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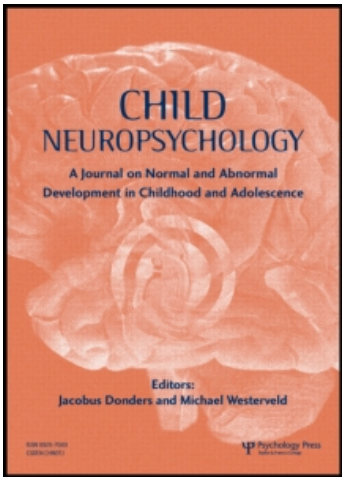

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Age-Related Changes in Executive Function: A Normative Study with the Dutch Version of the Behavior Rating Inventory of Executive Function (BRIEF)

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Age-related changes in executive function: A normative study with the dutch version of the Behavior Rating Inventory of Executive Function (BRIEF)

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This study examined age-related change in executive function by using a Dutch translation of the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000) that was applied to a normative sample (age range 5–18 years). In addition, we examined the reliability and factorial structures of the Dutch BRIEF. Results with respect to age revealed a decrease in reported executive function problems with increasing age. On the Behavior Regulation Index (BRI), 5- to 8-year-olds showed significantly more executive function problems than 9- to 11-year-olds, as did the 12- to 14-year-olds compared to 15- to 18-year-olds (except on the Shift subscale). On the Metacognition Index, we found that 9- to 11-year-olds differed significantly from 5- to 8-year-olds on the Working Memory subscale. In addition, the current study showed that the internal consistency of the Dutch BRIEF is very high, and that this version of the BRIEF has a high test-retest stability. Item factor analysis confirmed the expected eight common factor model, and factor analysis of the eight test scores confirmed the two-factor model, as proposed by Gioia et al., in the Dutch data.

Keywords: Executive function; Development; Children; Behavior regulation; Metacognition.

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INTRODUCTION

Executive function comprises cognitive processes that are necessary for goal-oriented, efficient, and adaptive (social) behavior. These processes include the capacity to think ahead, to suppress impulses, to temporarily hold information in mind, and to think flexibly. Executive function is essential for tasks that are complicated or novel, requiring sustained conscious attention (Miller & Cohen, 2001; Zelazo, Müller, Frye, & Marcovitch, 2003). Thus, executive function plays an essential role in everyday behavior.

A growing body of research has indicated that the development of executive function is a protracted process, which extends into early adulthood. In addition, different executive functions were found to follow different developmental trajectories (for reviews see Best, Miller, & Jones, 2009; Diamond, 2002). There appears to be an association between these developmental trajectories and the relatively slow maturation of the prefrontal cortex (e.g., Amso & Casey, 2006; Casey, Tottenham, Liston, & Durston, 2005). Impaired executive function is often related to psychiatric disorders, such as attention def-

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icit/hyperactivity disorder (ADHD; e.g., Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Nigg & Casey, 2005), Autism Spectrum Disorder (ASD; e.g., Bull, Phillips, & Conway, 2008; Happé, Booth, Charlton, & Hughes, 2006), neurological disorders, such as traumatic brain injury (e.g., V. Anderson & Catroppa, 2005; Mangeot, Armstrong, Colvin, Yeates, & Taylor, 2002; Yeates et al., 2004), or prematurity (e.g., P. J. Anderson & Doyle, 2004; Marlow, Hennessy, Bracewell, & Wolke, 2007). Problems with executive function may be manifested in impulsive behavior, difficulties in planning ahead, and in adapting behavior to changing circumstances. For adults and children, these difficulties may impede the child's daily functioning.

Executive function has been operationalized by a number of standard neuropsychological tasks, such as the Wisconsin Card Sorting Task (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993), and disk-transfer tasks, such as the Tower of Hanoi (ToH; Simon, 1975). Tests like the WCST and the ToH are however complicated, requiring a variety of component control processes to successfully complete the task, such as problem solving or performance monitoring to discover the new rule after a change, in addition to working memory and the ability to flexibly switch responses (see e.g., Miyake et al., 2000). This was one of the main reasons that led researchers to examine whether executive function is better conceived as a single, unitary mechanism that does not include distinct subfunctions (Baddeley, 1986; Cohen & Servan-Schreiber, 1992; Kimberg, D'Esposito, & Farah, 1997; Norman & Shallice, 1986), or as multifaceted, with distinct subfunctions each with a focal neural correlate (Stuss, Shallice, Alexander, & Picton, 1995).

Behavioral studies in a variety of samples, and using various standard executive function tasks, have yielded low or nonsignificant correlations between tasks, and factor-analytic studies have tended to yield multiple factors (Brocki & Bohlin, 2004; Lehto, 1996; Lehto, Juujaervi, Kooistra, & Pulkkinen, 2003; Levin et al., 1996; Rabbitt, Lowe, & Shilling, 2001; Welsh, Pennington, & Groisser, 1991), suggesting a multifaceted rather than a unitary model. Miyake et al. (2000) studied the organization of executive function and its role in standard neuropsychological tasks. Using confirmatory factor analysis, they identified as distinct but correlated factors three commonly postulated executive function components: Working Memory, Shifting, and Response Inhibition. Importantly, Miyake et al. applied a latent variable approach, which facilitates the examination of the organization of executive function in terms of the variance that the tasks have in common, rather than in terms of isolated task performance.

In an attempt to evaluate the developmental trajectory of executive function, Huizinga, Dolan, and van der Molen (2006) adopted the conceptual framework from Miyake et al. (2000). By taking a latent factor approach, Huizinga et al. modeled the underlying factorial structure of executive function across four age groups (7-, 11-, 15-, and 21-year-olds) using a variety of experimental tasks. The results of this study indicated that two, moderately correlated, common factors of working memory and shifting could be distinguished in each age group. The variables assumed to tap inhibition proved unrelated in each age group. Furthermore, they found a continuation of executive function development into adolescence.

As the notion of executive function got more well known from a cognitive psychological perspective, researchers in the field of clinical neuropsychology developed rating scales in order to evaluate executive function competence in the *real-world setting*. To date, only a few standardized psychometric instruments designed to measure executive function problems in children from a more day-to-day perspective have recently become available. These include the Childhood Executive Functioning Inventory (CHEXI; Thorell & Nyberg, 2008) and the Dysexecutive Questionnaire for Children (DEX-C; Emslie, Wilson, Burden, Nimmo-Smith,

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& Wilson, 2003). In addition, although geared towards investigating childhood temperament, a considerable part of the Child Behavior Questionnaire (CBQ) could be interpreted in terms of executive function behavior, as it also includes subscales assumed to tap inhibitory control, impulsivity, and the ability to focus (Rothbart, Ahadi, Hershey, & Fisher, 2001).

The current article focuses on the Dutch adaptation of probably the most well known and widely used (in English-speaking countries) questionnaire developed to tap daily life executive functions in children aged 5 to 18: the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). The BRIEF is a questionnaire comprising 86 items, which concern specific behaviors relating to executive functioning in children. The test is completed by raters (parent or teacher), who indicate how often a given behavior has occurred in the past 6 months by endorsing one of three responses, namely "Never," "Sometimes," or "Often." The BRIEF comprises eight clinical scales (Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor), two composite scores (Behavior Regulation and Metacognition), and a general executive function summary score (Global Executive Composite). Here, we focus on the parent data of The BRIEF. Exploratory factor analysis of the norm data of the BRIEF revealed 74% of the variance was accounted for by a two-factor structure: Behavior Regulation (comprising Inhibit, Shift, and Emotional Control) and Metacognition (Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor).[1] Overall, a decrease in executive function problems when children grow older was observed in the norm groups (boys and girls; 5–7, 8–10, 11–13, and 14–18 years old), but no statistical testing was performed, thus a closer inspection of the separate developmental trajectories of each clinical scale unfortunately is not possible. Several clinical studies that aimed at providing concurrent validity information of the BRIEF showed a strong relationship with interviews and other parent rating measures of behaviors seen in clinical disorders (e.g., Child Behavior Checklist – Parent version; Achenbach, 1991; Diagnostic Interview for Children and Adolescents; Reich, Welner, & Herjanic, 1997). Most importantly, no significant or low correlations were reported with performance-based measures of executive function (e.g., Tower of London; Test of Variables of Attention; Conners' Continuous Performance Test-2; Contingency Naming Test; Rey Complex Figure; V. A. Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Bodnar, Pralune, Cutting, Denckla, & Mahone, 2007; Mahone et al., 2002). These results appear to indicate that rating scales and behavioral measures appear to tap different constructs within the executive function domain.

Research using the BRIEF has shown that it is a reliable and valid measure of everyday executive function (e.g., Kenworthy, Yerys, Anthony, & Wallace, 2008; Mahone et al., 2002; Mangeot et al., 2002; Nadebaum, Anderson, & Catroppa, 2007; Toplak, Bucciarelli, Jain, & Tannock, 2009). The BRIEF has been used extensively in both clinical practice and research settings. However, its use has been limited to English-speaking countries. Other language versions of the BRIEF are lacking, with the exception of a Dutch version,

[1] Gioia, Isquith, Retzlaff, and Espy (2002) took a latent-factor approach in a revised nine-scale version of the BRIEF including a reexamination of the Monitor scale. The subject sample consisted of a mixed group consisting of children diagnosed with attention deficit/hyperactivity disorder (ADHD), learning disabilities, Autism Spectrum Disorders (ASD), Tourette Syndrome, affective disorders, and seizure disorders. The results of their study indicated that a three-factor model fit the data best. The factor structure was defined by a Behavior Regulation factor consisting of the BRIEF Inhibit and Self-Monitor scales, an Emotional Regulation factor consisting of the Emotional Control and Shift scales, and a Metacognition factor composed of the Working Memory, Initiate, Plan/Organize, Organization of Materials, and Task-Monitor scales.

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recently developed by Smidts and Huizinga (2009). The BRIEF was translated into Dutch and normative data were collected in the Netherlands.

The aim of the present article is twofold. First, we analyze the psychometric properties of the Dutch version of the BRIEF. We carried out item analysis of the parental ratings using discrete confirmatory factor analysis. These analyses serve to evaluate the factor structure at the item level, i.e., to validate the relationship between the item responses and the expected eight factors. In addition, we investigated the factor structure of the eight subtest scores, again using confirmatory factor analysis, to investigate the expected two common factor structure (i.e., the Behavior Regulation Index and the Metacognition Index). We carried out the item analyses and the subtest analyses separately to reduce the computational burden and to facilitate interpretation of the results. Such analyses have not previously been undertaken and are of general interest as they are relevant to the theoretical development and validity of the BRIEF dimensions.

The second aim of the article involves the analysis of the age differences with respect to the latent variables that the BRIEF purports to measure. We compare the age groups with respect to the two higher order factors supposedly underlying the eight first-order factors. We conduct this comparison in a multigroup factor model subject to measurement invariance, an important requirement for the age comparison of subtest scores. This provides us with an account of development with respect to the higher order factors underlying the eight first-order BRIEF factors.

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METHOD

Sample

The current sample includes all participants of the normative study, as described in the manual of the Dutch BRIEF (Smidts & Huizinga, 2009). Parents of 847 children (431 boys and 416 girls) completed the parent form of the Dutch version of the BRIEF. The following inclusion criteria were used: (a) age of the child between 5 and 18 years and (b) no history of psychiatric disorder and/or learning disorder. Participants were recruited through regular schools throughout the Netherlands. After approval of the school board, parents were invited by a letter to participate in the study. Part of the sample was recruited via an advertisement on a website for parents (www.ouders.nl). All participating parents received a package including a letter containing relevant information concerning the test, a copy of the questionnaire, and a self-addressed envelope. From the total sample, 93% was native Dutch (defined as both parents born in the Netherlands), compared to about 83% native Dutch residents in the Netherlands. There appeared to be insufficient information to estimate socioeconomic status (SES), because most of the participants refused to provide information about income. Therefore, the SES distribution is unknown for the current sample. The sample was subdivided into four different age groups: 5 to 8 years, 9 to 11 years, 12 to14 years, and 15 to 18 years (see Table 1).

Table 1 Distribution of Boys and Girls across the Age Groups.

Age Group	Boys	Girls	Total
5 to 8 years	167	144	311
9 to 11 years	101	104	205
12 to 14 years	106	108	214
15 to 18 years	57	60	117
Total	431	416	847

Material

The Dutch BRIEF (Smidts & Huizinga, 2009) consists of 75 items.[2,3] Each item pertains to specific everyday behavior, relevant to executive functioning. Parents were asked to indicate how often their child displayed a given behavior in the past 6 months by endorsing one of three responses, "Never," "Sometimes," or "Often." The items of the BRIEF are categorized into eight clinical scales: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. In addition, as detailed below, two composite scores can be obtained based on the eight scales: Behavior Regulation Index (BRI) and the Metacognition Index (MI). These composite scores form the summary score Global Executive Composite (GEC). All sum scores are transformed into *T*-scores and percentiles. A description of the clinical scales and indexes of the BRIEF follows below.

Clinical Scales

Inhibit (10 items). The Inhibit scale assesses the ability to suppress impulses and to stop one's own behavior at the appropriate time. Items include "Blurts things out" and "Gets out of seat at the wrong times."

Shift (8 items). The Shift scale assesses the ability to adjust behavior flexibly to changing demands of a situation. Items include "Is disturbed by change of teacher or class" and "Becomes upset by new situations."

Emotional Control (10 items). Items from this scale measure the capacity to modulate emotional responses. Items include "Becomes upset too easily" and "Has explosive, angry outbursts."

Initiate (8 items). The Initiate scale includes items concerning the initiation of tasks or activities and independent generation of ideas, strategies, and responses. Items include "Is not a self-starter" and "Has troubling organizing activities with friends."

Working Memory (10 items). The Working Memory scale measures a child's ability to hold information in mind with the objective of completing a task. Items include "Forgets what he/she was doing" and "Has trouble remembering things, even for a few minutes."

Plan/Organize (12 items). Items from the Plan/Organize scale measure the child's capacity to manage current and future-oriented task demands. Items include "Has good ideas but cannot get them on paper." The organizing component reflects the ability to

[2] The original American BRIEF consists of 86 items of which 11 items are not included in the clinical scales. In the Dutch version of the BRIEF, these items were excluded.

[3] The Dutch BRIEF consists of 75 items, of which 72 comprise the eight clinical scales. The remaining items comprise (among others) two validity scales "Negativity" (the extent to which the respondent answers selected BRIEF items in an unusually negative manner relative to the clinical samples [cf. Gioia et al., 2000]) and "Inconsistency" (the extent to which the respondent answers similar BRIEF items in an inconsistent manner relative to the clinical samples [cf. Gioia et al.]). Since the current study involves a normal, healthy developing, sample, these scales were not analyzed here.

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distinguish main ideas or key concepts and to bring order to information. Items include "Gets caught up in details and misses the big picture."

Organization of Materials (6 items). This scale contains items relating to orderliness of work, play, and storage spaces. Items include "Leaves playroom a mess" and "Cannot find things in room or school desk."

Monitor (8 items). The Monitor scale assesses the ability to check work and performance during and immediately after finishing a task. Items include "Makes careless errors" and "Work is sloppy."

Composite Scores. The clinical scales of the BRIEF may be combined to form two indices: Behavior Regulation Index (BRI) and the Metacognition Index (MI), and one composite summary score: the Global Executive Composite (GEC). The BRI represents the ability to shift cognitive set and modulate behavior and emotions. It comprises the scales Inhibit, Shift, and Emotional Control. The MI represents the ability to plan, organize, initiate, and hold information in mind for future-oriented problem solving. It comprises the scales Initiate, Working Memory, Plan/organize, Organization of Materials, and Monitor Scales. The GEC is a summary score that includes all eight clinical scales of the BRIEF.

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Statistical Analysis

Reliability was estimated by determining internal consistency and test-retest stability. Confirmatory factor analysis was performed in order to assess the construct validity of the Dutch BRIEF items and the eight scales. Further, effects of age and gender on the eight scales were examined.

Reliability.

Internal consistency. was evaluated by calculating Cronbach' alpha (α) for the eight clinical scales, the two composite indices of BRI and MI, and the overall GEC. In addition, the item-total correlation of each item with the total scale score was calculated.

Test-retest reliability indicates the stability of a measure over time. In order to establish the stability of the BRIEF scores, the questionnaire was administered twice, with a 6-week time interval (n = 12). The test-retest reliability was calculated by means of the intraclass correlation coefficient (ICC).

Item and Subtest Factor Structures. To investigate the factor structure of the Dutch BRIEF, we carried out two factor analyses. First, we conducted confirmatory factor analyses of the parental ratings on the 72 items (N = 847) to establish that these items are consistent with an eight common factor model. As the items are three-point scales, we used discrete factor analysis as implemented in Mplus (Muthén & Muthén, 2007). To evaluate the fit we used the Root Mean Square Error of Approximation (RMSEA) and the Non-Normed Fit Index (NNFI; Schermelleh-Engel, Moosbrugger, & Müller, 2003).

Second, we conducted confirmatory factor analyses of the eight subtest scores in the four age groups. We were specifically interested in examining whether the original two-factor model of Gioia et al. (2000) provided a reasonable fit to the data of the current sample. In the two-factor model, the two common factors represent BRI and MI. Inhibit, Shift, and

Emotion Regulation loaded on BRI, and Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor loaded on MI. To establish the relative fit of the two-factor model we also fit the single-factor model (in which in effect BRI and MI are correlated). We used (Jöreskog & Sörbom, 1999) LISREL to fit the two-factor model.[4] To evaluate the fit we considered the major and most frequently used measures of fit. These measures include the chi-square distribution (χ^2), the Root Mean Square Error of Approximation (RMSEA), the Consistent Akaike Information Criterion (CAIC), and the Non-Normed Fit Index (NNFI; Jöreskog, 1993; Schermelleh-Engel, Moosbrugger, & Müller, 2003). In comparing models, the model with the lower value of CAIC is preferable. Furthermore, an acceptable model approximation is indicated by a RMSEA value of about .08 or lower and good approximation by a value of .05 or lower. Finally, a value of NNFI of about .95 or greater indicates good fit (see Schermelleh-Engel et al.).

We carried out the multigroup confirmatory factor analyses of the eight subtest scores in the four age groups (e.g., Little, 1997). We used LISREL to carry out these analyses (Jöreskog & Sörbom, 1999). In order to establish that we measured the same factors in all age groups, we first specified the two common factor model in each age group, without any equality constraints over the groups. We denote this model CFA0. Secondly, we constrained the factor loadings of the observed indicators of the common factors to be the same in each age group. This constrained model was labeled CFA1. Finally, we examined whether the factor intercepts were equal over the age groups (CFA2).[5]

Analysis of Variance. Age group differences and gender differences were investigated by a multivariate variance analysis (MANOVA). The dependent variables included the eight clinical scales, in addition to the BRI, MI, and GEC. Age group (5- to 8-year-olds, 9- to 11-year-olds, 12- to 14-year-olds, 15- to 18-year-olds) and gender (boys and girls) were included as between-subjects factors. We expressed effect sizes using partial η^2. The partial η^2 represents the proportion of the effect and error variance that is attributable to the effect (e.g., Tabacknick & Fidell, 2001). According to Cohen (1992), a value of .01, .06, and .14 represent small, medium-sized, and large effects, respectively.

RESULTS

Reliability.

Internal Consistency. Table 2 shows the Cronbach's α coefficients of the scales, indices (BRI and MI), and total score (GEC). A commonly accepted rule of thumb is that an α of .6–.7 indicates acceptable reliability, and .8 or higher indicates good reliability (e.g., Cronbach, 2004). Cronbach's alpha of the eight clinical scales ranged from .78 to .90. The alpha coefficient of the BRI, MI, and GEC ranged from .93 to .96. Thus, the internal consistency of the Dutch BRIEF is good. For the item-total correlations, a value

[4] Note that we could have used Mplus. The choice to use LISREL here is arbitrary.

[5] Note that model CFA2 involves the simultaneous modeling of the means and the covariance structures in the four groups. If CFA2 fits to reasonable approximation, we can conclude (a) that the expected factor model fits reasonable; (b) that the factor loadings are equal over the four groups; (c) that the intercepts of the subtests are equal over the four groups. Note that in CFA2 the factor means and factor covariance matrices may differ over the groups. These common factor differences then account for the observed differences. This implies that we can interpret the observed mean differences as a function of the mean differences in the common factors, i.e., of the latent variables that the subtests measure.

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Table 2 Internal Consistency and Item-Total Correlations.

Clinical scale/Index	Cronbach's α	Item-Total Correlations
Inhibit	.87[1]	.45 – .67
Shift	.84[1]	.42 – .70
Emotional control	.89[1]	.53 – .72
Behavior Regulation Index	**.93[1]**	**.44 – .74**
Initiate	.78[1]	.39 – .53
Working Memory	.90[1]	.58 – .73
Plan/Organize	.86[3]	.43 – .65
Organization of Materials	.86[1]	.55 – .72
Monitoring	.81[2]	.43 – .59
Metacognition Index	**.95[1]**	**.32 – .73**
Global Executive Composite	**.96[1]**	**.34 – .70**

[1]N = 847. [2] n = 846. [3]n = 844.

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of .30 is generally regarded as satisfactory (Nunally & Bernstein, 1994). As Table 2 shows, all item-total correlations are greater than .30. This pattern of results is highly comparable with the original version of the BRIEF (Gioia et al., 2000); although item-total correlations on the BRI, MI, and GEC are unavailable for the original version.

Test-Retest Reliability. Table 3 shows the ICC's and the 95% confidence intervals of BRIEF scales and indices. According to Landis and Koch (1977), an ICC of less than .2 is regarded as very low, between .2 and .4 as low, between .4 and .6 as intermediate, and between .6 and .8 as high, and between .8 and 1.0 as very high. As shown, the ICC's are very high for the clinical scales Inhibit, Shift, Emotional Control, Initiate, Plan/Organize, and Organization of Materials. Similarly, the ICC's for the BRI, MI, and GEC are also very high. The ICC's for the clinical scales Working Memory and Monitor are high. Thus, we consider the stability of the test scores, over a 6-week interval, to be good. This pattern of results was also found within a subsample of the parent normative sample of the original BRIEF (Gioia et al., 2000). The mean test-retest stability (over a 2-week interval) on the clinical scales was .81 (range .76 – .85); on the BRI the test-retest correlation was .84, .88 on the MI, and .86 on the GEC.

Table 3 Intraclass Coefficients and 95% Confidence Intervals.

Clinical scale/Index	ICC*	95% Confidence Interval
Inhibit	.94	.80 – .98
Shift	.89	.61 – .97
Emotional control	.90	.64 – .97
Behavior Regulation Index	**.95**	**.82 – .99**
Initiate	.81	.34 – .95
Working Memory	.73	.06 – .92
Plan/Organize	.82	.36 – .95
Organization of Materials	.91	.69 – .98
Monitoring	.75	.14 – .93
Metacognition Index	**.84**	**.43 – .95**
Global Executive Composite	**.86**	**.51 – .96**

Table 4 Correlation among the Eight Factors Obtained in the Discrete Factor Analysis (Standard Errors in Parentheses).

	Inhibit	Shift	Emotional Control	Initiate	Working Memory	Plan Organize	Organization of Materials	Monitoring
Inhibit	1.00							
Shift	0.53	1.00						
	(.03)							
Emotional control	0.77	0.72	1.00					
	(.02)	(.02)						
Initiate	0.46	0.54	0.43	1.00				
	(.03)	(.03)						
Working Memory	0.61	0.55	0.48	0.79	1.00			
	(.03)	(.03)	(.03)	(.02)				
Plan/Organize	0.55	0.56	0.43	0.88	0.89	1.00		
	(.03)	(.03)	(.03)	(.01)	(.01)			
Organization of	0.50	0.33	0.38	0.59	0.61	0.64	1.00	
Materials	(.03)	(.04)	(.03)	(.03)	(.03)	(.03)		
Monitoring	0.76	0.57	0.57	0.68	0.71	0.78	0.57	1.00
	(.02)	(.02)	(.02)	(.02)	(.02)	(.02)	(.03)	

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Item and Subtest Factor Structures. The confirmatory factor analysis of the 72 items produced an NNFI of .920 and an RMSEA of .109. As both fit indices were slightly below par, we inspected the results to determine whether there was any local misspecification. We observed particularly large modification indices pertaining to the covariances among the residuals of three items.[6] Note that these covariances were initially fixed to zero in the confirmatory model, as they were not expected a priori. The modification indices indicated that the estimation of these covariances would greatly improve the model fit. In view of the item content (they all relate to handwriting skills), we considered the modifications reasonable. We repeated the analyses with these three parameters freely estimated. The NNFI equaled .95 and the RMSEA equaled .087. We consider these to be satisfactory given the sample size and the magnitude of the model, and we therefore undertook no further modification of the model.

All factor loadings were highly significant. The reliabilities of the individual 72 items ranged from .17 to .86 (M = .54, SD = .17). The estimates of the factor correlations and their standard errors are shown in Table 4. The correlations are moderate to high: notably Plan/Organize correlates quite highly with Initiate and Working Memory. We included the standard errors as these indicate that the correlations may be high but are no near unity, in view of the small standard errors. For instance the highest correlation is between Plan/Organize and Working memory (.89). The standard error equals .011, so that the approximate 95% confidence interval is about .89 +/- .02 (i.e., .011*1.96). The upper limit of the 95% confidence interval is therefore about .911.

In conclusion, the results of item-factor analysis of the Dutch BRIEF showed that the expected eight-factor model fit the data reasonably. The only modification concerned the addition of three covariances among item residuals. In view of the item content, we consider addition of these three parameters to be acceptable.

[6] The items referred to item 31 (“Has poor handwriting”; Monitor scale), item 60 (“Work is sloppy”; Monitor scale), and item 53 (“Written work is poorly organized”; Plan/Organize scale).

Table 5 Fit Indices Four-Group Confirmatory Factor Analyses.

Model	*df*	χ^2	RMSEA	CAIC	NNFI
CFA 0	76	343	.129	1117	.929
CFA 0b	68	168	.083	1004	.970
CFA 1	86	196	.078	893	.975
CFA 2	104	289	.092	846	.965

Note. CFA0 is the model without any constraints over the groups. In Model CFA0b we added two correlated residuals. They were retained in model CFA1 (equal factor loadings) and in model CFA2 (equal intercept, free factor means).

The results of the factor analyses of the subtest scores are shown in Table 5. As a check of the two-factor model, we first fit a single-factor model, but this model fit the data very poorly, $\chi^2(72) = 537.7$, RMSEA = .16, NNFI = .88, CAIC = 1288. We therefore turn to the two-factor models. Judging by the results in Table 5, the fit of the one-factor model (CFA0) was relatively poor (e.g., RMSEA of .129 and NNFI of .929). We modified the model in light of the standardized residuals and the modification indices (see Schermelleh-Engel et al., 2003) by allowing the residuals of the Inhibit and Shift clinical scales and the residuals of Inhibit and Monitor scales to correlate. We call the model CFA0b in Table 5. This resulted in a reasonable fit of the two-factor model in the four age groups. Next, we established that the factor loadings of this two-factor model were equal over each age group (CFA1) while retaining the correlated residual of model CFA0b. This model still fit reasonably well, so that we conclude that the factor loadings are equal. Finally we fit model CFA2 (again retaining the correlated residuals), i.e., we constrained the subtest intercepts to be equal and estimated the common factors in age groups 2 (9–11 years), 3 (12–14 years), and 4 (15–18 years) (the common factor means are fixed to zero in age group 1 [5–8 years] for reasons of identification). We note that this model is accompanied by a decrease in the RMSEA (.092), but that the CAIC is smallest for this model (846). In addition, the NNFI of this model is .965, which is still well within the acceptable range. The 90% confidence intervals of the RMSEA range from .079 to .104 and so straddle the values of .080. In light of these results, we decided to accept model CFA2 as it stands and thus conclude that the test is factorial invariant with respect to age group. This implies that the observed mean differences can be interpreted as reflecting the mean differences between the common factors. In other words, the results of the CFA indicate that the BRIEF main indices, BRI, MI, and GEC, measure the same construct in each age group and differences between the factor means may actually be interpreted in terms of differences between age groups.

Analysis of Variance.

Age-Related Differences. The results of the MANOVA showed that there are significant differences in means between age groups, Wilks $\Lambda = .81$, $F(24, 2404.95) = 7.79$, $p < .001$; partial $\eta^2 = .07$. Table 6 shows the means and standard deviations with respect to age. There are significant differences between the age groups with respect to all the clinical scales of the BRI and the GEC. Post hoc testing (using a Bonferroni correction) showed significantly higher scores on all BRI scales in 5- to 8-year-olds than in 9- to 11-

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Table 6 Age-Related Change on the BRIEF Clinical Scales and Indices.

	Age Group					
Clinical scale/Index	5 – 8 years	9 – 11 years	12 – 14 years	15 – 18 years	*F**	partial η^2
Inhibit	17.1 (4.1)	15.1 (3.9) **	15.2 (4.3)	14.0 (3.6) **	21.20[a]	.07
Shift	13.3 (3.4)	12.2 (3.4) **	12.3 (3.5)	11.6 (3.5)	8.40[a]	.03
Emotional control	17.9 (4.5)	16.6 (4.4) **	15.6 (4.4)	13.8 (3.8) **	28.38[a]	.09
Behavior Regulation Index	**48.3 (9.9)**	**43.8 (10.0) ** **	**43.1 (10.7)**	**39.4 (9.3) ** **	**26.08[a]**	**.09**
Initiate	14.0 (3.2)	14.3 (3.2)	14.7 (3.7)	13.9 (3.6)	2.67[b]	.01
Working Memory	18.2 (4.7)	17.0 (5.0) **	17.5 (5.0)	17.0 (5.3)	3.09[b]	.01
Plan/Organize	20.7 (4.9)	20.3 (5.4)	21.1 (5.3)	21.1 (5.6)	0.99	
Organization of Materials	12.8 (2.8)	12.9 (3.2)	12.5 (3.6)	12.7 (3.7)	0.73	
Monitoring	15.4 (3.3)	15.1 (3.8)	15.4 (3.7)	14.7 (3.7)	1.19	
Metacognition Index	**81.1 (15.6)**	**79.6 (17.4)**	**81.1 (18.3)**	**79.4 (18.8)**	**0.54**	
Global Executive Composite	**129.4 (22.9)**	**123.4 (25.0) ***	**124.2 (26.5)**	**118.7 (26.2)**	**5.87[a]**	**.02**

**df* = 3, 836; **post hoc (Bonferroni) significant difference relative to preceding Age Group.
[a]Significant with $\alpha = .001$. [b]Significant with $\alpha = .01$.

year-olds, and in 12-to 14-year-olds than in 15- to 18-year-olds (except Shift). With the exception of the clinical scales Initiate and Working Memory, no significant differences between the age groups were found within the MI. On the MI, 5- to 8-year-olds had a significantly higher score on the Working Memory scale than 9- to 11-year-olds. Post hoc testing did not reveal age-related differences on the Initiate scale.

Gender Differences. Table 7 shows the means and standard deviations with respect to gender. The results of the MANOVA indicated significant differences between means of the boys and girls, Wilks $\Lambda = .89$, $F(8, 829) = 12.30$, $p < .001$; partial $\eta^2 = .12$, with

Table 7 Gender Differences on the BRIEF Clinical Scales and Indices.

	Gender			
Clinical scale/Index	Boys	Girls	*F**	partial η^2
Inhibit	16.1 (4.4)	15.3 (4.0)	3.58	
Shift	12.9 (3.5)	12.1 (3.4)	7.63[b]	.01
Emotional control	16.4 (4.5)	16.5 (4.7)	1.08	
Behavior Regulation Index	**45.4 (10.5)**	**43.9 (10.5)**	**1.59**	
Initiate	14.7 (3.4)	13.8 (3.4)	13.37[a]	.02
Working Memory	18.2 (5.0)	16.9 (4.8)	14.73[a]	.02
Plan/Organize	21.7 (5.3)	19.9 (5.0)	22.47[a]	.03
Organization of Materials	12.6 (3.1)	12.8 (3.4)	0.82	
Monitoring	16.0 (3.6)	14.3 (3.4)	44.82[a]	.05
Metacognition Index	**83.3 (17.1)**	**77.7 (16.9)**	**19.96[a]**	**.02**
Global Executive Composite	**128.7 (24.6)**	**121.5 (25.0)**	**12.99[a]**	**.02**

**df* = 1, 836.
[a]Significant with $\alpha = .001$. [b] Significant with $\alpha = .01$.

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girls showing better executive skills than boys. Specifically, boys scored higher on the Shift scale of the BRI index and also on all scales but one of the MI index (the exception being the Organization of Materials scale). Age group and gender interaction was absent ($F < 1$). Statistical comparisons regarding age and gender are unavailable in the original version of the BRIEF (Gioia et al., 2000). Inspection of the original norm data shows, comparable to the current study, a decrease in executive function problems when children grow older and in girls compared to boys.

DISCUSSION

The BRIEF is a suitable questionnaire to measure everyday executive function behaviors in children between 5 and 18 years of age. The questionnaire has been used widely in both clinical practice and research settings, but its use has been limited to English-speaking countries. The current study was conducted to investigate the psychometric properties of the Dutch version of the BRIEF (parent sample) and to examine whether this questionnaire can be used as a reliable and valid measure of executive function in the Netherlands. In addition, this article examined the age-related and gender differences with respect to the latent variables that the BRIEF purports to measure.

The findings of this study show that the internal consistency and the test-retest stability of the Dutch version of the BRIEF are high to very high. These results are equivalent to the original version of the BRIEF (Gioia et al., 2000). Based on these findings, we conclude that the Dutch BRIEF is a reliable measure of executive function.

With regards to factor structure, we found that the expected eight-factor model fit the parental rating on the 72 items well. All estimated factor loadings were highly significant and the reliabilities of the individual items were excellent, with a mean of .54 (SD = .17). We found that the correlations among the eight factors were moderate to quite high (see Table 4). For instance, the correlations among factors Initiate, Working Memory, and Plan/Organize are about .80 to .90. Note also that the standard errors of the correlation (see Table 4) are small; i.e., the 95% confidence interval of none of these large correlations includes 1, so that we can conclude that the correlations are large, but not 1. In addition, we do not consider these correlations to be of great concern as they are observed in a normal population. It is very likely that the correlations will be appreciably lower in affected populations.

A promising focus of future research would be to examine the factor structure of executive function in developmental disorders. In a latent factor study, reexamining the Monitor scale, Gioia et al. (2002) found a three-factor structure fit the data best. This factor structure was defined by a Behavior Regulation factor consisting of the Inhibit and Self-Monitor scales, an Emotional Regulation factor consisting of the Emotional Control and Shift scales, and a Metacognition factor composed of the Working Memory, Initiate, Plan/Organize, Organization of Materials, and Task-Monitor scales. This study was however performed in a mixed group consisting of children diagnosed with attention-deficit/hyperactivity disorder (ADHD), learning disabilities, Autism Spectrum Disorders (ASD), Tourette Syndrome, affective disorders, and seizure disorders. In future research, one could test how specific problems with executive function in specific clinical groups affect the factor structure compared to normal populations. For example problems with impulsivity are reported in ADHD (Castellanos et al., 2006; Nigg & Casey, 2005) or problems with cognitive flexibility in ASD (Bull et al., 2008; Happé et al., 2006).

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A latent factor approach would give insight into the factor structure of these specific developmental disorders.

The results of the confirmatory factor analyses indicate that the expected two-factor model fits the data of the normative sample acceptably. Factorial invariance was found to be an acceptable to reasonable approximation (see Table 5). With respect to the general factor structure, these results are similar to the results by Gioia et al. (2000), indicating that the BRI and MI are correlated but distinct factors. In our analyses, we found the residuals of the Inhibit and Shift clinical scales and the Inhibit and Monitor scales were correlated. This implies that these common factors could not completely account for the covariances among Inhibition and Shift on the one hand and Inhibition and Monitor on the other. However, this does not detract greatly from the further interpretation of the factor structure. The finding that factorial invariance was tenable is important as it implies that we are measuring the same common factors, MI and BRI, in the four age groups, and that we therefore can interpret observed age differences as differences with respect to these factors. Overall, we found that the factorial structure of the BRIEF was consistent with our expectations. We consider these results to be an important prerequisite to further research into the validity of the BRIEF.

In addition to examining the psychometric properties of the BRIEF, we examined age and gender differences. In our MANOVA we observed main effects of age and gender. Overall, younger children showed more behavior problems related to executive function than older children and adolescents. We found significant differences between the age groups on all clinical scales of the BRI and the GEC, with different developmental patterns for each main index. On all scales of the BRI, 5- to 8-year-olds showed significantly more executive function problems than in 9- to 11-year-olds, as did the 12- to 14-year-olds compared to 15- to 18-year-olds (except Shift). In addition, on the MI we found significant differences between the age groups on the subscales Initiate and Working Memory. On the MI, 5- to 8-year-olds scored significantly higher on the Working Memory scale than 9- to 11-year-olds. We did not observe significant differences between the age groups on the Initiate scale. Finally, boys showed significantly more executive problems compared to girls, and this effect was consistent with advancing age of the participants. Although statistical comparisons regarding age and gender are lacking in the original version of the BRIEF (Gioia et al., 2000), the results of the present study are at face value comparable to the results of Gioia et al., who also showed a decrease in executive function problems when children grow older, and in girls compared to boys.

At this point, we argue that executive functions permeate all facets of children's goal-oriented, efficient, and adaptive (social) functioning. One important focus for future research involves establishing concurrent validity with experimental tasks purported to measure components of executive function. However, earlier studies found disappointingly low correlations between the BRIEF and experimental EF tasks (e.g., V. A. Anderson et al., 2002; Bodnar et al., 2007; Mahone et al., 2002), despite strong correlations between the BRIEF and other behavior rating scales, such as the Child Behavior Checklist (Achenbach, 1991; see also Achenbach & Rescorla, 2001). Unfortunately, associations between the Dutch BRIEF and Huizinga et al.'s (2006) experimental tasks could not be performed in the current study, as different groups of children were assessed with the lab tasks than with the BRIEF.

Experimental tasks are useful to assess aspects of executive function at a fine-grained functional level. Such tasks — as experimental, lab tasks — necessarily lack

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ecological validity. A psychometrically well-developed questionnaire that provides information on the role of executive function in the child's functioning in daily life forms an important complement to laboratory tasks. A clear bonus of the questionnaire is that it is relatively simple and cheap to administer. Thus a complete assessment of executive function requires both experimental tasks to assess fine-grained functional aspect and well-developed questionnaires to assess the role of executive function in every day behavior.

In sum, although it is beyond the scope of the present study, we note that the exact relationship between experimental tasks and the latent variables measured by the BRIEF is an important focus of future work. In this respect, of particular interest would be to examine how component processes of executive function contribute to the performance on classic neuropsychological tasks such as the Wisconsin Card Sorting Task (Heaton et al., 1993) and disk-transfer tasks such as the Tower of Hanoi (Simon, 1975) or the Tower of London (Shallice, 1982). Now that we have established the validity and the reliability of the Dutch BRIEF, a future step would be to incorporate the questionnaire in clinical studies. A particularly interesting question then relates to the examination of neuropsychological profiles in developmental disorders.

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