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Executive functions and processing speed in children with mild to borderline intellectual disabilities and externalizing behavior problems

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ABSTRACT

Several studies suggest impaired executive functions (EFs) in children with externalizing behavior problems and average intelligence (e.g., IQ > 85). Even though children with mild to borderline intellectual disabilities (MBID) are at higher risk of developing externalizing behavior problems compared to children with average intelligence, it is not yet clear if impaired EFs are also associated with the occurrence of externalizing behavior problems in children with MBID. In the current study, we therefore assessed three EF components (inhibition, cognitive flexibility, and working memory) as well as processing speed in children with MBID and externalizing behavior problems ($n = 71$) versus children with MBID with no such problems ($n = 70$). This was accomplished using a well-established computerized test battery. Even after IQ was controlled for, the children with MBID and externalizing behavior problems showed more impaired working memory performance. Differences for inhibition performance and processing speed were also found but less consistent across the tasks used to measure these aspects of EF. Cognitive flexibility was not more impaired in children with both MBID and externalizing behavior problems relative to children with MBID only. Our findings highlight working memory as a potential target to enhance the treatment of children with MBID and externalizing behavior problems.

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Externalizing behavior problems are generally assumed to be caused and maintained by the interplay between predisposing child vulnerabilities and adverse environmental circumstances (Dodge & Pettit, 2003). Executive functions (EFs) are among these child factors. EFs can be defined as the top-down control of cognitive processes to achieve a purpose or goal (Séguin & Zelazo, 2005). A large body of research has documented impaired EFs as being associated with the occurrence of externalizing behavior problems in children with average intelligence (Hobson, Scott, & Rubia, 2011; Hughes & Ensor, 2008). See also the following meta-analyses: Oosterlaan, Logan, &

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Sergeant, 1998; Schoemaker, Mulder, Deković, & Matthys, 2013). The goal of the present study was to examine EFs in children with mild to borderline intellectual disabilities (MBID) and externalizing behavior problems.

EFs and Externalizing Behavior Problems

EF consists of three interrelated components that can be subsumed under a higher-level EF construct: inhibition, cognitive flexibility, and working memory. These different EF components are correlated yet separable (Miyake et al., 2000; Miyake & Friedman, 2012). Inhibition can be defined as the ability to withhold a prepotent response. A dysfunction in inhibition may then result in inappropriate, impulsive responses and take the form of aggressive behavior (Oosterlaan, Scheres, & Sergeant, 2005; Oosterlaan & Sergeant, 1996). Deficits in inhibition have been documented in preschool children showing aggressive and externalizing behavior or disruptive behavior disorders (Raaijmakers et al., 2008; Schoemaker et al., 2012. See also the meta-analysis by Schoemaker et al., 2013). For school-aged children with disruptive behavior disorders, some studies report poor performance on inhibition (Matthys, Van Goozen, Snoek, & Van Engeland, 2004. See also the meta-analysis by Oosterlaan et al., 1998), while others do not (Oosterlaan et al., 2005; Van Goozen et al., 2004). It seems that children with attention deficit hyperactivity disorder (ADHD) and externalizing behavior problems resolve part of their developmental delay in inhibition from preschool age to school age (Schoemaker, Bunte, Espy, Deković, & Matthys, 2014). Commonly used tests to assess inhibition are the GoNoGo (GNG) task and the Stroop task.

Cognitive flexibility can be defined as the ability to adapt to changing environments by shifting between tasks or mental sets. Difficulty in flexibly changing a mental set within a new situation can thus lead to inappropriate problem-solving and may result in aggressive or other inappropriate behavior at times. A recent study in children with MBID demonstrates a relation between cognitive flexibility and externalizing behavior in individuals aged 14–31 years with MBID. However, these results were only found when using rating scales, rather than neuropsychological tasks, to measure cognitive flexibility (Visser, Berger, Van Schrojenstein Lantman-De Valk, Prins, & Teunisse, 2015). Working memory can be defined as the ability to hold, monitor, and manipulate information that is relevant to a particular goal (Baddeley, 2007). Poor maintenance of information in memory results in limited opportunities to combine this information with the information from prior experiences, as well as a limited ability to manipulate this information for further cognitive processing and decision-making, which can impede adequate social functioning (McQuade, Murray-Close, Shoulberg, & Hoza, 2013). According to a meta-analysis, impairments in cognitive flexibility and working memory are associated with externalizing behavior problems in preschool children with average intelligence (defined here as $IQ > 85$; Schoemaker et al., 2013). For older children the results with regard to working memory are inconsistent; some studies report impaired working memory for aggressive children (Séguin, Boulerice, Harden, Tremblay, & Pihl, 1999), while others report no impaired working memory for such children (Brocki, Nyberg, Thorell, & Bohlin, 2007; Oosterlaan et al., 2005; Van Goozen et al., 2004). The inconsistency in findings concerning the relation between working memory and externalizing behavior in prior studies is possibly due to the variety of

working memory tasks used in the studies. Several studies emphasize that the results found in their study depend on the task used (Oosterlaan et al., 1998; Visser et al., 2015). Cognitive flexibility is often measured using the Wisconsin Card Sorting Test, while the Digit Span Task and Letter-Number Sequencing Task are commonly used to measure working memory. The reported impairments in EFs cannot be attributed to comorbidity with ADHD, as ADHD was controlled for in most of the aforementioned studies (e.g., Raaijmakers et al., 2008; Schoemaker et al., 2012). In sum, EFs enable appropriate goal-directed behavior and are essential for children's adaptive social functioning (e.g., McQuade et al., 2013).

In addition to EFs, an aspect of cognitive functioning that also has importance for social functioning is processing speed (Brunnekreef et al., 2007). Slower processing may limit the possibilities for responding adequately to social cues. Daily life situations call for quick social responding; low processing speed may affect accuracy for such responding (Brunnekreef et al., 2007). With regard to the processing speed of children showing externalizing problem behavior, the findings are inconsistent. On the one hand, children with externalizing behavior problems have been found to be slower on EF tasks compared to children with internalizing behavior problems and children without problem behavior (Brunnekreef et al., 2007). On the contrary, a study of children with oppositional defiant disorder (ODD) revealed no significant differences from control children for the speed of processing EF tasks (Mayes & Calhoun, 2007).

EFs in Children with MBID

Children with MBID are defined as those who have an IQ between 55 and 85 with problems in their adaptive functioning. Whether EFs are impaired in children with MBID is not totally clear. EFs, and particularly working memory, are likely to co-vary with IQ, as EFs and IQ partly overlap as constructs and positively correlate in the general population with an average IQ, ranging $r = .72$ to $r = .85$ (Kane, Hambrick, & Conway, 2005; Oberauer, Schulze, Wilhelm, & Süß, 2005; Séguin et al., 1999). According to Ackerman, Beier, and Boyle (2005), however, EFs and IQ are constructs with less overlap than is often thought. Based on a meta-analysis of 86 studies, they conclude that working memory and intelligence share less than 25% of its variance. The strong overlap in the constructs found earlier might be due to methodological issues and overlap in EF and IQ instruments. No significant relation between IQ and working memory has been found in children with learning disabilities for example (defined here as severe learning problems and deficient school achievement), possibly due to range restriction on IQ and working memory (Maehler & Schuchardt, 2009). However, for children with moderate intellectual disabilities (ID, mean IQ 55), a significant positive association of IQ with working memory was found ($r = .80$; Osório et al., 2012).

Some recent studies compared the EFs of individuals with ID in general or MBID in particular to the EFs of individuals with average intelligence. The results with regard to inhibition are inconsistent. A meta-analysis showed that children with ID performed poorer than average intelligent controls on inhibition (Bexkens, Ruzzano, Collot d'Escury-Koenings, Van der Molen, & Huizinga, 2013). In contrast, no inhibition differences were found for adults with ID versus control participants with average intelligence (Danielsson, Henry, Rönnerberg, & Nilsson, 2010). In children, EF

impairments comprised difficulties in cognitive flexibility (Danielsson, Henry, Messer, & Rönnerberg, 2012) and working memory (Danielsson et al., 2010; Schuchardt, Gebhardt, & Mäehler, 2010). The results of other studies also show individuals with MBID to perform worse on cognitive flexibility and working memory when compared to same-aged participants with average intelligence, but not when matched with regard to mental age (Danielsson et al., 2012; Henry & MacLean, 2002). Taken together, these findings suggest developmental delays in the EFs of children with MBID (Van der Molen, Van Luit, Jongmans, & Van der Molen, 2007).

The results of the few studies to consider processing speed in children with ID in general and MBID in particular suggest that both EFs and processing speed may be delayed as this is known to be related to the development of intelligence and EFs (Kail, 2000). More importantly, processing speed may show deficits in children with MBID, especially when tasks become more complicated (Ponsioen & Van der Molen, 2002).

EFs and Externalizing Behavior in Children with MBID

The question that remains to be answered is whether or not these EF and processing speed impairments also relate to the occurrence of externalizing behavior problems in children with MBID. So far, EFs have been under-studied in children with MBID and externalizing behavior problems. This is unfortunate, as children with MBID are three to four times more likely than children with average intelligence to develop externalizing behavior problems (Baker, Blacher, Crnic, & Edelbrock, 2002; Dekker, Koot, Van der Ende, & Verhulst, 2002). The externalizing behavior problems of children with MBID, moreover, tend to persist over time (Emerson, Einfield, & Stancliffe, 2011).

The evidence regarding the association between EFs and the occurrence of externalizing behavior problems in children with MBID is very thin. Indications can nevertheless be found for an association of inhibition with aggression and delinquency in children with MBID. In a study in which a rating scale was used to assess inhibition, a clear relation to aggression in the children with MBID was found (Van Nieuwenhuijzen, Orobio de Castro, Van Aken, & Matthys, 2009). In a study in which cognitive impulsivity was assessed using performance-based measures, impulsivity was found to be higher among serious delinquents with a relatively low IQ compared to those with relatively high IQs (Koolhof, Loeber, Wei, Pardini, & Collot d'Escury, 2007). The association between the other components of EF and externalizing behavior in children with MBID have yet to be studied.

Empirical study is needed as EFs have been shown to be linked to such psychological processes as effective problem-solving, which provide a basis for adaptive social behavior (Morgan & Lilienfeld, 2000). The malfunctioning of underlying cognitive functions may lead to externalizing behavior problems at a given point in time and under adverse environmental circumstances. In most of the aforementioned studies the exact level of ID (mild, moderate or severe) was not distinguished. Inspection of the studies, however, shows that the majority of the participants had severe ID. Questionnaires or indirect measures of EF were mostly used, rather than actual performance-based measures such as computer tasks (for further discussion of the differences between these assessment procedures, see Toplak, West, & Stanovich 2013).

The Present Study

Given the cognitive impairments of children with MBID, EFs might play a crucial role in the highly prevalent behavior problems of these children. If EFs are found to be related to the occurrence of externalizing behavior problems in children with MBID then they might be targeted in the treatment of such children. In sum, whether or not a relation between impaired EFs and externalizing behavior problems exists for children with MBID is still not clear. In the present study we therefore compared inhibition, cognitive flexibility, and working memory, as well as processing speed, in two groups of children with MBID: a group with accompanying externalizing behavior problems ($n = 71$) and a group with no such behavior problems ($n = 70$), using performance-based measures of EFs. We expected the children with MBID and externalizing behavior problems to show poorer performance on tasks measuring inhibition, cognitive flexibility, and working memory than children with MBID without externalizing behavior problems. In addition, we expected the children with MBID and externalizing behavior problems to also show slower processing speeds than the other children.

Method

Participants

Families of 141 children with MBID aged 9 to 16 years participated in this cross-sectional study. The mean age of the children was 12.33 years ($SD = 2.01$) and 71% were male. The children had a mean intelligence score of 71.01 ($SD = 7.81$). The average socioeconomic status (SES) was 4.88 ($SD = 2.07$) along a 10-point scale, which indicates a lower vocational level of education for the parents on average. The study sample consisted of two groups: a problem behavior group ($n = 71$) and a comparison group ($n = 70$).

The problem behavior group consisted of children who were receiving treatment for their externalizing behavior problems accompanying the MBID in a day treatment center in the Netherlands. In the Netherlands there are 21 special treatment centers for children with MBID and externalizing behavior problems, 12 of which participated in this study. All of the treatment centers require that the children have an IQ between 55 and 85 and demonstrate severe adjustment problems in one or more social contexts as well as impairments in their daily functioning due to ID and externalizing behavioral problems. For our study, the children in the problem behavior group were selected for inclusion in this group when they scored above the 90th percentile on one or both of two subscales from the Dutch Child Behavior Check List (CBCL; Achenbach & Rescorla, 2001; for the Dutch version, see Verhulst, Van der Ende, & Koot, 1996): Aggression and Rule-Breaking. The CBCL was completed for the children by either the parent(s) or the day care staff (see the Measures subsection below). Assessment of the children in the problem behavior group was part of the pre-intervention assessment for a randomized controlled trial on the effectiveness of a parent-child intervention to reduce externalizing behavior problems in children with MBID (Schuiringa, Van Nieuwenhuijzen, Orobio de Castro, Lochman, & Matthys, *in press*).

The comparison group consisted of 70 children and their families, selected from five schools for special education. Each school is located near one of the participating

treatment centers located in the center of the Netherlands. The inclusion criterion for these schools is an IQ between 55 and 85. Children attending these schools may have mild behavior problems, but children with severe externalizing behavior problems do not attend the schools. Children in the comparison group were selected for inclusion in the present study when they received a score under the 90th percentile on both the Aggression and Rule-Breaking scales from the Teacher's Report Form (TRF; Achenbach & Rescorla, 2001; for the Dutch version, see Verhulst, Van der Ende, & Koot, 1997).

We are aware that our definition of ID differs from that most often used for mild ID in the international literature (IQ, ranging from 50–55 at the low end to 70 at the high end). We adopted the broader definition of mild ID as used in the Netherlands (IQ 55–85). In the Dutch situation, individuals with borderline intelligence (71–85) with severe limitations in adaptive functioning are also included in the healthcare and special education system for individuals with mild ID. Children with mild ID or borderline intelligence with severe limitations in adaptive functioning are present in both of the settings from which we selected participants for the problem behavior group and comparison group. Moreover, the children with mild ID (IQ 55–70) did not differ significantly from the children with borderline ID (IQ 71–85) on EF and externalizing behavior problems in the present study.

For both groups, further selection criteria for inclusion in this study were living at home with their parents or caregivers and fluency in Dutch for both the parents and children. Any children or parents suffering from psychosis, severe vision problems, or severe hearing problems were excluded from the study. In addition, children with autism spectrum disorders were excluded from the study in order to assess EFs and processing speed specifically with regard to MBID and externalizing behavior problems.

Where possible, both parents participated in the study and jointly completed one set of questionnaires about demographic data and their child's behavior. When this was not possible, the main caregiver was asked to complete the questionnaire. The majority of the participating children were of a Dutch origin (95%), with the remainder Antillean (1.4%), Surinamese (0.7%), or some other ethnic background (2.9%). A total of 82% of the participating mothers and 74% of the participating fathers were of Dutch origin. The main ethnic origins for the other parents were Antillean (father 3.6%, mother 3.6%), Moroccan (father 5.1%, mother 2.9%), Turkish (father 7.2%, mother 3.6%), and Surinamese (father 4.3%, mother 2.9%). This distribution of ethnic backgrounds is representative of the Dutch population as a whole (Statistics Netherlands, 2012). In Table 1, means, standard deviations (*SDs*), and group differences between the problem behavior group and comparison group on age, SES, IQ, and behavior are provided.

Procedure

The Dutch Medical Ethical Committee from the participating university approved the present study (CCMO nr 08/249). Children were initially selected for inclusion in the study on the basis of their TRF or CBCL scores, as provided by the teachers, parents, or care staff (see the Participants subsection above). Consent was next obtained from the parents, when the treatment institutions or special education schools sent out letters with detailed information on the study and a request for written consent. Additional information was provided when needed by the researchers or employees of the institutions and schools. Assessment appointments were next made with the children's

Table 1. Means, Standard Deviations, and Group Differences for Study Variables.

	Problem behavior group	Comparison group	<i>F</i>	<i>p</i>	<i>d</i>
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)			
Age	12.42 (1.73)	12.23 (2.26)	0.33	.57	0.09
IQ	71.32 (8.08)	70.70 (7.58)	0.22	.64	0.08
SES (0–10)	4.41 (2.04)	5.36 (2.01)	7.72	.006	0.50
TRF <i>t</i> -score ^a	68.66 (10.18)	50.01 (7.60)	128.32*	<.001	2.07
CBCL <i>t</i> -score ^b	67.72 (7.29)	52.79 (8.60)	120.42*	<.001	1.87

Note. *Raw scores were used to test for differences between groups; ^a*n* = 57 (problem behavior group) and *n* = 69 (comparison group); ^b*n* = 57 (problem behavior group) and *n* = 65 (comparison group)[]]. CBCL = Child Behavior Checklist, Externalizing Behavior; SES = socioeconomic status; TRF = Teacher Report Form, Externalizing Behavior.

teachers. The child measures (i.e., EF computer tasks and two IQ subtests; see the Measures section below) were individually administered by a trained test assistant from Utrecht University in a quiet room at the child's school. The EF tasks were performed on a laptop supplied by the research assistant. The IQ subtests were completed on paper. For the problem behavior group, the parents completed the subscales of the CBCL and the demographic information during a home visit. Teachers filled out a questionnaire about the child's behavior that was sent and returned by mail.

For the comparison group, the CBCL and the demographic information were obtained from parents via telephone. Thus, in both groups the research assistant was available to provide assistance when necessary both in the home situation and on the phone with the parents. Research assistants were given a guideline with synonyms and explanations of difficult words to ensure clear and unambiguous explanations of questionnaire items when participants did not understand an item. The research assistant posed the questions and recorded the answers provided in both the problem behavior and comparison groups. The teachers' selection assessments on child behavior on the TRF were used in the analyses of the comparison group. Teachers completed a questionnaire that was sent and returned by mail.

The response rate for teachers on the TRF was 80% in the problem behavior group and 99% in the comparison group. For the children in both the problem behavior group and comparison groups, 100% of the questionnaires on EFs and IQ were available. For the parents, 92% of the CBCL questionnaires and demographic information were available in the problem behavior group and 93% in the comparison group. Reasons for parental non-response were impossibility of reaching them after trying for several weeks or not being home for an appointment on several occasions.

Measures

Externalizing Behavior Problems

Parents, teachers, and care staff completed the Dutch version of the Externalizing Behavior subscale of the CBCL (Achenbach & Rescorla, 2001; for the Dutch version, see Verhulst et al., 1996) or TRF (Achenbach & Rescorla, 2001; for the Dutch version, see Verhulst et al., 1997). These measures are virtually identical and assess the child's externalizing behavior problems in the preceding two months along a three-point scale (0 = *not true*, 1 = *somewhat or sometimes true*, 2 = *very true or often true*). The Dutch versions of the CBCL and TRF have been shown to have good reliability and validity for

children both of average intelligence (Verhulst et al., 1996, 1997) and with MBID (Dekker et al., 2002). In the present study, a Cronbach's alpha of .93 was obtained for the CBCL Externalizing Behavior scale and .97 for the TRF Externalizing Behavior scale. In the further analyses, the raw sum scores for the Externalizing Behavior scales of the CBCL and the TRF were used. For descriptive purposes only, *t*-scores on the Externalizing Behavior scales were calculated using the Dutch norms.

Efs and Processing Speed

The Amsterdam Neuropsychological Tasks (ANT; De Sonneville, 1999) test was used to assess inhibition, cognitive flexibility, working memory, and processing speed. The ANT consists of a series of computerized tasks designed to evaluate the speed and accuracy of executive cognitive functioning. Ample studies have shown the ANT to have good validity and satisfactory psychometric properties in children of average intelligence (De Sonneville, 1999, 2005; Polderman et al., 2007). The test-retest reliability for the ANT is moderate to high (e.g., Huijbregts, De Sonneville, Licht, Sergeant, & Van Spronsen, 2002; Polderman et al., 2007). Convincing evidence exists for the construct validity of the ANT (e.g., Huijbregts et al., 2002). Also, the first results on criterion validity of the ANT tasks show moderate to high correlations with other computerized measures (e.g., Rommelse et al., 2008), and there is some evidence for differences in ANT profiles for different clinical disorders, indicating discriminant validity (Brunnekreef et al., 2007; Huijbregts, Warren, De Sonneville, & Swaab-Barneveld, 2008).

Prior to each task the child is given the standard verbal ANT instructions for that task. The child is given a practice session to ensure that the task is understood and to familiarize him or her with the task. The child is instructed to respond as fast and accurately as possible. Three subtasks of the ANT were used: GNG to assess inhibition, Response Organization Objects (ROO) to assess inhibition and cognitive flexibility, and Spatial Temporal Span (STS) to assess working memory. Reaction time measures on the GNG and ROO tasks were used to assess processing speed.

Inhibition

Inhibition was assessed with the GNG task of the ANT. During the task, 24 Go signals and 24 NoGo signals are presented in a random order. The Go signal is an empty square and the NoGo signal a filled square[.]. The child is instructed to press the mouse key with the index finger of the preferred hand as fast as possible when a Go signal appears on-screen. When a NoGo signal appears on-screen, the child should not respond. Each signal appears for 800 ms. A valid response window is set to 200–2300 ms post stimulus onset. Trials with responses faster than 200 ms after offering the stimulus are automatically replaced with trials of a similar type. GNG Inhibition is the number of false alarms, which represents the number of responses to a NoGo signal, and thus problems in inhibition.

In addition, inhibition was measured with the ROO task from the ANT. This task has three parts, and for all three parts the child was instructed to pay attention to the central fixation cross presented in a gray bar. The stimulus is a ball, presented randomly to the left or right of the cross. The ball indicates the type of response required, which can vary depending on the part of the task being performed. For all parts of the ROO

task, the signal is offered until a response is given between 200 and 6000 ms, otherwise the signal is replaced. Part 1 of the ROO task is designed to acquire a baseline for the speed and accuracy of the participants' responding. A total of 6 practice trials and 30 experimental trials are offered. The ball is green and compatible responses are required. The child was instructed to lay both index fingers on the response keys and to press the response key corresponding to the side of the screen where the green ball appears as quickly and accurately as possible.

Part 2 of the ROO task is designed to assess the suppression of a natural tendency to provide a compatible response in order to generate a non-automatic incompatible response that can be presumed to require inhibition (De Sonneville, 2005; Rommelse et al., 2007). Part 2 contains 6 practice trials and 30 experimental trials. The ball is red and incompatible responses are required. The participant is instructed to press the response key on the *opposite* side of the screen to the ball and to do this as quickly and accurately as possible. The performance on the subsequent parts of the task can be compared to the baseline information in order to provide data on inhibition (part 1 versus part 2). In the ROO task, inhibition is operationalized as a difference score between the error scores for the incompatible trials in part 2 and the compatible trials in part 1 (ROO Inhibition).

Cognitive Flexibility

Cognitive flexibility was assessed using parts 1 and 3 of the ROO task from the ANT. Both compatible and incompatible responses are required in part 3 of the ROO task, and alternating between compatible and incompatible responses can be expected to require cognitive flexibility (De Sonneville, 2005; Rommelse et al., 2007). On this trial, the color of the ball tells the participant how to respond; press the key on the same side as the ball when the ball is green (as in part 1), or press the key on the opposite side to the ball when the ball is red (as in part 2). Cognitive flexibility is operationalized as the difference in errors between the compatible trials in part 3 minus the compatible trials in part 1 (ROO Cognitive Flexibility). The difference scores were used in the analyses.

Working Memory

Working memory was assessed using the STS task of the ANT. The stimulus is a large rectangle with nine squares arranged in a 3×3 matrix. On each trial, a computer-driven hand points at a sequence of squares. The show duration is 1000 ms with an interval of 750 ms between shows. The child is instructed to pay close attention to the matrix on the screen. The test assistant explains that a computer-driven hand will point to a number of squares and that it is important to remember which squares are pointed to and in what order.

When the computer-driven hand has finished pointing to a series of squares, the participant is asked to reproduce the sequence of squares, but then in the *opposite* order, using a computer mouse to move the cursor (i.e., hand) around the matrix of squares displayed on-screen. The complete STS task includes a “forward” part to assess short-term memory and a “backward” part to assess working memory. In the current study, we only examined working memory and thus only used the data from the “backward” part of the task, which consists of 1 practice trial and 16 experimental

trials. The scores for STS Working Memory Correct Targets and the STS Working Memory Correct Order were used as separate variables to indicate working memory.

Processing Speed

Both the GNG task and the ROO task include reaction time measures, which thus gave us information on processing speed. The following variables were used for this purpose: Reaction Time Hits on the GNG (GNG Processing Speed) and ROO Reaction Time for part 1 (ROO Processing Speed). Of all the parts of the ROO task, Reaction Time on part 1 (i.e., baseline measurement of strictly compatible responses) was judged to be most representative of the participant's processing speed. Part 1 does not require complex judgments or responding, which could delay reaction times or might need more time to consider an adequate response.

Intelligence

An estimate of each participant's intelligence was obtained using two measures: the Vocabulary and Block Design subtests from the Dutch version of the Wechsler Intelligence Scale – Third Edition (WISC-III; Kort et al., 2005; Silverstein, 1970a). These two subtests taken together have been shown to correlate more strongly ($r = .86$) with the complete WISC-III than any other subscale, and thus provide an accurate estimate of children's overall intelligence (Silverstein, 1970b). The same WISC-III subtests have also been used in previous research to estimate the intelligence of children with MBID (e.g., Van Nieuwenhuijzen & Vriens, 2012).

Data Analyses

First, we checked for possible differences between the groups on demographic variables and externalizing behavior in an analysis of variance (ANOVA). Second, possible differences between the groups on EFs were tested for in a series of seven univariate analyses of covariance (ANCOVAs), with Group (problem behavior group, comparison group) as the independent variable, the ANT variables as the dependent variables (DVs), and SES, gender, and IQ as the covariates. These ANCOVAs were conducted because the groups were found to differ significantly with regard to both the demographic variables of SES and gender. There is also debate in the research literature on whether IQ should be controlled for in studies of EFs (Dennis et al., 2009; Kane et al., 2005; Oberauer et al., 2005; Séguin et al., 1999). We therefore decided to conduct all of the analyses both with and without IQ included as a covariate. If the pattern of the results was found to be the same in these analyses, we only described the analyses including all of the covariates (i.e., IQ, SES, and gender).

Several of the EF outcome variables were observed to include extreme individual values. To determine the robustness of our findings, we repeated the ANCOVA analyses with extreme values on these EF variables limited to a maximum of two *SDs* from the mean (Tabachnick & Fidell, 2007). Similar patterns of results were found and the results of the original ANCOVAs were therefore used further and reported on in the remainder of this study.

To ensure the robustness of the findings on inhibition and cognitive flexibility of the ROO task, analyses were also performed with repeated measures ANCOVAs with

Group as the between-subjects factor (problem behavior group, comparison group) and Part as the within-subject factor (part 1, part 2, part 3). Again, SES, gender, and IQ were added in the analyses as covariates. Testing for an interaction between Group and Part of the ROO task allowed us to determine if the patterns of errors differed for changes in errors from part 1 to part 2 of the task for inhibition and from part 1 to part 3 of the task for cognitive flexibility.

Results

Preliminary Analyses

Tests of homogeneity of variance, homogeneity of regression, and normality were performed. Assumptions with regard to homogeneity of regression were met for all variables, interaction terms of the covariates with group on the DV[] were non-significant. In addition, the differences between groups on variances fell within the acceptable range. Therefore ANCOVA analyses were conducted for all measures.

The demographic characteristics of both groups are summarized in [Table 1](#). The groups did not differ significantly with regard to age or IQ, but they did differ significantly with regard to gender and SES: 79% of the problem behavior group and 43% of the comparison group was male ($\chi^2 = 19.22, p < .001$). The families in the problem behavior group also had a significantly lower SES than the families in the comparison group. Gender and SES were therefore included as covariates in the main analyses.

As expected, the children in the problem behavior group were reported to have significantly more externalizing behavior problems than the children in the comparison group (see [Table 1](#)).

Group Differences in EF and Processing Speed

The descriptive statistics according to group are reported in [Table 2](#).

Inhibition

As shown in [Table 2](#), no significant group difference was found for GNG Inhibition. However, a significant difference was found for ROO Inhibition, with a stronger increase in errors from baseline measurement for the problem behavior group relative to the comparison group. This shows less inhibition in the children with MBID and externalizing behavior problems than in the children with MBID and no such behavior problems.

Cognitive Flexibility

The groups of children with MBID did not differ significantly with regard to their performance on the cognitive flexibility task (i.e., ROO Cognitive Flexibility). No significant difference between groups was found on the ROO Cognitive Flexibility. The results on inhibition and cognitive flexibility assessed with the ROO task presented in this paper were confirmed with additional repeated measures analyses.

Table 2. Adjusted Means, Standard Deviations, and Group Differences for Study Variables with SES, Gender, and IQ as Covariates.

	Problem behavior group		Comparison group		<i>F</i>	<i>p</i>	<i>d</i>	Range
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)				
Inhibition								
GNG Inhibition	1.46 (1.38)	1.47 (1.67)	0.00	.97	0.01		0–24	
ROO Inhibition	2.26 (4.37)	1.76 (3.48)	4.05	.046	0.13		0–30	
Cognitive Flexibility								
ROO Cognitive Flexibility	4.04 (4.21)	4.29 (4.06)	0.30	.58	0.06		0–30	
Working Memory								
STS Working Memory Correct Targets	66.80 (18.05)	78.06 (6.36)	25.62	<.001	0.83		0–144	
STS Working Memory Correct Order	33.18 (24.80)	53.43 (14.41)	39.80	<.001	1.00		0–144	
Processing Speed								
GNG Processing Speed	520.83 (92.03)	497.04 (90.48)	3.51	.06	0.26		200–2300	
ROO Processing Speed	475.57 (170.90)	423.14 (151.86)	5.80	.02	0.32		200–6000	

Note. GNG = GoNoGo; ROO = Response Organization Objects; STS = Spatial Temporal Span.

The results on inhibition and cognitive flexibility assessed with the ROO task presented in this paper were confirmed with additional repeated measures analyses. No significant difference was found on the increase of errors from part 1 to part 3 of the ROO task between the problem behavior group and the comparison group, $F(1,139) = 0.35$, $p = .56$, representing cognitive flexibility. The increase in errors from part 1 to part 2 of the ROO task is significantly stronger in the problem behavior group compared to the comparison group, $F(1,139) = 4.51$, $p = .04$, representing inhibition.

Working Memory

The children in the problem behavior group performed less accurately on the working memory tasks than the children in the comparison group (see Table 2). They produced significantly fewer Working Memory Correct Targets and significantly fewer Working Memory Correct Orders. The children in the problem behavior group were thus less able to remember the squares and sequence of squares in the opposite order than the children in the comparison group.

Processing Speed

Significant group differences were found for ROO Processing Speed and a trend towards significant group differences for GNG Processing Speed was found. The processing speed of the children in the problem behavior group was slower than the processing speed of the children in the comparison group.

The results on the GNG Inhibition task might indicate floor effects, as an average score of 1.46/1.47 false alarms with *SDs* of 1.38 and 1.67 on a 0–24 range indicates that the task might have been too easy. On the ROO task however, a score of 2.26–4.29 does not indicate a floor effect as the score represents a calculation where the number of errors on part 1 of the task are subtracted from the number of errors on part 2 of the task. The working memory task indicates no floor or ceiling effects. Also the processing

speed tasks do not indicate a floor effect, as the maximum scores for processing speed mean that the participant does not respond and the stimulus is replaced.

Discussion

The main aim of this study was to answer the question whether children with MBID and externalizing behavior problems perform worse on EF tasks as compared to children with MBID without externalizing behavior problems. Children with MBID and externalizing behavior problems performed worse on working memory tasks compared to children with MBID with no externalizing behavior problems, even when controlling for IQ. Differences in inhibition between children with MBID and with and without externalizing behavior problems were inconsistent, just as differences between groups in processing speed occurred but not consistently across tasks. Cognitive flexibility was not more impaired in the children with MBID and externalizing behavior problems when compared to the children with MBID and no such problems.

The findings are partly in line with those of other studies in children with average intelligence and externalizing behavior problems. In our study, children with MBID and externalizing behavior problems showed poorer working memory performance than children without such behavior problems. Working memory is related to the ability to keep goal-related representations actively in mind, engage in a deliberate search of memory for additional goal-related information, and select a behavioral response on the basis of the information available (Barrett, Tugade, & Engle, 2004). Impaired working memory of children with MBID, therefore, may result in externalizing behavior problems.

In the literature, the findings to date for children with average intelligence and externalizing behavior problems are inconsistent (Oosterlaan et al., 2005; Séguin et al., 1999; Van Goozen et al., 2004). In a recent meta-analysis of studies in preschool children with average intelligence, for example, the effect size is small (Schoemaker et al., 2013). The effect size in the present study with older children with MBID is large ($d = 0.83\text{--}1.00$). It is certainly possible that impaired working memory may be more strongly associated with externalizing behavior in children with MBID than in preschool children with externalizing behavior from the general population, simply because a minimal level of working memory is required to process social information adequately. As children with MBID tend to already perform poorly in working memory, they may not attain this minimum level (Danielsson et al., 2010; Van der Molen et al., 2007), which may lead to inadequate processing of social information and externalizing behavior problems.

In line with this, a recent study (McQuade et al., 2013) showed poor working memory to be associated with physical aggression and impaired conflict-resolution skills in typically developing fourth- and fifth-grade children. Furthermore, the association between poor working memory and social competence was found to be mediated by the children's conflict-resolution skills. Children with working memory impairments may thus have difficulties in considering multiple pieces of social information, thinking through their actions, and referencing prior social knowledge (McQuade et al., 2013). Also, it can be speculated that poor working memory results in frustration due to being

overwhelmed by information-processing demands. Working-memory impairments in children with MBID may similarly affect their social competence and such problem-solving skills as goal-setting, the evaluation of alternative behavioral solutions, and the selection of an appropriate solution among the various solutions available, which may lead to inappropriate social responding and externalizing behavior problems.

In line with the findings of two meta-analyses showing inhibition deficits in children with externalizing behavior problems and average intelligence (Oosterlaan et al., 2005; Schoemaker et al., 2013), the children with MBID and externalizing behavior problems in the present study were expected to show poor performance on inhibition as well. The results of the study were mixed, however. On the one hand, no differences between the children with and without externalizing behavior problems were found on the GoNoGo task. On the contrary, the children with externalizing behavior problems made more errors than those without on the ROO task, indicating compromised inhibition. These mixed findings can nevertheless be explained by different levels of task difficulty. Inhibiting one's responses on the ROO task is likely to be more complex than inhibiting one's responses on the GNG task. On the GNG task, the respondent simply has to react or not react to a neutral figure on the screen, which means that the inhibition required by this task might have been too easy for most children. Participants in both groups scored an average of 1.47 false alarms on a 0–24 range, indicating that the GNG task was easy to perform for the participating children in both groups. Differences between groups may appear only when tasks become more complex (Ponsioen & Van der Molen, 2002). However, on the ROO task, the participants must switch from an automatic (i.e., compatible) response during part 1 of the task to a non-automatic (i.e., incompatible) response during part 2 of the task. The results on the ROO task do not indicate a floor effect.

Regarding cognitive flexibility, no significant differences between groups were found. In a recent meta-analysis, the association between cognitive flexibility and externalizing behavior problems in preschool children showed the lowest effect size compared to the other components of EF (Schoemaker et al., 2013). In our study, only one task was used to assess cognitive flexibility and did not show significant differences between the two groups. In a recent study in individuals with MBID (Visser et al., 2015) a relation between cognitive flexibility and externalizing behavior was only found when using rating scales to measure cognitive flexibility. When using a neuropsychological task, as was done in the current study, these results were not confirmed. It is important to use multiple tasks to assess an EF construct due to the large variability in the characteristics of such tasks and which might lead to heterogeneous outcomes (Schoemaker et al., 2013).

The results for processing speed are mixed. On the ROO task the children with MBID and externalizing behavior problems had a slower processing speed than the children with MBID and no such problems; on the GNG task, in contrast, the groups did not differ significantly. This inconsistency in processing speed findings is actually in keeping with the results of studies with samples of children with average intelligence and externalizing behavior problems (Brunnekreef et al., 2007; Mayes & Calhoun, 2007). Taken together, these findings suggest that slowed processing speed may only become a problem when quick and complex responding is required, as is often the case in daily life (i.e., for social responding). It may be that children with MBID and

externalizing behavior problems are capable of adequately performing EF tasks when given sufficient time but are placed at a disadvantage when more time is needed to process incoming information.

Strengths and Limitations

This study is to our knowledge the first to directly assess EFs in children with MBID and externalizing behavior problems as opposed to indirectly assessing EFs via questionnaires. Some possible limitations should nevertheless be considered when interpreting the results. First, the study was cross-sectional, which means that the data do not provide insight into the role of EFs in the development of externalizing behavior in children with MBID.

Second, each aspect of EF was only assessed using one or two tasks. If multiple tasks had been used, latent variables could have been created, thereby reducing the possibility of error and minimizing the influence of random factors. In addition, these differences between tasks could be informative about the specific problems in inhibition—for example, the differentiation between hot and cool EFs (Hobson et al., 2011). However, EFs in this study mainly concerned handling non-social information with little emotional salience. Possibly, relations between EFs and externalizing behavior problems are particularly strong when emotionally salient information is at stake, so called “hot EF” (Hobson et al., 2011).

Third, the same tasks were used with all of the children in the study despite a large age range (9–16 years). Perhaps adaptive testing—adjusting the difficulty of items to the participants’ cognitive level or developmental age—is a promising alternative for studies covering broad ranges of ages or IQ.

Fourth, this study only examined the spatial and not the verbal part of working memory. However, it has been shown that the verbal and spatial central executive are covered in a single system of working memory (McQuade et al., 2013), therefore based on our data we can carefully conclude upon the central executive of working memory. Nevertheless, the use of other measures of complex span would be an interesting future direction.

Fifth, in this study we used the Dutch criterion for MBID (IQ 55–85), therefore, results cannot be generalized to children with an IQ of 70 and below. However, in the current study, children with MBID (IQ 55–70) and borderline ID (IQ 70–85) did not differ significantly on EFs or externalizing behavior problems; therefore, it is likely that results also account for children with moderate ID.

Sixth, the number of analyses we performed may have increased the risk on false positive findings. However, including a larger group of participants would not be feasible in this target group and Bonferroni correction would increase the risk of making Type 2 errors.

Seventh, in the current study information on ADHD symptoms was lacking, and therefore we were unable to control for possible confounding effects of comorbid ADHD symptoms.

Eighth, the lack of norm scores on the ANT measures means that the interpretation of EF performance of children with MBID and externalizing behavior cannot be easily compared to the general population of children of average intelligence aged 9–16 years.

Finally, the individuals from the problem behavior group were not matched to individuals in the comparison group on SES and gender. Instead, an ANCOVA was used to statistically control for differences between groups on SES and gender. The groups were not matched on SES and gender, as these factors are typically associated with externalizing behavior. An advantage of using ANCOVA over-matching is the ability to use select samples instead of more extreme subgroups that are more forcedly formed because they match on the key variables (Tabachnick & Fidell, 2007).

Implications for Research and Practice

It is crucial that the EF tasks sufficiently differentiate between levels of EF performance, particularly when the population is children with MBID. The tasks should match the cognitive abilities of the children—i.e., not too difficult or too easy—in order to distinguish between those children who perform well and those who perform poorly in one or more areas of EF. In future research attention should be paid to the development of EFs in children with MBID and externalizing behavior problems together with environmental factors that may affect this development, such as parenting (Hughes & Ensor, 2009; Hughes, Roman, Hart, & Ensor, 2013). If so, insight into these factors is needed in order to constitute possible targets for intervention. Longitudinal data is needed to provide insight into the development of EFs into early adulthood.

The literature is unclear about the relation between EFs and IQ. The results of the current study indicate that working memory could be an independent risk factor for externalizing behavior, given the group differences after controlling for IQ in the analyses. When EF deficits and low IQ are risk factors for externalizing behavior, an additive effect can be expected. Future research with longitudinal data should examine whether EF deficits mediate some of the effects of low IQ on externalizing behavior.

Several experimental studies have recently demonstrated the possibility of improving working memory with the use of both computerized training programs (Klingberg, 2012; Van der Molen, Van Luit, Van der Molen, Klugkist, & Jongmans, 2010) and non-computerized training programs. The largest effects have been found for training programs that present challenging EF tasks that increase in difficulty (Diamond & Lee, 2011). These findings, together with our own, suggest that EF training may become part of intervention programs aimed at decreasing externalizing behavior problems. For example, existing intervention programs already focus on improving social information processing (e.g., Lochman & Wells, 2002) and have been shown to effectively decrease problem behavior. To increase the effectiveness of these programs, training on response inhibition and the strengthening of working memory may be introduced in addition to interventions aimed at improving social problem-solving in general (McQuade et al., 2013). In the long run, the exact content of the interventions for individual children may then be made dependent on the individual EF profiles of the children (Matthys, Vanderschuren, Schutter, & Lochman, 2012).

In particular, children with poor inhibition might have difficulties thinking through social responses and evaluating the optional responses before enacting behavior. Likewise, deficits in working memory may limit the ability to incorporate several pieces of information that are used for interpretation of intent, evaluation of responses, and, finally, response selection. EFs are likely required to enable the child to integrate

information about intent and reach a decision for behavior (Cushman, Sheketoff, Wharton, & Carey, 2013; McQuade et al., 2013), which suggests that children might benefit more from interventions focusing on improving social information processing and social skills when impairments in EF are simultaneously reduced.

Conclusion

This study is the first to examine the relation between EFs and externalizing behavior problems in children with MBID. The occurrence of the externalizing behavior problems appears to be related to specific EF impairments in children with MBID. In a related recent study, intervention aimed at reducing externalizing behavior problems in children with MBID through the combination of cognitive behavioral therapy and parent management training showed promising results (Schuiringa et al., *in press*). The results of the present study suggest that this promising intervention might be supplemented with response inhibition and working memory training in order to make the intervention even more promising.

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