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The Relationship Between Cognitive and Behavioral Measures of Executive Function in the Context of Elementary School

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Abstract

Cognitive and behavioral measures are used to assess executive functions. Previous research shows that these measures tap different underlying aspects. However, much less is known about this relationship, when assessed in the context of elementary education. The current study aims to contribute to this body of research by examining the relationship between cognitive and behavioral measures (rated by parents and teachers) of executive functioning in an elementary school context, using two study designs. In study 1, the relationship between behavioral measures (using the Behaviour Rating Inventory of Executive Function: BRIEF) and cognitive measures was examined in terms of inhibitory control, planning and organization abilities as well as processing speed using a sample of 51 children (8-10 years old). In study 2, the relationship between behavioral measures and cognitive measures of inhibitory control, cognitive flexibility, and working memory was studied in a sample of 27 children (8-10 years old). Spearman's rho coefficients were calculated between the BRIEF and neuropsychological tasks measuring the aforementioned cognitive functions. Only processing speed appeared to be positively related to parent- and teacher rated executive function problems: lower speed of information processing was associated with more executive function problems in daily life. No other correlation between cognitive and behavioral measures of executive functioning was statistically significant. These findings in the elementary school context confirm that cognitive and behavioral measures reflect different but complementary aspects of executive functioning. Furthermore, they suggest that behavior ratings of executive functioning might reflect general problems, such as slower speed of information processing.

Key words: executive functions, cognitive measures, behavioral measures, neuropsychological assessment, education.

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Novelty and Significance

What is already known about the topic?

- The relationship between cognitive and behavioral measures of executive functioning has been studied mostly in children with different (mental) disorders.
- Only very small to modest relationships between cognitive and behavioral measures were previously found, demonstrating that cognitive and behavioral measures reflect different aspects of executive functioning.

What this paper adds?

- Our results in typically developing elementary school children showed that speed of information processing was related to more executive function problems, as reported by both parents and teachers.
- The other relationships between cognitive and behavioral measures of executive functioning were not significant, confirming that both measures should be considered as complementary.
- The findings suggest that behavior ratings of executive functioning might reflect general problems, such as slower speed of information processing.

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Executive functions (EF) refer to higher order cognitive functions which are necessary to organize information and to control behavior (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000; Salthouse, Atkinson, & Berish, 2003). These cognitive functions are especially required in complex, new, and ambiguous situations, when automatic behavior is insufficient to achieve set goals (Shallice, 1988). Miyake *et alii* (2000) identified three mental processes, called core EF, which allow individuals to regulate and adapt their behavior. These processes include 1) storing, updating, and manipulating incoming information (i.e., working memory), 2) inhibition of prepotent responses (i.e., inhibitory control), and 3) shifting between mental sets (i.e., cognitive flexibility). Research suggests that these three core EF are separable, but overlapping constructs (Miyake & Friedman, 2012).

Typically, EF develop rapidly through childhood and adolescence. The development of EF has been related to the development of neuronal networks encompassing the prefrontal cortex, which continues into the mid-twenties (Diamond, 2013). Consequently, EF are not entirely established until early adulthood. The development of EF does not necessarily proceed linearly, but also includes spurts at different developmental stages. All EF seem to follow a unique developmental path, with each function being mastered at a different age. However, with respect to most EF, the largest performance-based improvement is found between the ages of seven and nine years (Anderson, 2002).

EF are essential for successful everyday functioning. Indeed, studies have shown a positive relationship between EF, mental health, physical health, school achievement, and overall well-being. For example, inhibitory control in childhood appears to be positively related to multiple outcomes throughout life, such as persistence in childhood, performance in school, and salary and happiness in adulthood (Diamond, 2013). Whereas adequate EF have been related to positive health outcomes, impaired EF have been associated with negative health outcomes, such as obesity and substance abuse in adulthood (Crescioni *et alii*, 2011). Furthermore, it has been suggested that impaired EF underlie the behavioral characteristics of several psychological disorders, such as Attention-Deficit/Hyperactivity Disorder (ADHD; Diamond, 2013), as a transdiagnostic factor (Ros & Graziano, 2020).

Given the impact of EF on developmental tasks and mental and physical health outcomes, early identification of EF problems is important to provide children with adequate support. For example, children with problems in executive functioning benefit from a more structured learning environment (Higgins, Sluder, Richards, & Buchanan, 2018; Iovannone, Dunlap, Huber, & Kincaid, 2003), and several interventions are known to improve EF or to provide compensation strategies (e.g., working memory training programs (Spencer-Smith & Klingberg, 2015) and self-regulatory programs at school (Liew, 2012)).

To identify EF problems, two methods of measurement haven been used frequently: cognitive measures using neuropsychological tests (NPT), and behavioral measures. NPT are standardized tests, administered by a trained test leader in a controlled and well-structured environment (Krivitzky, Bosenbark, Ichord, Jastrzab, & Billinghurst, 2019), which often assess response time and/or accuracy as measures of executive functioning. Behavior ratings, for instance the Behaviour Rating Inventory of Executive Function (BRIEF; Huizinga & Smidts, 2012), mostly consist of questionnaires regarding everyday behavioral functioning, associated with executive functioning. The questionnaires about children's EF are completed by informants, often by parents or teachers. Both NPT

and behavior ratings have specific advantages and disadvantages (see Toplak, West, & Stanovich, 2013). NPT provide insight into the efficiency of cognitive functions in a well-structured test administration. Due to this well-structured test administration, NPT might lack ecological validity. Moreover, behavior ratings can be used to screen for EF problems in daily life in (large groups of) children, for instance in the context of school, which is cheaper and less time-consuming. However, behavioral measures are also prone to informant biases. For example, informant characteristics such as parental depression influence how parents view and judge their children`s behavior (Berg-Nielsen, Vika, & Dahl, 2003). Furthermore, problems on behavioral measures of executive functioning may not necessarily indicate problems in the underlying cognitive processes. For instance, based on the observed behavior, an informant might think that the child has a working memory problem, while the underlying cognitive problem appears to be a lowered speed of information processing and the child merely needs more time to retain and process information. Nonetheless, cognitive and behavioral measures are both commonly used to assess executive functioning in clinical and nonclinical settings.

In recent years, the relationship between cognitive and behavioral measures of executive functioning has been studied frequently. A review (see Toplak *et alii*, 2013) on the relationship between cognitive measures on the one hand and self- and parent ratings on the other hand concluded that these two methods of measurement capture different aspects of EF (processing efficiency versus functioning in everyday life in order to pursue goals). Looking more specifically at parent ratings in children using the BRIEF, some studies found no significant correlations between cognitive and behavioral measures in children with different (brain) disorders (Vriezen & Pigott, 2002; De Vries et alii, 2018; McAuley, Chen, Goos, Schachar, & Crosbie, 2010) and a group of typically developing children (McAuley *et alii*, 2010). Other studies found weak to moderate relationships between some cognitive and behavioral measures of EF in children with brain disorders (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Krivitzky *et alii*, 2019; Payne, Hyman, Shores, & North, 2011), in term and preterm born children (O'Meagher, Norris, Kemp, & Anderson, 2018), and in typically-developing children (Anderson *et alii*, 2002; Dekker, Ziermans, Spruijt, & Swaab, 2017; Muñoz & Filippetti, 2021). In children with a brain tumor, moderate correlations were found between cognitive measures and teacher ratings (De Vries *et alii*, 2018). In conclusion, previous research has shown only very small to modest relationships between these two methods of measurement, demonstrating that cognitive and behavioral measures reflect different aspects of executive functioning. One possible explanation for these findings is that cognitive and behavioral measures of EF, estimate different underlying aspects of functioning. Whereas cognitive measures seem to capture the efficiency of executive functioning under optimal circumstances (i.e., processing efficiency), by pre-structuring the test situation and giving test instructions, behavior ratings seem to capture complex adaptive strategies in everyday life that enable children to pursue goals (see Toplak *et alii*, 2013). In other words, cognitive measures assess executive functioning of individuals in optimal performance situations and behavioral measures reflect the ability to use these functions in everyday life. Although much research has been done on the relationship between cognitive and behavioral measures of executive functioning, the relationship has not been investigated frequently in school classes of elementary school children, for example to screen for EF problems. Possibly, differences in context (performance at school versus at home) have an impact on the relationship between cognitive and behavioral measures of EF (Duku & Vaillancourt, 2014). Therefore, the aim of this

study is to assess the relationship between cognitive and behavioral measures (rated by parents and teachers) of EF in children assessed in the elementary school context.

As part of a larger study exploring the effects of an executive function training, two pilot studies were conducted. In these independent samples different neuropsychological tasks and behavioral measures were combined as a baseline and as such, were reported as two separate studies here. In study 1, the relationship between behavior ratings on the BRIEF and cognitive measures of inhibitory control, planning and organization abilities, as well as processing speed as basic cognitive function, will be investigated. In study 2, the relationship between behavior ratings on the BRIEF and cognitive measures of inhibitory control, cognitive flexibility, and working memory will be investigated. Based on the review of Toplak *et alii* (2013), weak correlations between parental behavior ratings and cognitive measures of EF are expected to be found. Based on studies that have shown that teacher ratings correlate stronger with cognitive measures than parent ratings (De Vries *et alii*, 2018; Dekker *et alii*, 2017), a moderate correlation is expected for the relationship between teacher ratings and cognitive measures of EF. Regarding the relationship between processing speed and behavioral measures in study 1, lower processing speed is expected to be associated with more EF problems reported by informants. In previous studies a strong correlation has been found between processing speed and working memory and significant correlations between working memory tasks and behavior ratings (Dekker *et alii*, 2017; Krivitzky *et alii*, 2019).

STUDY 1

METHOD

Participants

A total of 51 elementary school children in the 3rd grade (group 5 in The Netherlands; 35.3%) and 4th grade (group 6 in The Netherlands; 64.7%) of a regular Dutch elementary school participated in study 1. The age of the children ranged from 8 to 10 years (M= 8.80, SD= 0.53), 45.1% of the children were boys. There were no exclusion criteria.

Materials

Bourdon-Vos test (Vos, 1998). This test was used as a measure of information processing speed. The task consists of target and non-target (dotted) figures. Participants have to cross out target figures (groups of four dots), while ignoring the non-target figures. The average time that participants need to complete different rows of the task was measured, according to the manual, without correcting for errors. A lower average reaction time on the Bourdon-Vos test indicates higher speed of information processing.

Stroop Color Word Test (Stroop CWT; Hammes, 1971). The Stroop CWT was used to assess inhibitory control. The Stroop CWT consists of three conditions, each presented on a sheet. In the first condition (reading condition), participants were asked to read the names of color words (for instance, the words 'red' and 'green'). In the second condition (naming condition), participants were asked to name the colors of colored bars. In the third condition (inhibition condition), participants were requested to name the ink color of incongruent color words (for instance, when the word 'green' was printed in yellow, participants should answer 'yellow' and inhibit the prepotent response to read 'green'). The time required to complete the task was recorded for all conditions.

Contrast scores were calculated by subtracting the time on condition two from the time on condition three. These contrast scores were used as a measure of inhibitory control. Higher contrast scores indicate less inhibitory control.

Behavioral Assessment of the Dysexecutive Syndrome for Children Zoo Map (BADS-C Zoo Map; Emslie, Wilson, Burden, Nimmo-Smith, & Wilson, 2003). The BADS-C Zoo Map was used to assess planning skills and consists of two conditions. In this paper and pencil task, participants had to plan and carry out a (hypothetical) route in a zoo according to a number of rules. The score of this test was calculated by subtracting the number of errors/rule violations from the number of correctly visited places (scores ranged from 0 to 8), where higher scores indicate better planning skills. The second condition of this task measures the ability to follow an externally imposed strategy, but this condition was not used in the current study.

Behaviour Rating Inventory of Executive Function (BRIEF; Dutch version Huizinga & Smidts, 2012). The BRIEF was included to assess everyday problems in the EF of children in their home environment (i.e., parent-rated version of the BRIEF) and in their school environment (i.e., teacher-rated version of the BRIEF). In these questionnaires, both parents and teachers were asked to rate the likelihood that children engaged in specific behavior in the past six months on a three-point Likert scale from 1 (never) to 3 (often). For instance, parents and teachers had to rate the statement 'can concentrate only briefly'. Each questionnaire consists of 75 items and results in eight subscales (i.e., inhibition, shifting, emotional control, initiation, working memory, planning and organization, organization of materials, and monitor) by summing up the scores of the corresponding items. In this study, total scores (representing overall EF problems) were used, which were calculated by summing up the scores on the eight subscales and ranged from 72 to 216 in the parent-rated BRIEF and from 73 to 219 in the teacher-rated BRIEF. Higher total scores are indicative of more everyday executive problems. Moreover, scores on the subscale inhibition (ranged from 10 to 30 in the parent- and teacher-rated BRIEF) and planning (ranged from 12 to 36 in the parent-rated BRIEF and from 10 to 30 in the teacher-rated BRIEF) were used. Higher scores are indicative of more everyday problems related to inhibition or planning.

Procedure

All procedures of the current study were in accordance with the Declaration of Helsinki and approved by the Faculty Ethics Review Board of the Faculty of Social and Behavioural Sciences of the University of Amsterdam (2014-DP-3839). Participants were recruited as part of a study investigating the effects of an executive function training. The recruitment of the participants took place on a regular elementary school in The Netherlands, where all children in the 3rd and 4th grade and their parents were informed about the purpose of the study through an information letter. In addition, a parent information evening was held where information was provided on the goals of the study, the rights of the participants, the confidentiality of the data collection, and the option to end participation at any point during the study. When children and their parents agreed to participate in the study, written informed consent was signed. Participation took place at school, was completely voluntary and there was no financial compensation. The participants of this study also participated in a feasibility study of an executive function training program (i.e., Braingame Brian; Prins *et alii*, 2013), conducted in the school classroom. For this feasibility study, participants completed several (neuropsychological) tasks, such as EF tasks, language tests, and calculation tests. In addition, their parents and teachers completed questionnaires about the children's behavioral functioning, for example emotion regulation and executive functioning. The neuropsychological tests and questionnaires included in the baseline-measurement of the feasibility study which focused on EF were included in this study (see materials).

Data Analysis

Data were analyzed using IBM SPSS Statistics version 26.0. First, missing data were explored. The number of missing data was small. For one participant it was not possible to complete all conditions of the Stroop CWT, due to a lack of understanding of the task. Therefore, no contrast score could be calculated for this participant. Moreover, four items were missing in the teacher-rated BRIEF and 14 in the parent-rated BRIEF, distributed over 12 participants. Missing values were replaced by the mean score of the specific subscale. In two questionnaires completed by parents, a few items were double ticked. In these cases, the mean score of both answers was used. Before the correlation analyses were performed, assumptions and extreme scores were checked and found to be violated for linearity and normality. Moreover, five outliers were detected (greater than three standard deviations above or below the mean; Kannan, Manoj, & Arumugam, 2015). To minimize the effects of the outliers and the violations of the assumptions, Spearman's *rho* was used to calculate correlations between the total scale of the BRIEF, the inhibition scale of the BRIEF, and the plan/organize scale of the BRIEF (all rated by parents and teachers) and scores on the NPT Stroop CWT, BADS-C Zoo Map, and Bourdon-Vos test. Due to the large number of correlations, alpha was set at $p \leq .01$ to control for Type I errors.

RESULTS

Correlation coefficients between cognitive measures and behavior ratings on the BRIEF varied from -.10 to .41. (see Table 1). The Bourdon-Vos score was the only cognitive measure which was significantly related to behavior ratings: a higher score on processing speed (i.e., a larger reaction time) was related to more total executive function problems rated by both parents ($r(51) = .36$, $p < .009$) and teachers ($r(51) = .41$, $p < .003$). According to Dancey and Reidy (2007), the effect size was weak between processing speed and parent ratings and moderate between processing speed and teacher ratings. More specifically, results indicated that a higher score on processing speed was positively related to problems in planning and organization reported by both parents ($r(51) = .40$, $p < .003$) and teachers ($r(51) = .37$, $p < .008$), meaning that a lower processing speed was related to more everyday problems in planning and organization, with a moderate respectively weak effect size.

Correlation coefficients between parent- and teacher-rated EF problems on the total score, the inhibition scale, and the planning and organization scale of the BRIEF varied from .50 to .60 (see Table 1). Parent-rated EF problems were significantly related to teacher-rated EF problems on the total score of the BRIEF ($r(51) = .51$, $p < .001$), the inhibition scale ($r(51) = .50$, $p < .001$), and the planning and organization scale ($r(51) = .60$, $p < .001$), each with a moderate effect size. This reflects that the more EF problems

Table 1. Spearman's rho coefficients between the cognitive and behavioral EF measures.

	1	2	3	4	5	6	7	8
1. Stroop CWT	-							
2. BADS-C Zoo Map	-.12	-						
3. Bourdon-Vos	.36	.22	-					
4. BRIEF total-Parent	.18	.02	.36*	-				
5. BRIEF total-Teacher	.27	.14	.41*	.51*	-			
6. BRIEF inhibition-Parent	.06	-.10	.26	.74*	.26	-		
7. BRIEF inhibition-Teacher	.01	-.01	.20	.33	.52*	.50*	-	
8. BRIEF Plan/Organize-Parent	.22	.00	.40*	.89*	.66*	.55*	.35	-
9. BRIEF Plan/Organize-Teacher	.35	.20	.37*	.48*	.84*	.25	.37*	.60*

Note: *= $p < .01$.

were reported by parents, the more EF problems were reported by teachers, showing that teacher and parent ratings of the executive behaviors of these children show a fairly high level of consistency.

STUDY 2

METHOD

Participants

A total of 27 elementary school children in the 3rd grade (group 5 in the Netherlands) of a Dutch regular elementary school participated in study 2. The age of the children ranged from 8 to 10 years (M= 8.63, SD= 0.69), 48.15% were boys. There were no exclusion criteria to participate in the study.

Materials

Wechsler Intelligence Scale for Children (WISC-III-NL; Kort *et alii*, 2005). The subtest digit span of the third edition of the WISC-III-NL was included as a measure of the working memory capacity. In this subtest, participants were asked to repeat an increasing number of digits, both forwards and backwards. The total raw score of this subtest was calculated by summing up the scores for the forward condition and the backward condition; higher scores are indicative of higher working memory capacities.

Stroop Color Word Test (Stroop CWT; Hammes, 1971). The Stroop CWT was used as a measure of inhibitory control (see study 1 for the description of the measurement).

The Trail Making Test (TMT; Bowie & Harvey, 2006). The TMT was used to assess cognitive flexibility. The TMT consists of two conditions, condition A and B. In condition A, participants were asked to connect the numbers 1 to 25 in ascending order. In condition B, participants were asked to connect the numbers 1 to 13 and the letters A to L in ascending and alphabetical order respectively, while alternating between the numbers and the letters. For both conditions, the time required to complete the task was recorded. Contrast scores were calculated by subtracting the time on condition A from the time on condition B, reflecting a set-switching cost (Arbuthnott & Frank, 2000) and therefore used as a measure of cognitive flexibility in the current study. Higher contrast scores are indicative of less cognitive flexibility.

Behaviour Rating Inventory of Executive Function (BRIEF; Dutch version Huizinga & Smidts, 2012). The BRIEF was used to rate everyday problems in the EFs of children in their home environment (i.e., parent-rated version of the BRIEF) and in their school environment (i.e., teacher-rated version of the BRIEF; see study 1 for the description of the measurement). Scores on the subscale inhibition, flexibility and working memory were calculated by summing up the scores from the relevant subscale. Scores ranged from 10 to 30 in the parent- and teacher-rated BRIEF on the subscales inhibition and working memory, and from 8 to 24 in the parent- and from 10 to 30 in the teacher-rated BRIEF on the subscale flexibility. Higher scores are indicative of more everyday problems in the specific area.

Procedure

All procedures of the current study were in accordance with the Declaration of Helsinki and approved by the Faculty Ethics Review Board of the Faculty of Social and Behavioural Sciences of the University of Amsterdam (2014-DP-3839). Participants were recruited as part of a study investigating the effects of an executive function training (see study 1 for a detailed description of the procedure). Participation took place at school, was completely voluntary, and there was no financial compensation. For the effect study

participants completed several (neuropsychological) tasks and questionnaires, such as questionnaires on sleep and movement. In addition, their parents and teachers completed questionnaires about the children's behavior, for example about executive functioning, ADHD symptoms and symptoms of autism spectrum disorder. The neuropsychological tests and questionnaires included in the baseline-measurement of the feasibility study which focused on EF were included in this study (see described materials).

Data Analysis

The data were analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY). First, missing values were explored. Two participants did not complete all conditions of the Stroop CWT and one participant did not complete all conditions of the TMT, due to a lack of understanding of the task. Therefore, no contrast score could be calculated for these participants. No participant was completely excluded from the study, as all other tasks could be completed appropriately. Moreover, four items were missing in the parent-rated BRIEF, distributed over four participants. Missing values were replaced by the mean score of the specific subscale. In three questionnaires completed by parents, some items were double ticked. In these cases, the mean score of both answers was used. Before the correlation analyses were performed, assumptions and extreme scores were checked and found to be violated for linearity and normal distribution. Moreover, four outliers were detected, with a value greater than three as a standard score (Kannan *et alii*, 2015). To minimize the effects of the outliers and the violations of the assumptions, Spearman's rho was used to calculate correlations between the behavior ratings of parents and teachers and scores on NPT. More precisely, correlations between the inhibition scale of the BRIEF, the flexibility scale of the BRIEF, and the working memory scale of the BRIEF (all rated by parents and teachers), and the scores on the NPT Stroop CWT, Trail Making Test, and Digit Span were calculated. Two teachers completed the BRIEF for each child, therefore the scores on the inhibition scale, the flexibility scale and the working memory scale were averaged over the two teachers. Due to the large number of correlations alpha was set at $p \leq .01$ to control for Type I errors.

RESULTS

Correlation coefficients between cognitive measures and behavior ratings on the BRIEF varied from -.24 to .18. (see Table 2). No significant correlations were found between cognitive measures and behavioral measures, aimed to measure the same domain of executive functioning (i.e., inhibition, cognitive flexibility, working memory).

The correlation coefficients between teacher- and parent-rated EF problems on the inhibition sale, the flexibility scale, and the working memory scale of the BRIEF varied from .32 to .49 (see Table 2). No significant correlations were found between

Table 2. Spearman's rho coefficients between the cognitive and behavioral EF measures.

	1	2	3	4	5	6	7	8
1. Stroop CWT	-							
2. Trail Making Test	.10	-						
3. Digit span	-.06	-.53*	-					
4. BRIEF inhibition-Parent	-.21	-.11	-.06	-				
5. BRIEF inhibition-Teacher	-.11	.02	-.13	.49	-			
6. BRIEF flexibility-Parent	-.06	-.12	-.24	.49*	.00	-		
7. BRIEF flexibility-Teacher	-.19	.10	.07	.36	.15	.32	-	
8. BRIEF working memory-Parent	.14	.18	-.10	.31	.24	-.03	.03	-
9. BRIEF working memory-Teacher	.17	.17	-.22	.28	.65*	-.08	-.22	.47

Note: *= $p < .01$.

parent- and teacher-rated EF problems on the inhibition scale, the flexibility scale, and the working memory scale of the BRIEF. Although the correlations were not significant, they show weak to moderate effect sizes according to Dancey and Reidy (2007).

Discussion

In two studies, the relationship between cognitive and behavioral measures (parent- and teacher ratings) of EF was examined in an elementary school context. The cognitive measure processing speed was found to be significantly related to behavioral measures, showing that larger reaction times were related to more EF problems, as reported by both parents and teachers. No other significant relationships between cognitive and behavioral measures (parents and teachers) of EF (i.e., inhibition, planning/organization, flexibility and working memory) were found in this sample.

In study 1, parent ratings of total EF problems, inhibition problems, and planning and organization problems were positively related to teacher ratings on these domains, such that the more EF problems were reported by parents, the more EF problems were reported by teachers. However, in study 2, no significant relationships were found between parent- and teacher rated EF problems and correlation coefficients showed weak to moderate effect sizes. Regardless of whether parent- or teacher ratings were used, no significant relationships were found between cognitive and behavioral measures of EF. This is consistent with previous findings that demonstrated overall that these two methods of measurement capture different aspects of EF (e.g., Toplak *et alii*, 2013).

The significant relationship that was found between processing speed and behavioral measures of EF has not been described before. Slower processing speed has been shown to be strongly related to weaker general cognitive performance (Kail & Salthouse 1994), suggesting a relationship between basic information processing and behavioral measures of EF. This is also in line with studies that found positive relationships between behavior ratings of specific EF and behavior ratings of general behavioral problems and general intelligence measures (Teunisse, Roelofs, Verhoeven, Cuppen, Mol, & Berger, 2012). It seems that behavior ratings of EF might reflect general problems in daily life, caused, for example, by slower speed of information processing or lower intelligence, rather than problems in specific EF. As expected, parent- and teacher ratings of EF were positively related in study 1, implying that the more EF problems are observed by parents, the more EF problems are observed by teachers. In study 2, however, this relationship could not be confirmed, possibly due to a power problem.

The lack of a relationship between cognitive and behavioral measures of EF can be explained in several ways. The most obvious explanation, mentioned by Toplak et alii (2013), is that both methods of measurement assess different aspects of EF. Cognitive tasks measure the efficiency of specific cognitive functions. In doing so, these tasks are highly structured in nature, which limits their potential to address (other) important elements of executive function, such as the ability to set realistic goals, show self-initiative and self-structuring that are required in the more complex reality of daily life (Boelema & Fasotti, 2022). In turn, behavioral ratings show whether individuals are able to apply complex adaptive strategies in everyday life that enable them to pursue goals and function independently (see Toplak *et alii*, 2013). There is some evidence that the BRIEF also includes a social-emotional component, that is not assessed with the cognitive measures, which might explain the lack of significant correlations (Payne *et alii*, 2011; Anderson *et alii*, 2002). Moreover, parents and teachers may not be able

to perceive subtle differences in the EF of the child (O'Meagher *et alii*, 2018), while these can be measured using cognitive measures. Another explanation is that the rater completing the behavioral measure might be biased, for instance by the characteristics of the parent or teacher themselves, or by expectations of the child's overall abilities (Gomez, Burns, Walsh, & De Moura, 2003). Furthermore, cognitive measures of EF also depend on other (basic) cognitive skills such as language or processing speed, in addition to the intended EF. Therefore, 'pure' measurements of EF are very hard to accomplish (Anderson, 2002). Although this study attempted to take this into account (by controlling for the effect of processing speed by calculating contrast scores on the TMT and the Stroop CWT), it cannot be ruled out that basic information processing influenced the results on the cognitive measures.

Although this study contributes to the body of evidence regarding the relationship between cognitive and behavioral measures of executive functioning, it also has some limitations. The main limitation concerns the small sample size, which could lead to a power problem. In addition, specific, validated and internationally widely used neuropsychological tasks were selected for the assessment of the different EF. However, neuropsychological tasks do not only examine the specific EF but for example also reading competencies and could therefore bias the results. The inclusion of other EF tasks that control more strongly for basic cognitive functions may provide purer measures of the specific EF, which would have made the study designs stronger (Anderson *et alii*, 2002). On the other hand, the inclusion of more unstructured neuropsychological tasks, where skills such as goal setting and self-regulation are required to perform the tasks, could have resulted in a more complete picture of executive functioning and thus stronger correlations with behavioral measures (Boelema & Fasotti, 2022). Given the suggestions that the BRIEF includes also a social-emotional component, that is not assessed with the cognitive measures basically used (Anderson, 2002; Payne *et alii*, 2011), follow-up research could focus on examining the relationship between behavioral measures and emotional functioning. Furthermore, the relationship between cognitive measures assessing information processing speed and behavioral measures of EF could be investigated in more detail.

Taken together, the current study confirms the assumption that both methods of measurement, cognitive and behavioral, reveal different aspects of EF, also in a regular elementary school context. Behavioral measures alone provide insufficient information about the cognitive processes, underlying these behaviors, while cognitive measures in itself provide insufficient information about executive functioning on a behavioral level in daily life. Cognitive and behavioral measures should be considered as complementary, when examining executive functioning in more detail.

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