating Inventory* (ATTEX) scales. DVs = dependent variables; IVs = independent variables; MD = mathematics difficulties; LA = low mathematics performance; AC = average or higher mathematics scores.
*$p < .05$. **$p < .01$. ***$p < .001$.

As Table 2 shows, the mathematics performance groups had a significant effect on each ATTEX scale, with the exception of Impulsivity and Hyperactivity; males had significantly more problems than females on all ATTEX scales among the whole sample when mathematics performance groups were controlled for. Figure 1 illustrates the gender differences on the ATTEX scales within the whole sample and the performance groups. The gender differences on the ATTEX scales were negligible among the MD group. Table 2 shows the means and standard deviations for both genders within the whole sample.

Post hoc testing revealed that adolescents with MD had significantly more problems with distractibility ($p = .004$ and $d = .40$), directing attention ($p = .001$ and $d = .45$), shifting attention ($p = .019$ and $d = .35$), initiative ($p = .001$ and $d = .44$), planning ($p = .032$ and $d = .32$), execution of action ($p = .011$ and $d = .38$), and evaluation ($p = .027$ and $d = .32$) than the LA group, but the differences in impulsivity ($p = .067$), hyperactivity ($p = .596$), and sustaining attention ($p = .059$) were not significant. The effect sizes for these differences in EF problems were small to medium (.20 – .50). Only the effect sizes for distractibility, directing attention, and initiative problems between the MD and LA groups were close to medium and can be considered the most substantial. Compared to the AC group, adolescents with MD had significantly more problems with distractibility ($p = .002$ and $d = .35$), directing attention ($p < .001$ and $d = .48$), sustaining attention ($p = .003$ and $d = .34$), shifting attention ($p < .001$ and $d = .62$), initiative ($p < .001$ and $d = .53$), planning ($p < .001$ and $d = .52$), execution of action ($p < .001$ and $d = .49$), and evaluation ($p < .001$ and $d = .46$) but not with impulsivity ($p = .463$) or hyperactivity ($p = .987$). The effect sizes for the differences in shifting attention, initiative, and planning problems between the MD and AC groups were medium (>.50) and can be regarded as the most substantial. The percentages of students with MD who had scores higher than +1 standard deviation were 59% for distractibility, 55% for directing attention, 59% for sustaining attention, 74% for shifting attention, 65% for initiative, 62% for planning, 60% for execution of action, and 59% for evaluation. The LA group had significantly more problems with shifting attention ($p = .030$ and $d = .26$) than the AC group. However, the effect size for this difference in shifting-attention problems between the LA and AC groups was small (≥ .20) and cannot be considered very substantial. The percentage of LA students with scores higher than +1 standard deviation was 59% for shifting attention. Table 2 shows the means and standard deviations for the performance groups. Figure 1 illustrates the differences on the ATTEX scales among the mathematics performance groups in terms of the effect sizes.

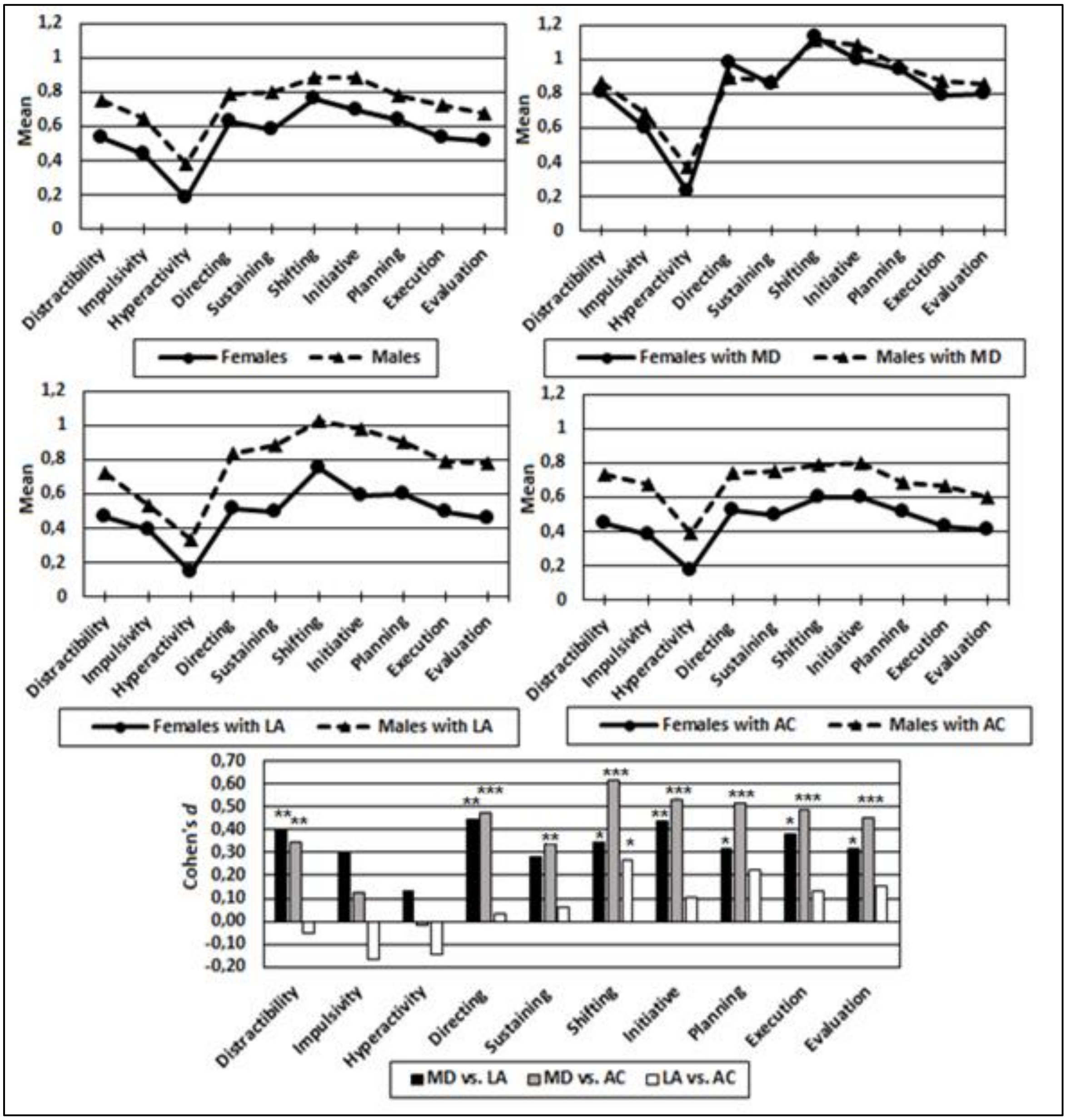

Figure 1. Gender differences among the whole sample and the mathematics performance groups and Cohen's *d* for the differences between the mathematics performance groups on the *Attention and Executive Functions Rating Inventory* (ATTEX) scales.

Note. The descriptive statistics are the mean scores for the ATTEX scales and the values of Cohen's *d*. MD = mathematics difficulties; LA = low mathematics performance; AC = average or higher mathematics scores. A positive Cohen's *d* represents more problems with the ATTEX scales for the first comparison group (MD vs. LA, MD vs. AC, LA vs. AC). *$p < .05$. **$p < .01$. ***$p < .001$.

As summarized in Figure 1, all the effect sizes for the differences in EF problems between the mathematics performance groups were small to medium. The effect sizes for the differences in distractibility, directing attention, and initiative problems between the MD and LA groups were close to medium. Thus, these EF problems predominantly distinguish the MD and LA groups. The effect sizes for the differences in shifting-attention, initiative, and planning problems between the MD and AC groups were medium. Thus, the MD group had mainly shifting-attention, initiative, and planning problems when compared to the AC group. Although the LA group showed significantly more shifting-attention problems than the AC group, the effect size for this difference was small and cannot be considered very substantial.

Discussion

The results support the first hypothesis, as we found that adolescents with MD had more problems with all teacher-rated behavioral EFs except hyperactivity and impulsivity relative to their peers with average or higher mathematics scores. The greatest differences between these groups were found in shifting attention, initiative, and planning, as only the effect sizes for these differences were medium. We even found that adolescents with MD had more problems with all behavioral EFs than their peers with low mathematics performance except hyperactivity, impulsivity, and sustaining attention. However, these groups differed mainly in distractibility, directing attention, and initiative problems, as only the effect sizes for these differences were close to medium. In turn, adolescents with low mathematics performance had only more shifting-attention problems than those with average or higher mathematics scores, but this difference was small in terms of the effect size. As proposed, we found that males had more problems with all behavioral EFs than females, but these differences were negligible among adolescents with MD.

Our study confirms the finding that adolescents with MD have problems with teacher-rated attention (Swanson, 2012). We even found that adolescents with MD had more teacher-rated shifting- and directing-attention problems than their peers with low mathematics performance. Our results conflict with McGlaughlin et al.’s (2005) finding of a nonsignificant difference in self-reported inattention behaviors between adolescents with MD and those with low mathematics performance but in line with findings of significant differences in teacher- (Raghubar et al., 2009) and parent-rated (Wu et al., 2014) inattention behavior between these groups in primary school. The inconsistent results might be because McGlaughlin et al. used a self-reported behavioral rating scale or conceptualized attention to include hyperactivity and impulsivity (see Dulaney, Vasilyeva, & O’Dwyer, 2015), which are not central in mathematics performance (Merrell & Tymms, 2001). Students with MD might self-report attention problems differently from their teachers. The reliability of self-reported inattention and hyperactivity behaviors might be lower than teachers’ ratings (Du, Kou, & Coghill, 2008).

This study is the first to show that teacher-rated shifting-attention problems are central among adolescents with MD. Indeed, 74% of adolescents with MD showed these problems more than Finnish students in general. Our results conflict with Clark et al.’s (2010) finding of a nonsignificant relation between teacher-rated shifting-attention behaviors of preschool children and mathematics performance. The conflicting result might be because shifting attention is central in older students when complex mathematics problems occur (Toll et al., 2011) or because we focused on students with MD. In fact, our results are line with findings that primary school children with MD have problems with complex cognitive tasks requiring shifting between schema (McLean & Hitch, 1999; van der Sluis et al., 2004) but conflict with findings that children with MD do not have problems with simple tasks requiring shifting between responses or operations (Raghubar et al., 2009; van der Sluis et al., 2004). Different cognitive tests (complex vs. simple; van der Sluis et al., 2004) or different behavioral and cognitive measures might cause conflicting results (Raghubar et al., 2009). These studies suggested that complex cognitive tasks and teacher rating of shifting attention might identify shifting-attention problems of students with MD, although attention behavior does not necessarily relate to abilities to shift between simple mathematical operations (Raghubar et al., 2009).

The study is also the first to show that adolescents with MD have problems with teacher-rated goal-directed behaviors and distractibility. However, the clearest differences were found in initiative and planning between adolescents with MD and those with average or higher mathematics scores, as the effect sizes for these differences were medium. Although Desoete (2009) found that adults with MD reported planning and evaluation problems, we found that teacher-rated initiative problems are central among adolescents with MD. Our results expand findings that adolescents and children with MD have problems with cognitive tasks requiring abilities to plan (Cai et al., 2013; Kroesbergen et al., 2003) and to inhibit irrelevant numerical information (referring distractibility; Cai et al., 2013; Szűcs et al., 2013). Gilmore et al. (2015) showed that the ability to inhibit irrelevant numerical information is related to adolescents' mathematics performance. Although behavioral rating and cognitive tests might identify distractibility and planning problems among adolescents with MD, behavioral and cognitive aspects are not necessarily the same, at least among young children (Clark et al., 2010). Several external stimuli (nonnumerical) might harm the mathematics learning of adolescents with MD in the classroom.

Interestingly, we found that adolescents with MD did not show problems with hyperactivity and impulsivity behaviors, at least in their teachers' views. Our results conflict with findings that adolescents and children with MD (Cai et al., 2013; Swanson, 2012; Szűcs et al., 2013) have problems with cognitive tasks requiring inhibiting responses (referring to impulsivity). Thus, teacher-rated impulsive behaviors in the classroom context might be related to a noncognitive component, such as motivation. However, students with MD have more problems with cognitive tasks requiring working memory (Swanson, 2012) and inhibiting irrelevant numerical stimuli (Szűcs et al., 2013) than impulsivity control, suggesting that impulsivity is not central among students with MD. Our results expand findings that teacher-rated hyperactivity and/or impulsivity is not central in mathematics performance among primary and preschool children (Merrell & Tymms, 2001; Sims et al., 2016), including adolescents with MD, but conflict with Clark et al.'s (2010) finding of a significant relation between teacher-rated hyperactivity and/or impulsivity behaviors of preschool children and their mathematics performance. Inconsistent results might be because Clark et al. focused on young children or did not control for the effect of inattention (see Sims et al., 2016).

We found that distractibility, directing-attention, and initiative problems predominantly distinguish adolescents with MD from adolescents with low mathematics performance, while adolescents with low performance did not differ from those with average or higher mathematics scores. Our results extend previous findings that used the same cutoff score to determine students with MD and low mathematics performance and showed that students with MD had more problems with EFs, such as attention behavior (Wu et al., 2014) and working memory (Geary et al., 2008; Passolunghi & Mammarella, 2012), than students with low performance and average or higher mathematics scores. The two latter groups did not differ in these EF problems. Therefore, to understand the EF problems of students with MD, the groups should be separated.

Our results extend the findings that males show more teacher- and parents-rated EF problems than females (e.g., Huizinga & Smidts, 2011; Klenberg et al., 2010), including the mathematics classroom, and extend findings that male adolescents self-report more problems with goal-directed behavior in mathematics than female adolescents (Cleary & Chen, 2009; Kenney-Benson et al., 2006), including several teacher-rated behavioral EFs. Although some studies showed that males had more problems with cognitive tasks requiring planning and attention than females across the whole age range (Naglieri & Rojahn, 2001; Sussman & Tasso, 2013), others found no significant gender differences in several cognitive EFs among adolescents (Cai et al., 2013). Thus, males' problems in EFs might emerge more clearly in the classroom in relation to actual learning than in a controlled cognitive test situation. Although Willcutt and Pennington (2000) found that males with reading difficulties had more parent-rated inhibition behaviors than corresponding females in primary school, we found that gender differences in teacher-rated behavioral EFs were negligible among adolescents with MD. Our study expands the suggestion that females struggling with mathematics have problems with attention behaviors (Wu et al., 2014), including several EFs. Thus, the behavioral EFs of females and males with MD should be supported.

Our results raise the question why shifting-attention, initiative, and planning problems predominantly distinguish adolescents with MD from those with average or higher mathematics scores. These problems may represent critical cognitive deficits (Fuchs et al., 2006). Behaviors such as shifting from one activity to another (see Kotsopoulos & Lee, 2012), planning tasks beforehand, and starting a task without help might need aid in mathematical problem solving and learning. As the relation between cognitive shifting-attention and attention behaviors is not significant (Raghubar et al., 2009), noncognitive aspects might be associated with behavioral EF problems. Fuchs et al. (2006) suggested that inattention prevents students from persevering with mathematics tasks. Adolescents who are unable to initiate and plan actions and shift attention might not orient to mathematics learning and thus have MD. In turn, students with MD might have problems with shifting attention, planning, and initiative (e.g., need help) because of low mathematics skills. Individuals with MD reported that their behavioral EF problems were not understood in the school context (Desoete, 2009). Teachers do not necessarily instruct in a way that is useful to students with MD and EF problems (Fuchs et al., 2006). As teachers may need many years to become aware of the importance of these problems, educators should stress this when training mathematics teachers (Gilmore & Cragg, 2014). Teachers' attention (Fuchs et al., 2006), initiative, and planning ratings might be affected by students' low mathematics performance. However, our results indicated large standard deviations for behavioral EFs, suggesting variability within mathematics groups. Hence, there were students with MD whose teachers did not consider them to have problems with behavioral EFs and students without MD whose teachers considered them to have these problems.

Some limitations of this study need to be recognized. First, the risk of using teacher rating scales is that factors other than students' behaviors may influence teachers' evaluations. Teacher assessments are reliable for evaluating students' problems with behavioral EFs (Du et al., 2008). Second, we used only one teacher-rated behavioral rating inventory to assess behavioral EFs. However, the ATTEX determines EFs comprehensively and demonstrated good internal reliability and criterion validity (Klenberg et al., 2010). Third, mathematics performance was operationalized broadly, and whether students' problems with specific mathematics skills were associated differently with behavioral EFs remains unanswered in our study (see Kroesbergen et al., 2003). However, the standardized mathematics test used in our study is designed to screen general mathematical difficulties instead of specific skills (Räsänen & Leino, 2005) and is reliable and widely used for this purpose in Finland (Kyttälä, 2008). Fourth, the use of cutoff scores on the mathematics test to determine performance groups should be considered critically; individuals classified near the cutoff point might be misclassified. However, follow-up analyses indicated that our results did not differ when students near the cutoff score were eliminated from the analyses (available from the first author upon request). We also used cutoff scores widely used in previous research to define mathematics performance groups (e.g., Wu et al., 2014). As we found that mainly adolescents with MD had behavioral EF problems, correlational analyses would not show the EF problems of these vulnerable adolescents. Fifth, our study sample consisted only of Finnish adolescents with low or average mathematics performance.

Our results raise suggestions for future research and practical implications. Although more work is needed to investigate EFs among adolescents with MD, we suggest that shifting attention is the main future research topic among adolescents with MD. Although teacher rating of behavioral EFs might be a central method for finding EF problems among adolescents with MD in the classroom, we suggest that future studies should use other EF measures, such as parent- (Wu et al., 2014) and self-reported (McGlaughlin et al., 2005) behavioral rating scales and cognitive tests (Gilmore et al., 2015). Our findings suggest that strategic instruction and self-monitoring might be important practical methods when supporting shifting attention, planning, and initiative problems of adolescents with MD in their classroom. Adolescents with MD might learn to cope with shifting-attention and planning problems if teachers direct student to follow steps, such as planning activities beforehand and shifting attention to other phases in mathematics problem solving and learning (Mooney, Ryan, Uhing, Reid, & Epstein, 2005;

Naglieri & Gottling, 1997). Adolescents with MD might learn to initiate action in the classroom if they self-monitor, record, and control initiative behaviors and are rewarded for controlling them (e.g., starting tasks without help; Mooney et al., 2005). In the future, whether these two methods help adolescents with MD cope with these problems in the classroom should be investigated. Our results imply that although adolescents with impulsivity and hyperactivity often take up teachers' attention, they not need the most support in mathematics. As there were relatively large standard deviations for behavioral EFs among the MD group, not all adolescents with MD needed support for EFs. The ATTEX might be an effective tool when identifying EF problems among students with MD and designing support for them in the classroom.

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