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Cognitive functioning and its relation to frontal functioning after acquired brain injury as observed by patients with neuropsychiatric symptoms and their significant others.

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Abstract

Self-reported functioning, in contrast to functioning as reported by informants, often does not correspond to the actual cognitive functioning of patients after acquired brain injury (ABI). Therefore the aim of the study was to investigate the difference between reports of patients' frontal functioning by patients' and informants' measured with the Frontal Systems Behavioural Scale (FrSBe), and whether patients' cognitive functioning was associated with either reports of frontal functioning. It was expected that patients and informants would differ in their ratings of the patients' frontal functioning and that patients' cognitive performance on various tests for measuring executive functioning, would not be related to patient's own ratings in contrast to informants' ratings. We used data from patients with ABI and neuropsychiatric symptoms (N=84) and their informants (N=53). It was found that patients and informants did not differ in their ratings of patients' frontal functioning. Additionally, cognitive performance was not related to either patients or informants reports, suggesting that cognitive tests for executive functioning and the FrSBe measure different constructs. However, a significant association (β=-.403, p=.042) was found between verbal fluency and patients' self-reported frontal functioning. This suggests that problems with verbal fluency are more apparent to patients than to informants in daily living and that verbal fluency is a good indicator of self-perceived frontal functioning. However the small sample size makes interpretation difficult. Awareness and various injury-related variables are possibly important factors and could be considered by future studies on the association of cognitive functioning and self-reported functioning in this unique population.

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Keywords: frontal functioning, executive functions, self-reported functioning, acquired brain injury, Frontal Systems Behavioural Scale

Introduction

All brain injuries acquired after birth due to neurosurgery, trauma, cerebrovascular accidents or other non-genetic causes are considered ABI. While estimates of prevalence and incidence of ABI in the Netherlands are scarce, annually approximately 85.000 persons suffer traumatic brain injury (TBI; VeiligheidNL, 2013) and an additional 40.000 persons suffer a cerebrovascular accident (CVA; Hartstichting, 2011), which are the two leading causes of ABI. These injuries generally result in significant impairment for the patient and environment (Corrigan, Selassie & Orman, 2010; Pound, Gompertz, & Ebrahim, 1998; Taphoor & Klein, 2004).

Cognitive and behavioural problems are common after ABI. Patients suffering from ABI may experience different neuropsychological difficulties, depending on the severity and the area of impact among other injury related features. Follow-up studies found that the experienced difficulties and the corresponding recovery are not uniform across patients and vary greatly (Millis et al., 2001). When damage is done to the frontal regions of the brain, patients may experience different deficits in behaviour depending on the specific frontal area (Szczepanski & Knight, 2014). This indicates that the frontal lobes are involved in a great variety of behaviours, which is described as frontal functioning. Four distinct groups of functions of the frontal lobes have been proposed, i.e. executive processes, behavioural/emotional regulatory processes, "energization" (also initiation or activation) processes and metacognitive processes (Oddy & Worthington, 2009). Executive processes include different functions that are labelled executive functions, which mostly rely on the lateral prefrontal cortex (Szczepanski &

Knight, 2014). Executive functioning is an umbrella-term containing different functions such as planning, reasoning, organizing, set-shifting and monitoring (Jurado, & Rosselli, 2007; Stuss, 2011). Behavioural/emotional regulatory processes include emotional processing functions like the acquisition and reversal of stimulus-reward association (Oddy & Worthington, 2009). These processes are involved in reinforcement learning and behavioural inhibition. These functions mostly rely on the ventral medial prefrontal cortex (Szczepanski & Knight, 2014). Energization processes are important for initiation and sustaining any response mode (Oddy & Worthington, 2009). These processes are involved in evoking and sustaining interest and action for stimuli. The last category of meta-cognitive processes is suggested to be important for higher-order integration of various cognitive constructs which in general implies a reflective representation of a person's own mental state, beliefs, attitudes and experiences (Oddy & Worthington, 2009). The distinction between these four processes shows the diverse function of the frontal regions of the brain and explains how damage in the frontal lobe can have a consequential diverse impact on cognitive functioning.

Especially executive functioning, as part of frontal functioning, is a widely invoked psychological construct. On the grounds that damage to the frontal lobes generally leads to deficits in executive functioning, forthcoming terms dysexecutive syndrome (problems with executive processes) and frontal syndrome (problems with frontal functioning as a whole) are often used interchangeably to describe behavioural deficits due to problems with executive functioning (Oddy & Worthington, 2009). Behavioural deficits due to shortcomings in executive processes are present in the form of psychomotor slowing, problems with sustaining appropriate goal-directed behaviour, and difficulties with initiating behaviour or behavioural apathy (Busch, McBride, Curtis & Vanderploeg, 2005). These deficits show that executive processes and the other categories of frontal processes greatly intertwine when the deficits are considered on a behavioural level. In summary, deficits in executive functioning can be part of problems with frontal functioning, which can have disabling consequences for activities of daily living. Therefore, in order to help patients cope with these deficits and to be able to provide recommendations it is important to quantify these deficits.

Numerous neuropsychological tests and questionnaires are available to quantify executive dysfunctions. Cognitive measures tend to have little relationship to self-reports of executive functioning (Chaytor & Schmitter-Edgecombe, 2003). Previous

research (Lengenfelder, Arjunan, Chiaravalloti, Smith & DeLuca, 2013) compared self-reported frontal functioning to other cognitive processes such as verbal fluency, mental flexibility, response inhibition, planning and problem-solving abilities in patients with TBI. They found a diffuse relationship between self-reported frontal functioning and various cognitive processes, where only some cognitive outcomes were related to some components of self-reported frontal functioning.

Various possibilities have been proposed to explain the differences found between cognitive functioning as measured by cognitive tests and self-reported functioning. Lengenfelder and colleagues (2013) suggested that information from the self-report measure of frontal functioning used, the Frontal Systems Behavioural Scale (FrSBe), differed from information gathered from cognitive tests. It is more often proposed that different constructs are being measured to explain the lack of association between cognitive tests and questionnaires (Toplak, West & Stanovich, 2013). This would imply that a self-report measure regarding frontal functioning and cognitive tests do not measure aspects of the same construct as they are intended to do.

An additional explanation for the discrepancy found between functioning reported by patients and their cognitive functioning could be an impaired awareness of patients about their own functioning. Impaired awareness about functional and behavioural deficits, also called anosognosia, is common after ABI (FitzGerald, Carton, O'Keeffe, Coen & Dockree, 2012; Orfei, Caltagirone & Spalletta, 2009; Prigatano, & Altman, 1990). Lengenfelder and colleagues (2013) also investigated differences between patients' and informants' reports and did not find significant differences in their sample. However, other studies did find differences and it is highly interesting that in contrast to patient-ratings, informant-ratings are often significantly related to patient's cognitive functioning (Chaytor & Schmitter-Edgecombe, 2003). This may imply that often patients do not have the ability to correctly judge their own functioning, suggesting some degree of anosognosia. It is possible for patients to either overestimate or underestimate their own functioning, which leads to a positive or negative discrepancy between patients' and informants' reports of their functioning (Smeets et al., 2014). Impaired self-awareness after ABI is pre-dominantly seen in studies as an unawareness of the nature or extent of deficits, leading to an overestimating of functioning by patients (FitzGerald et al., 2012). Thus, it would be expected that patients with ABI overestimate their functioning.

Another possible explanation could be the ecological validity of the tests used. Self-reported functioning is often a reflection of experienced functioning of activities of daily living. When comparing tests for executive functioning designed to be more ecological valid, like the Behavioural Assessment of Dysexecutive Syndrome (Wilson, Alderman, Burgess, Emslie & Evans, 1996) and more traditional tests, like the Stroop Colour Word Test (Stroop, 1935) or Trail Making Test (Armitage, 1946), the more ecological valid tests seem to be better predictors of the ability to perform activities of daily living (Burgess et al., 2006; Chaytor & Schmiter-Edgecome, 2003). Hence, the use of more ecological tests is stressed to bridge the gap between functioning as reported on questionnaires and functioning on cognitive tests. However, differences between performance on cognitive tests and reports by patients with ABI will not be bridged when using an ecological valid tool when these patients are expected to not be able to estimate their functioning correctly.

These findings spark the interest in further examining the associations between self-reported frontal functioning and cognitive functioning while also considering differences between patients' and informants' reports. The first aim of this study was to determine whether patients and their informants rate the frontal functioning of the patient to the same extent. The second aim of the study was to determine the relationship between executive functioning and self-reported frontal functioning. The third aim of the study was to determine the relationship between executive functioning and informant's ratings of the patient's frontal functioning. First, it was hypothesized that reports of patient's frontal functioning significantly differ between patients and informants. It was expected that patients would overestimate their own frontal functioning in comparison to informants. Second, it was hypothesized that executive functioning is not associated with self-reported frontal functioning by patients. It is expected that cognitive functioning is not related to self-reported frontal functioning even when measured with a more ecological valid test. Third, it was hypothesized that better executive functioning by patients is associated with higher ratings of informants' reports of patients' frontal functioning. More specifically, it was expected that this relation is strongest when using ecological valid tests to assess executive functioning. Hence, it was expected that patients' performances on executive tests are better predictive of informants' reports in contrast to patients' own reports.

Methods

Participants

All participants were patients with ABI with neuropsychiatric or behavioural problems who were referred to two participating Dutch mental health institutions (GGZ Oost-Brabant department ABI Huize Padua and Altrecht GGZ department Vesalius) during the period from September 2010 to January 2012, and their significant others. Inclusion criteria for participants were: Existence of ABI, a minimum age of 18 years and completion of the Frontal Systems Behavioural Scale (FrSBe). Patients were excluded if they suffered from neurodegenerative diseases or whiplash syndrome, if there were more than 25% missing values on the FrSBe, or if there were indications for suboptimal performance. Inclusion criteria for the informants were: A minimum age of 18 years and a familiarity with the patient's life. Informants were excluded if they were suffering from a neurological or psychiatric disorder, did not master the Dutch language enough to complete the FrSBe adequately, or if there were more than 25% missing values on the FrSBe.

Procedure

The current study was a retrospective study with previously gathered data, which was acquired from a database. This database contains data of patients that were seen as part of an intake session by a neuropsychologist at one of the two participating mental health institutions. The patients that fulfilled the criteria were selected to participate in the study. Patients were tested by a diagnostic assistant as part of general clinical treatment at one of the two mental health institutions. Tests that were administered included: Frontal Systems Behavioural Scale, Digit Span of the Wechsler Adult Intelligence Scale III, Stroop Colour Word Test, Trail Making Test, Verbal Fluency 1+2 of the Groninger Intelligence Test and the Behavioural Assessment of Dysexecutive Syndrome. The designated informants were asked to complete the FrSBe about the patient. The informants completed the FrSBe at home and sent the completed versions to the mental health institutions by mail. Written informed consent was acquired from patients and informants.

Materials

Frontal Systems Behavioural Scale (FrSBe)

The FrSBe is a behaviour rating-scale consisting of 46 items, designed to measure dysfunctions regarding behaviours associated with the frontal regions of the brain (Grace & Malloy, 2001). For this study a Dutch adaptation was used. Each item is rated on a 5-point scale and these rating-scales are administered to both the patient (self rating form) and an informant (family rating form). The items are dividable in three subscales: Apathy (A), disinhibition (D) and executive dysfunction (ED), respectively consisting of 14, 15 and 17 items. For these subscales, three separate scores are computed as well as a total (T) score by adding up the relevant items. Higher scores are indicative of poorer self-reported functioning.

The total score and the subscales have shown high internal consistency and satisfactory test-retest reliability and suggest that the scales have strong construct, discriminant, convergent, and ecological validity (Malloy & Grace, 2005). According to the manual Cronbach's alphas for the total scale and A, D and ED subscales are respectively 0,92, 0,78, 0,80 and 0,87 for the patient form and 0,88, 0,72, 0,75 and 0,79 for the family form (Grace & Malloy, 2001). Additional research (Stout, Ready, Grace, Malloy & Paulsen, 2003; Velligan, Ritch, Sui, DiCocco, & Huntzinger, 2002) found even higher Cronbach's alphas for the total scale and various subscales.

The FrSBe has proven it's clinical utility in different populations, such as in patients with Alzheimer's disease (Cahn-Weiner, Grace, Ott, Fernandez & Friedman, 2002; Stout, Wyman, Johnson, Peavy & Salmon, 2003; Deutsch et al., 2013), Parkinson's disease (Cahn-Weiner et al., 2002), multiple sclerosis (Chiaravalloti & DeLuca, 2003), schizophrenia (Velligan, Ritch, Sui, DiCocco & Huntzinger, 2002), substance abuse (Verdejo-García, Bechara, Recknor & Perez-Garcia, 2006) and traumatic brain injury (Reid-Arndt, Nehl & Hinkebein, 2007). Factor-analysis of the FrSBe for clinical use in a population of patients with traumatic brain injury indicated that the total-score and the family administration were appropriate measures when considering its psychometric properties. However the subscale scores and the patient administration need more examination (Niemeier, Perrin, Holcomb, Nersessova, & Rolston, 2013).

Digit Span of the Wechsler Adult Intelligence Scale III (DS-WAIS)

The WAIS III (Wechsler, 1997) consists of 17 subtests, of which the DS-WAIS. It is designed to measure working memory and attentional capacity, which as constructs are

linked to executive functioning (McCabe, Roediger McDaniel, Balota & Hambrick, 2010). The DS-WAIS consists of three trials in which a sequence of numbers is read aloud. In the first trial participants have to repeat the numbers in the same order as they are read to them, in the second trial in backwards order and in the third trial in ascending order. Per trial a score is calculated by adding up how many tasks they completed correctly and then a total-score is obtained by adding scores for the three trials. Higher scores are indicative of a better performance.

Stroop Colour Word Test (SCWT)

The SCWT is a neuropsychological test for measuring interference and response inhibition (Stroop, 1935). The first card contains typed colour words which participants have to read aloud (e.g. the typed word "red"), the second card contains coloured rectangles which they have to name (e.g. a red coloured rectangle) and the third card contains typed colour words printed in incoherent colour ink of which they have to name the colour the word is printed in (e.g. the typed word "red", printed in blue colour). An interference score is calculated by subtracting the average time to complete the first and the second card from the time to complete the third card. A higher score is indicative of a poorer performance.

Trail Making Test (TMT)

The TMT is a neuropsychological test for measuring mental flexibility (Armitage, 1946). The task consists of two trials presented on a blank sheet with circles. Both trials are preceded by a practice trial. During the first trial participants have to connect circles in chronological manner according to their number (1-2-3-4-5 etc.). During the second trial participants have to connect circles the same way but have to alternate between numbers (chronological) and letters (alphabetical) (1-a-2-b-3-c etc.). By dividing the time on the second trial by the time on the first trial, a ratio-score is calculated. A higher ratio is indicative of a poorer performance (Arbuthnott & Frank, 2000).

Verbal Fluency 1+2 of the Groninger Intellingence Test (VF-GIT)

The VF-GIT consists of 9 subtests, of which the last subtest measures verbal fluency with two trials (Luteijn & van der Ploeg, 1983). Verbal fluency tasks require executive functioning when inhibiting irrelevant or duplicate responses and these tasks are the

most sensitive to frontal lobe dysfunctions (Jurado, & Rosselli, 2007). For the first trial participants are asked to name as many words that belong to the category 'animals', within 1 minute. For the second trial participants are asked to name as many words that belong to the category 'professions', again with a time limit of 1 minute. Every new and correct word, belonging to the category, counts up to a total score per trial. Higher scores are indicative of a better performance.

Behavioural Assesment of Dysexecutive Syndrome (BADS)

The BADS is a test battery consisting of six subtests for measuring executive functioning in a more ecologically valid manner (Wilson, Alderman, Burgess, Emslie, Evans, 1996; Wilson, Evans, Emslie, Alderman & Burgess, 1998). The first subtest is the Rule Shift Cards: In this test participants have to follow a rule ("yes" for red cards and "no" for black cards) when responding to black or red cards. This rule changes twice during the subtest. The second subtest is the Action Program Test. In this test participants have to solve a practical problem ("get the cork out of a tube") using various materials like water and iron wire without touching the tube containing the cork itself. The third subtest is the Key Search Test. In this test participants have to find a key in a field, represented by a square on an otherwise blank piece of paper. They have to draw the line they would walk, using a pen. The fourth subtest is the Temporal Judgment Test. In this test participants have to answer four short questions by estimating the duration of a realistic event (e.g. "How long does it take to blow up a balloon"). The fifth subtest is the Zoo Map Test. In this test participants have to plan a route on the map of a zoo to visit several attractions while following certain rules. The sixth subtest is the Modified Six Elements Test. In this test participants have to perform certain tasks (telling a story, doing math and name pictures) twice within 10 minutes while never doing the same task in succession of another of the same kind (e.g. telling a story again directly after doing it the first time). The subtests respectively measure inhibition of dominant response, ability to implement solutions to a practical problem, goal-directed behaviour, ability to make realistic estimates from common knowledge, planning of behaviour, and organization and prospective memory. A total score is calculated by adding up the scores of each trial. Higher scores are indicative of a better performance.

The BADS has shown good construct validity; it could discriminate between brain-damaged and healthy participants, and good concurrent validity (Norris & Tate,

2000). As mentioned, the ecological validity is suggested to be superior to standard executive functioning tests in terms of predicting functional outcome of patients (Norris & Tate, 2000). Additionally, it has been shown to be better predictive of everyday executive disfunctioning than other cognitive tests (Bennett, Ong & Ponsford, 2005; Wilson, 1993).

The BADS has proved its usefulness in patients with schizophrenia (Katz, Tadmor, Felzen & Hartman-Maeir, 2007; Evans, Chua, McKenna & Wilson, 1997) and TBI (Boelen, Spikman, Rietveld & Fasotti, 2009; Bennett, Ong & Ponsford, 2005; Norris & Tate, 2000; Wood & Liossi, 2006). In addition, the BADS showed utility in adequately distinguishing between anterior and posterior lesions (Emmanouel, Kessels, Mouza, & Fasotti, 2014). In a group of psychiatric patients the test-retest reliability was high for some subtests but lower for the others and it was recommended that the BADS should not be administered twice just a few weeks apart (Jelicic, Henquet, Derix & Jolles, 2001).

Data preparation and analyses

Educational level was classified according to the standardized Dutch schooling system (De Bie, 1987). The categories were reduced to low (1–4) and high (5–8) educational level. Data was screened for outliers, extreme (>2 SD) or erroneous cases were deleted. Because only participants of one of the two mental health institutions completed the VF-GIT and the BADS, 20 and 19 respectively, these cognitive measures were examined in a different model tot maximize the sample size per outcome. For the remaining measures, DS-WAIS, SCWT and TMT, a compound score was calculated. The scores were converted to z-scores, based on the mean and standard deviation of the sample size of the current study, which allowed for the scores to be added up obtaining a compound score for executive functioning. Before adding up z-scores of the DS, SCWT and TMT, the scores of the SCWT and TMT were multiplied by -1 to assure the same direction of values since higher scores on the DS and lower scores on the SCWT and TMT implicate a better performance. Test-scores were transformed, inverted, added up and averaged to obtain the compound score for executive functioning, as follows:

Executive functioning compound =
(z(DS-WAIS$_{total}$) + -$zLOG_{10}$(SCWT$_{interference}$) + -$zLOG_{10}$ (TMT$_{ratio}$))/3.

To answer the first research question, the differences between patients' and informants' reports of the patient's frontal functioning were examined. A one sample independent t-test was conducted to compare FrSBe total-scores of patients with FrSBe total-scores of informants. To answer the second research question, the relation between cognitive functioning and self-reported frontal functioning was examined. It was analysed if various tests for cognitive functioning were predictive of self-reported frontal functioning. Multiple regression analyses were conducted whereby in a first model either the executive functioning compound score, scores on the GIT or scores on the BADS were entered through the enter method with FrSBe scores on the patient version as dependent variable. As a second model gender, age and education were entered to control for potential confounding. To answer the third research question, the relation between cognitive functioning and informants' ratings of the patients' frontal functioning was examined. It was analysed if various tests for cognitive functioning were predictive of frontal functioning as reported by informants. The same practice as for the second research question was used, with the informant version of the FrSBe as an outcome variable instead of the patient version of the FrSBe. All of the analyses were performed with SPSS 21.0 for Windows. P-values smaller than .05 were considered significant. P-values larger then .05 but smaller than .10 were considered borderline significant.

Results

Initially 114 patients were recruited. Of these, 13 patients were not included because of no proven brain injury, 5 because of a lack of consent and 12 because of various reasons such as a deficient language comprehension, crisis situation or because they were younger than 18 years. Of the remaining patients, 31 informants were excluded mostly because of a lack of consent. Eventually, after applying inclusion and exclusion criteria 84 patients and 53 informants remained. An overview of patient characteristics is shown in Table 1.

Table 1: Mean (M), standard deviation (SD) and range or percentage (%) and number (N) of various patient characteristics (age, years since injury, gender, educational level, type of ABI, side of brain injury and location of brain injury; N=85).

	M (SD)	**Range**
Age	44,8 (12,9)	18-76
Years since injury	11,7 (11,3)	0.3-41.9
	%	**N**
Gender		
Female	31.8	27
Male	68.2	58
Educational Level		
Low	75.3	64
High	24.7	21
Type of ABI		
Traumatic	45.9	39
Vascular	25.9	22
Intoxication	4.7	4
Tumour	3.5	3
Inflammation	3.5	3
Hypoxia	1.2	1
Multiple	11.8	10
Other	3.5	3
Side of brain injury		
Left	18.8	16
Right	21.2	18
Bilateral	40	34
Unspecified	20	20
Location of brain injury		
Diffuse	49.4	42
Local	35.3	30
Unspecified	15.3	13

For the SCWT one outlier was deleted that had an unrealistic score probably due to an error with the administration of the test. For the TMT one outlier was deleted that also had an unrealistic score probably due to erroneous administration of the test. In addition, both on the SCWT and on the TMT respectively 2 and 1 outlier(s) were detectd with scores higher than two times the SD, due to slow yet realistic performances. Because both tests were positively skewed first a log transformation was applied in order to attain normally distributed scores to explore whether these performances still were as deviant. After the log transformation both the SCWT and the TMT were

normally distributed and only one outlier remained for the SCWT. Since the score was a realistic performance and more importantly, scores on the various cognitive measures would be added up to obtain a compound score, this outlier was left unaltered until the compound score was calculated. Additional inspection would have to indicate if the score would still have to be deleted after calculating the compound score. For the other cognitive measures no outliers were detected. BADS scores were negatively skewed; therefore individual scores were subtracted from 25 (maximum possible score + 1) and log-transformed after which scores were normally distributed. Scores on the FrSBe-p, FrSBe-i and VF-GIT were also normally distributed. The measurement characteristics for the various measurements are shown in Table 2.

Table 2: Mean, standard deviation (SD), median, interquartile range (IQR) and range for scores on the various measurements.

Measurement	N	Mean (SD)	Median (IQR)	Range
FrSBe-p	84	105.94 (2.49)	109 (35.75)	55-148
FrSBe-i	53	106.08 (3.70)	112 (38.50)	46-177
$DS\text{-}WAIS_{total}$	71	13.73 (0.40)	13 (5.00)	5-24
$SCWT_{interference}$ (sec)	82	68.02 (11.23)	47 (31.63)	6.50-839
TMT_{ratio}	83	2.50 (0.12)	2.19 (0.12)	0.96-7.92
$VF\text{-}GIT_{total}$	20	38.90 (2.58)	36 (17.50)	19-66
$BADS_{total}$	19	18.26 (0.78)	19 (5.00)	11-22

Note. FrSBe-p, Frontal Systems Behavioural Scale-completed by patients; FrSBe-i, Frontal Systems Behavioural Scale-completed by informants; DS-WAIS, Digit Span of the Wechsler Adult Intelligence Scale IV; SCWT, Stroop Colour Word Test; TMT, Trail Making Test; VF-GIT, Verbal Fluency of the Groninger Intelligence Test; BADS, Behavioural Assesment of Dysexecutive Syndrome.

To validate the calculation of a compound score, the associations between the DS-WAIS, SCWT and TMT were examined by calculating Pearson moment correlations. Scores on the DS-WAIS and SCWT ($r(69) = -.48$, $p < .05$), DS-WAIS and TMT ($r(69) = -.42$, $p < .05$) and SCWT and TMT ($r(80) = .31$, $p < .05$), were all significantly correlated, yielding moderate to strong correlations. This supported the idea of a shared underlying construct, and validated the calculation of a compound score. Ultimately, compound scores were normally distributed and no outliers were present.

Difference between patients' and informants' scores on the FrSBe

Analysis of the difference between patients' FrSBe scores (M=105.94, SD=2.49) and informants' FrSBe scores (M=106.08, SD = 3.70) yielded no significant difference (t (137)=.107, p = .915). It was expected that patients and informants differed significantly but this hypothesis was not supported.

Executive functioning compound and patients' scores on the FrSBe (N=66).

Before ($F(1, 65) = .194$, $p=.661$, $R^2 = .003$, $R^2_{Adjusted} = -.012$) and after ($F(4, 62) = 1.835$, $p=.133$, $R^2 = .106$, $R^2_{Adjusted} = .048$) adjustment for potential confounders, no significant model was found (N=66). Executive functioning compound score was not significantly associated with self-reported frontal functioning in model 1 (regression coefficient B = -1.66, standardized regression coefficient $\beta = -.055$, $t(66) = -.441$, $p=.661$, CI=-9.155−5.844) and model 2 (B=-3.62, $\beta = -.119$, (66) = -.441, $t(66) = -.891$, $p=.377$, CI = -11.750−4.507). In model 2, age was the only variable that was significantly associated with self-reported frontal functioning (B=-.549, $\beta = -.3$, $t(66) = -2.279$, $p < .05$, CI=-1.031−-.068) meaning a higher age is associated with lower scores on the FrSBe, which are indicative of better frontal functioning as reported by patients themselves. A graphical representation of the crude association between executive functioning compound scores and the patients' FrSBe-scores is shown in Figure 1. A summary of the models is shown in Table 3.

It was expected that executive functioning would not be associated with self-reported frontal functioning. Our results support this hypothesis.

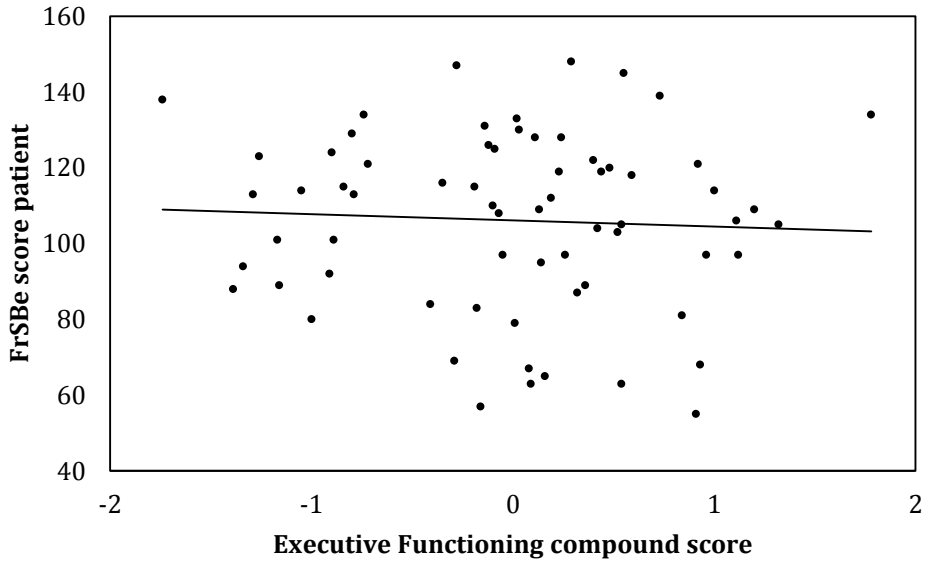

Figure 1: Scatterplot of compound scores of executive functioning and patients' FrSBe scores. A lower FrSBe-p score indicates better frontal functioning as reported by patients. A higher compound score indicates better executive functioning.

VF-GIT scores and patients' scores on the FrSBe (N=18).

The first model explained a borderline significant amount of the variance of self-reported frontal functioning by patients ($F(1, 17) = 3.458$, $p=.08$, $R^2 = .169$, $R^2_{Adjusted} = .120$). The analysis showed a borderline significant association between GIT score and self-reported frontal functioning (B=-.884 , β= -.411, $t(18) = -1.859$, $p=.08$, CI: -1.887–.119). Model 2 was significant ($F(4, 14) = 5.852$, $p=.006$, $R^2 = .626$, $R^2_{Adjusted} = .519$) and it was found that higher VF-GIT scores were associated with lower scores on the FrSBe which is indicative of better frontal functioning as reported by patients (B=-.868, β= -.403, $t(18) = -2.234$, $p < .05$, CI: -1.7–-.035). In this model a higher age was associated with lower scores on the FrSBe, which are indicative of higher self-reports of frontal functioning (B=-1.310, β= -.744, $t(18) = -4.076$, $p < .05$, CI: -2–-.621) In addition, there was a borderline significant association between gender and FrSBe scores (B=-30.328, β= -.384, $t(18) = -2.130$, $p = .051$, CI: -60.869–.212) meaning being male is associated with lower scores on the FrSBe which are indicative of better frontal functioning as reported by patients themselves. Educational level did not significantly predict self-reported frontal functioning. A graphical representation of the crude

association between VF-GIT scores and the patients' FrSBe-scores is shown in Figure 2. A summary of the models is shown in Table 3.

After examining the distribution of VF-GIT scores in association with patients' FrSBe scores a possible influential case was detected. Without this case no significant association between verbal fluency and frontal functioning was found after adjustment for potential confounders. However, the differences in regression coefficient were minimal and significance levels did not drop considerably considering the small size of the sample. Thus, the influential case was evaluated as a tolerable case.

It was expected that executive functioning, measured as verbal fluency, would not be associated with self-reported frontal functioning. Our results do not support this hypothesis.

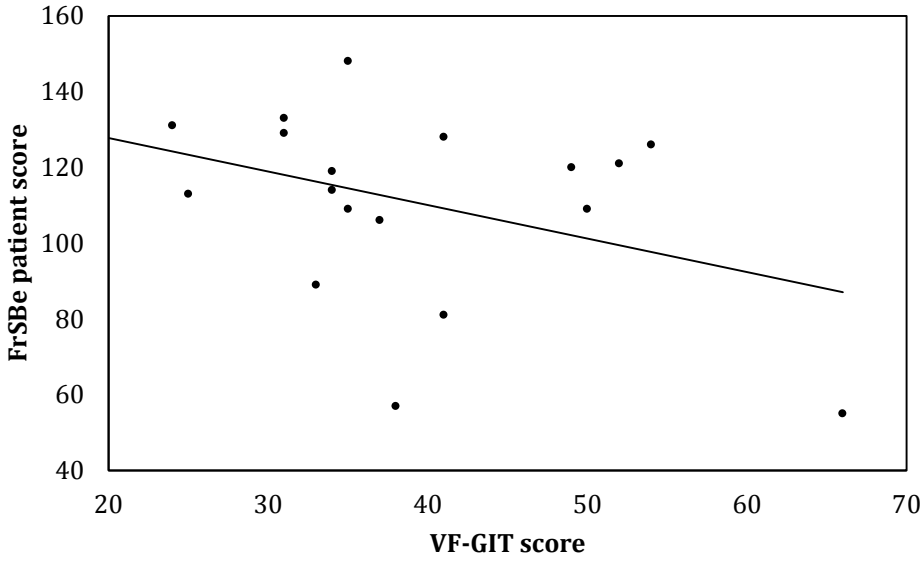

Figure 2: Scatterplot of the VF-GIT scores and the patients' FrSBe scores. A lower FrSBe-p score indicates better frontal functioning as reported by patients. A higher VF-GIT score indicates better verbal fluency.

BADS scores and patients' scores on the FrSBe (N=18).

Model 1 was not significant ($F(1, 17) = .964$, $p=.34$, $R^2 = .054$, $R^2_{Adjusted} = -.002$), BADS score was no significant predictor for patients' score on the FrSBe ($B= -27.094$, $\beta = -.232$, $t(18) = -982$, $p=.34$, CI: -85.301–31.113). Model 2 was significant ($F(4, 14) = 3.484$, $p=.036$, $R^2 = .499$, $R^2_{Adjusted} = .356$), however no significant association of executive

functioning with self-reported frontal functioning was found (B= 11.589, β =.099, t(18) = .428, p = .675, CI= -46.536−69.713). A higher age (B= -1.387, β= -.787, t(18) = -3.116, p < .05, CI: -2.341−-.432) and being male (B=-32.403, β= Beta = -.41, t(18) = -1.954, p = .071, CI: -67.975 −3.168) were (borderline) significantly associated with better frontal functioning as reported by patients (lower FrSBe scores). A graphical representation of the crude association between BADS scores and the patients' FrSBe-scores is shown in Figure 3. A summary of the models is shown in Table 3.

It was expected that better executive functioning would not be associated with better frontal functioning as reported by patients. This hypothesis was supported by our results.

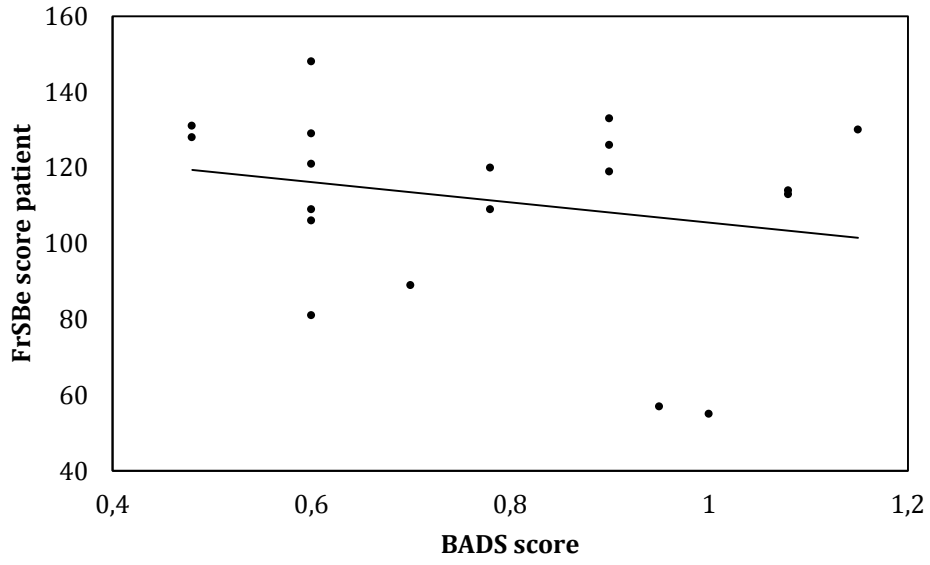

Figure 3: Scatterplot of the BADS scores after log transformation and the patients' FrSBe scores. A lower FrSBe-p score indicates better frontal functioning as reported by patients. A higher BADS score indicates better executive functioning.

Executive functioning compound and informants' scores on the FrSBe (N=43).

Both model 1 (F(1, 42) = .422, p=.520, R^2 = .01, $R^2_{Adjusted}$ = -.014) and model 2 (F(4, 39) = 1.771, p=.154, R^2 = .154, $R^2_{Adjusted}$ = .067) were not significant. Executive functioning compound score was no significant predictor of FrSBe-i score in model 1 (B = 3.807 β = .100, t(43) = .649, p=.520, CI= -8.026−15.640) and model 2 (B= .818 , β = .021, t(43) = .132, p = .896, CI = -11.760−13.396). In model 2, age was the only variable that was significantly associated with self-reported frontal functioning (B= -.702, β -.333, t(43) = -2.035, p < .05, CI =-1.400−-.004) meaning a higher age of patients is associated with

lower scores on the FrSBe-i, which are indicative of better frontal functioning as reported by informants. A graphical representation of the crude association between executive functioning compound scores and the informants' FrSBe-scores is shown in Figure 4. A summary of the models is shown in Table 4.

It was expected that better executive functioning performance of patients would be associated with better frontal functioning as reported by informants. Our results do not support this hypothesis.

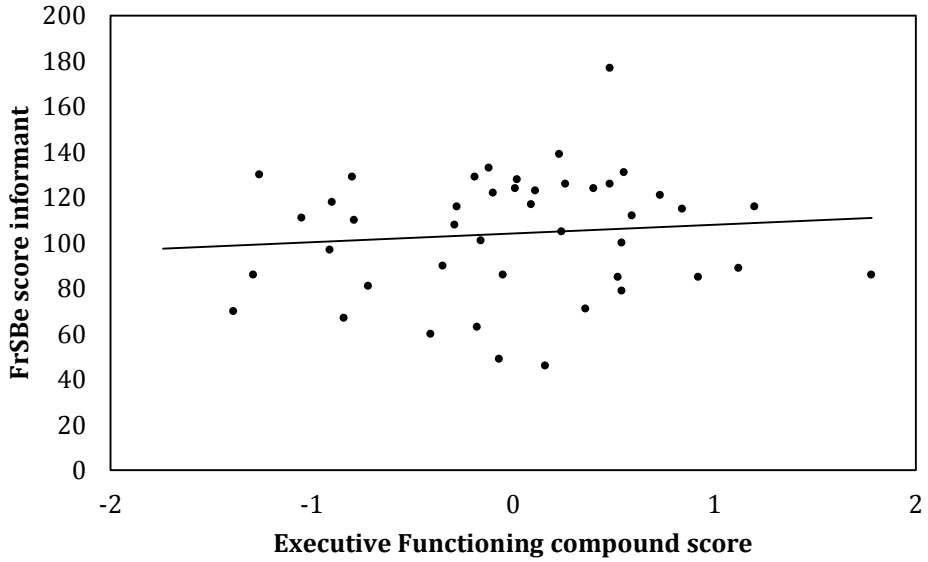

Figure 4: Scatterplot of the compound scores of executive functioning and the informants' FrSBe scores. A lower FrSBe-i score indicates better frontal functioning as reported by informants. A higher compound score indicates better executive functioning.

GIT scores and informants' scores on the FrSBe (N=12).

Before ($F(1, 11) = 2.186$, $p=.167$, $R^2 = .166$, $R^2_{Adjusted} = .090$) and after ($F(4, 8) = 1.459$, $p=.300$, $R^2 = .422$, $R^2_{Adjusted} = .133$) adjustment for potential confounders, verbal fluency as measure of executive functioning was not significantly associated with frontal functioning as reported by informants. GIT scores was not significantly associated with FrSBe-i score in model 1 ($B= 1.182$, $\beta= .407$, $t(11) = 1.479$, $p=.167$, CI = -.577–2.941) and model 2 ($B=.935$, $\beta = .322$, $t(12) = 1.128$, $p = .292$, CI =-.977–2.847). Additionally, none of the potential confounders was significantly associated with frontal functioning as reported by informants. A graphical representation of the crude association between

GIT scores and the patients' FrSBe-scores is shown in Figure 5. A summary of the models is shown in Table 4.

It was expected that better executive functioning performance of patients, measured by the GIT as verbal fluency, would be associated with better frontal functioning as reported by informants. Our results do not support this hypothesis.

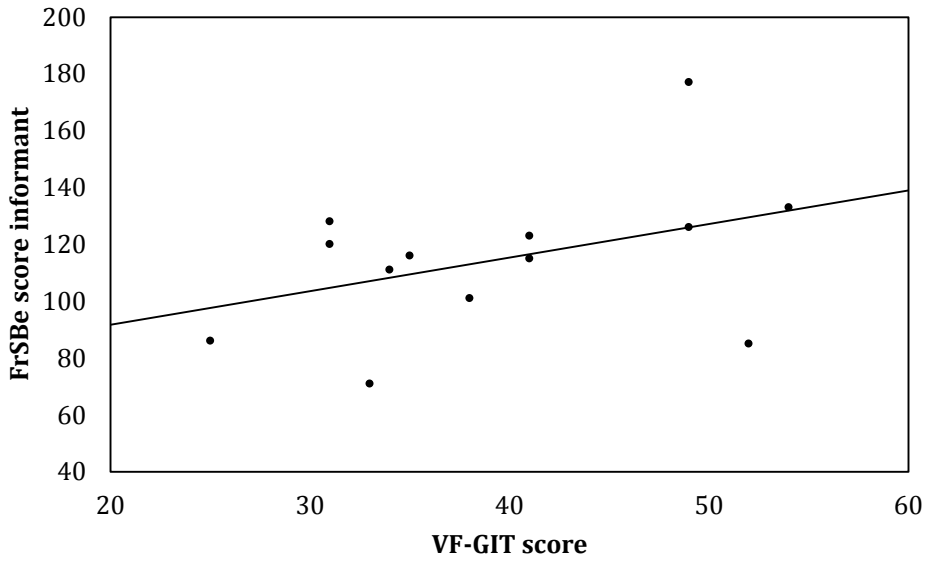

Figure 5: Scatterplot of the VF-GIT scores and the informants' FrSBe scores. A lower FrSBe-i score indicates better frontal functioning as reported by informants. A higher VF-GIT score indicates better verbal fluency.

BADS scores and informants' scores on the FrSBe (N=12).

Model 1 was not significant ($F(1, 10) = .032$, $p=.863$, $R^2 = .003$, $R^2_{Adjusted} = .602$), BADS score was no significant predictor for FrSBe-i score ($B=-5.555$, $\beta=-.056$, $t(11) = -.178$, $p=.863$, CI = -75.242−64.132). Model 2 was significant ($F(4, 7) = 5.161$, $p=.030$, $R^2 = .747$, $R^2_{Adjusted} = .602$) with a borderline significant association between BADS scores and frontal functioning as reported by informants ($B=55.337$, $\beta =.559$, $t(11) = 2.151$, $p = .069$, CI = -5.499−116.172) meaning higher scores on the BADS were predictive of higher scores on the FrSBe-i which are indicative of poorer frontal functioning as reported by informants. A higher age of patients ($B=-1.127$, $\beta = -.943$, $t(11) = -3.370$, $p < .05$, CI = -1.917 − -.336) was significantly associated with better frontal functioning as reported by informants. The above results suggest that BADS score was only a significant predictor because of a strong association with age. The relation between age

and BADS scores was analysed by calculating a correlation. A strong negative correlation was found ($r(10) = -.582$, $p < .05$), indicating that a higher age of the patient is associated with lower BADS scores which are indicative of poorer executive functioning. With age as a significant predictor of frontal functioning as reported by informants, it seems that the association found between BADS scores and FrSBe-i scores are due to negative confounding. This could explain the difference found in regression coefficient of BADS score after controlling for the effect of age and supports the notion that a significant association was only found because of negative confounding of age. A graphical representation of the crude association between BADS scores and the informants' FrSBe-scores is shown in Figure 6. A summary of the models is shown in Table 4.

It was expected that better executive functioning, measured by the BADS, would be associated with better frontal functioning. Multiple regression analysis yielded a significant model where better executive functioning was associated with poorer, instead of better frontal functioning as reported by informants, albeit borderline significant. However, after further examination it seems that the significant association is mostly due to a high correlation between age and BADS scores. Overall, in any case our results do not support the hypothesis.

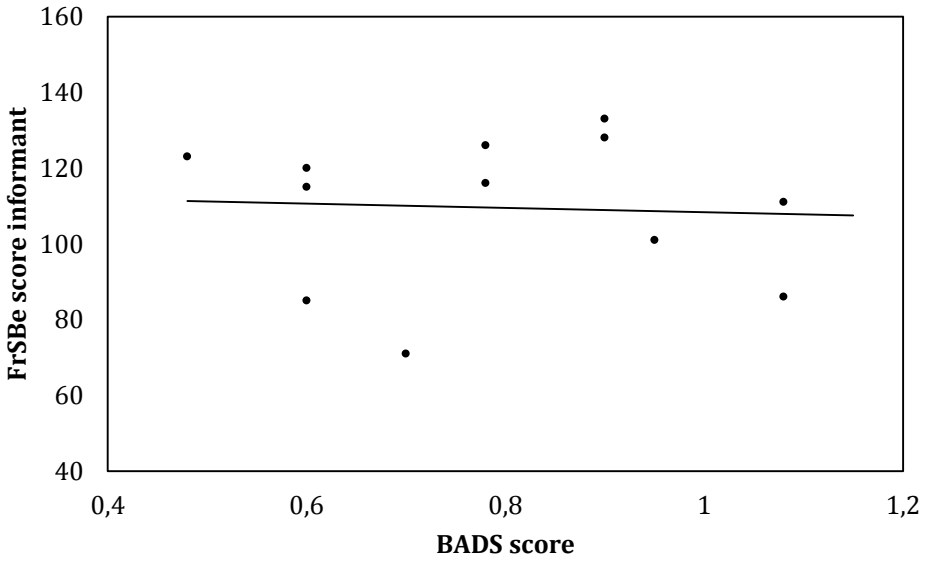

Figure 6: Scatterplot of the BADS scores after log transformation and the informants' FrSBe scores. A lower FrSBe-i score indicates better frontal functioning as reported by informants. A higher BADS score indicates better executive functioning.

Table 3: Coefficients of determination (R^2 and $R^2_{Adjusted}$) and p-value of models for patients' scores on the FrSBe with unstandardized (B) and standardized regression coefficients (β), p-value and confidence interval for the predictors (EF compound scores, VF-GIT scores or BADS scores) and potential confounders (age, gender and educational level).

		R^2	$R^2_{Adjusted}$	p		B	β	p	95% confidence interval
EF compound	Model 1	.003	-.012	.661	EF compound	-1.656	.055	.661	-9.155 – 5.844
(N=66)	Model 2	.106	.048	.133	EF compound	-3.622	-.119	.377	-11.750 – 4.507
					Age*	-.549	-.300	.026	-1.031 – 0.068
					Gender	-4.019	-.083	.498	-15.806 – 7.767
					Educational Level	-2.912	-.053	.694	-17.655 – 11.831
VF-GIT	Model 1[a]	.169	.120	.080	GIT[a]	-.884	-.411	.080	-1.887 – .119
(N=18)	Model 2*	.626	.519	.006	GIT*	-.868	-.403	.042	-1.700 – -.035
					Age*	-1.310	-.744	.001	-2.000 – -0.621
					Gender[a]	-30.328	-.384	.051	-60.869 – 0.212
					Educational Level	1.981	-.038	.840	-18.690 –22.652
BADS	Model 1	.054	-.002	.340	BADS	-27.094	-.232	.340	-85.301 – 31.113
(N=18)	Model 2*	.499	.356	.036	BADS	11.589	.099	.675	-46.536 – 69.713
					Age*	-1.387	-.787	.008	-2.341 – -0.432
					Gender[a]	-32.403	-.410	.071	-67.975 – 3.168
					Educational Level	-5.699	-.109	.601	-28.532 – 17.134

* significant at p<.05

[a] borderline significant (.10>p>.05)

Note. EF compound, executive functioning compound; VF-GIT, Verbal Fluency of the Groninger Intelligence Test; BADS, Behavioural Assesment of Dysexecutive Syndrome. Lower FrSBe scores are indicative of better frontal functioning as reported by patients.

Table 4: Coefficients of determination (R^2 and $R^2_{Adjusted}$) and p-value of models for informants' scores on the FrSBe with unstandardized (B) and standardized regression coefficients (β), p-value and confidence interval for the predictors (EF compound scores, VF-GIT scores or BADS scores) and potential confounders (age, gender and educational level).

		R^2	$R^2_{Adjusted}$	p		B	β	p	95% confidence interval
EF compound	Model 1	.010	-.014	.520	EF compound	3.807	.100	.520	-8.026 – 15.640
(N=43)	Model 2	.154	.067	.154	EF compound	.818	.021	.896	-11.760 – 13.396
					Age*	-.702	-.333	.049	-1.400 – -.004
					Gender	12.778	.233	.128	-3.836 – 29.392
					Educational Level	-.090	-.001	.993	-22.202 – 22.021
VF-GIT	Model 1	.166	.090	.167	GIT	1.182	.407	.167	-.577 – 2.941
(N=12)	Model 2	.422	.133	.300	GIT	.935	.322	.292	-.977 – 2.847
					Age	-.173	-.108	.740	-1.332 – .987
					Gender	33.398	.473	.139	-13.525 – 80.321
					Educational Level	11.370	.203	.518	27.391 – 50.131
BADS	Model 1	.003	-.097	.863	BADS	-5.555	-.056	.863	-75.242 – 64.132
(N=12)	Model 2*	.747	.602	.030	BADS[a]	55.337	.559	.069	-5.499 – 116.172
					Age*	-1.127	-.943	.012	-1.917 – -.336
					Gender	15.292	.303	.198	-10.138 – 40.722
					Educational Level	9.495	.219	.360	-13.443 – 32.433

* significant at p<.05

[a] borderline significant (.10>p>.05)

Note. EF compound, executive functioning compound; VF-GIT, Verbal Fluency of the Groninger Intelligence Test; BADS, Behavioural Assesment of Dysexecutive Syndrome. Lower FrSBe scores are indicative of better frontal functioning as reported by informants.

Discussion

The first aim of this study was to examine the differences in patients' and informants' reports of patients' frontal functioning measured with the FrSBe in a sample of patients with ABI and neuropsychiatric symptoms. The second aim was to examine associations between performances on various cognitive tests and patients' own and informants' ratings of the patients frontal functioning. No significant differences were found between patients' and informants' reports. Overall the results showed that patients' cognitive performances on tests for executive functioning were not associated with patients own rating of their frontal functioning and not associated with informants' ratings of the patients' frontal functioning.

Our results showed that patients and informants did not significantly differ in their ratings of the patients' frontal functioning. The results are in line with the results of the study by Lengenfelder and colleagues (2013), who also found no differences in patients' and informants' ratings. This finding could be explained by a sufficient awareness in patients about their shortcomings, which would imply that a lack of awareness is not that common in ABI patients and that a large portion is able to judge its own functioning. However, other studies did find differences between patients' and informants' reports (Chaytor & Schmitter-Edgecombe, 2003) and overestimation of functioning is an often seen consequence of brain injury (FitzGerald et al., 2012; Orfei et al., 2009; Prigatano, & Altman, 1990). Thus, the suggested explanation presumably may not explain the lack of difference between self- and informant-ratings.

Another explanation could be the existence of different groups of patients considering awareness of their cognitive shortfalls after ABI (Smeets et al., 2014). While it is known that patients often overestimate their own functioning (FitzGerald et al., 2012), it is also possible that patients underestimate their own functioning. Smeets and colleagues (2014) created different groups of patients based on discrepancy scores on the Patient Competency Rating Scale (PCRS; Prigatano et al., 1986). The PCRS is designed to measure the ability of patients to function properly, and higher scores on the PCRS indicate better overall functioning. The distinction in awareness was made based on discrepancy scores between patient ratings and informants or clinicians ratings per item. A positive discrepancy indicates that patients are overestimating their functioning, while a negative discrepancy indicates that patients are underestimating

their functioning. The highest number of items where the discrepancy between patients and informants or clinicians was negative, positive or neutral determined to which group the patients were assigned. In the current study no distinction was made between these levels of awareness and because analysis of differences was done over group means, these differences were possibly neglected. Therefore it is possible that some patients were inadequately judging their own functioning although we did not find differences between patients' and informants' ratings of frontal functioning. However, because the FrSBe is not designed to measure awareness, the same practice as is used by the PCRS is not studied with the FrSBe.

Additionally, it was found that patients' executive functioning was not associated with both patients' as informants' reports of frontal functioning except for verbal fluency. The hypothesis that patients' cognitive performance would not be associated with their self-reported functioning, even when measured with a more ecological valid tool, was supported by the results. Standard cognitive tests (DS-WAIS, TMT, SCWT) and a more ecologically valid measure for executive functioning (BADS) were not associated with self-reported frontal functioning while verbal fluency (VF-GIT) was found to be significantly associated with self-reported frontal functioning. In contrast to patients' own ratings of their functioning, it was expected that patients' cognitive performance would be associated with informants' ratings of their frontal functioning. More specifically, it was expected that the association would be strongest when using a more ecological valid tool. This association was not found since none of the measures for executive functioning were associated with frontal functioning as reported by informants.

Except for the significant association of verbal fluency with self-reported frontal functioning, results seem to indicate that in this sample the cognitive tests measure different constructs than questionnaires. The ecological validity of the tests did not seem to explain the results, because a more ecological valid tool was not associated with either frontal functioning as reported by patients (as expected) and as reported by informants. Further, it has been suggested that questionnaires, like the FrSBe, do not measure behaviour per se but shortfalls encountered in daily living (Toplak, West & Stanovich, 2013). The behaviours intended to be measured and the shortcomings experienced in daily life, may be different constructs than the cognitive functioning that is measured by tests.

To explain the significant association between verbal fluency and patients' own rating of their frontal functioning, the role of the frontal regions on verbal fluency should be explained. The function of the frontal lobe on verbal fluency had been disputed since different types of verbal fluency seem to rely on different neuronal regions (Troyer, Moscovitch, Winocur, Alexander & Stuss, 1998). Studies suggest that the frontal lobe is more correlated with phonemic fluency (letter-based word retrieval), whereas semantic fluency (category-based word retrieval) is more correlated with temporal regions (Baldo, Schwartz, Wilkins & Dronkers, 2006). Although a semantic fluency task was used in the current study, still a significant association was found with (self-reported) frontal functioning. A more recent meta-analysis by Robinson, Shalice, Bozalli and Cipolotti (2012) found that all fluency tasks are sensitive to damage to the frontal lobe, but phonemic fluency shows specificity to frontal damage. Thus, although we did not use a phonemic fluency task it is possible that the semantic fluency task we used was also sensitive to frontal lobe damage. However, we did not expect to find associations of verbal fluency with patient's own reported frontal functioning, while not finding an association with informants' ratings. This could suggest that shortcomings in verbal fluency are more apparent to patients' themselves than to their significant others in daily life. It would additionally suggest that shortcomings in verbal fluency are also measured with the FrSBe. These suggestions need further examination and it is difficult to draw such conclusions from our results.

This study has several strengths including a sample of patients with neuropsychiatric symptoms after ABI, which are often excluded from research. This feature could also be considered a limitation because it may be difficult to perform group-based analysis in this heterogeneous population. The reason why this group of patients is often excluded from analysis is the great heterogeneity among the patients. This heterogeneity is caused by great variety in injury-related variables such as localization, severity and time since injury and the behavioural outcome of those lesions, Another reason why these patients are often excluded from analysis is the possible confounding effects of neuropsychiatric symptoms on test results. Single-case studies are argued to be the first choice in describing and analysing patients because of individual differences (Barlow & Hersen, 1973; Tate et al., 2008). However, single case designs are more susceptible to biases and have a risk to be threatening to internal and external validity (Perdices & Tate, 2009). The current study intended to examine

differences between groups thus a single case study design would not be appropriate for research on the current subject.

A second limitation is the arguable ecological validity of the BADS. While the BADS was specifically designed to measure executive functioning in a more ecological valid manner, it has been suggested that some of the subtests of the BADS are not ecological valid measures for executive functioning in contrast to other subtests (Wood & Liossi, 2006). In addition, previous research has shown that the BADS was not associated with patients' own rating of their executive functioning as measured by the Dysexecutive questionnaire (DEX; Wilson, Alderman, Burgess, Emslie & Evans, 2003). This could also point out that cognitive tests and questionnaires measure different constructs as is found in the current study. This suggests that even the more ecologically valid measures for executive functioning do not measure everyday executive functioning. Because neuropsychological tests and outcome measures of everyday functioning generally only seem moderately related, it was suggested that clinicians take other measures in account like informant and clinicians ratings, behavioral observations and demographical variables (Chaytor & Schmitter-Edgecome, 2003).

A third limitation is the small sample size for the majority of the analyses. Scores for the BADS and GIT were only available for patients in one of the two mental health institution, severely lowering the sample size for these analyses. The consequence of a small sample is a reduced ability to acquire valid results to draw solid conclusions. For example, for the analysis of the association between verbal fluency and self-reported frontal functioning it is uncertain whether an influential case is an exceptional or an extreme yet plausible case.

In short, executive functioning as measured by cognitive tests and frontal functioning either reported by patients themselves or their informants do not seem to be associated. This suggests that cognitive tests and related questionnaires about cognitive functioning are measuring different aspects of patients' functioning in a population of patients with both ABI and neuropsychiatric symptoms. For the clinical practice it is important to emphasize not to rely exclusively on cognitive test performance or reports by patients themselves or informants. The current study endorses the use of multiple different outcome variables when making clinical decisions, for example cognitive measures and reports by patients and informants but also clinician ratings and behavioural observations.

Future research should consider examining the role of awareness in this group of patients. As proposed it would be interesting to create groups of patients who are over- or underestimating their functioning, to examine differences between these groups in the association with cognitive performance on tests and self-reported functioning. The sample size of the current study and a lack of a proper tool, did not allow for this distinction to be made. The use of another measurement tool, such as the PCRS, is advised to make a distinction on levels of awareness to further examine differences between these groups with regard to the association between cognitive functioning and self-reported functioning. However, the uniqueness of this population makes it difficult to attain large sample sizes especially when the sample will be divided into subgroups. It will be laborious but valuable to attain a larger sample size so that patients could be differentiated on their rate of awareness of cognitive impairments. Another factor to consider for future research is the aspect of the brain injury such as the location (left versus right), type (TBI, CVA, tumour, etc.) and time since injury (acute versus post-acute). While some details of the injury are mentioned in the current study, these characteristics were not specifically included. It would be interesting to examine if lateralization of injury and time since injury plays a role in the associations of cognitive performance with self-reported functioning. These suggestions for future research indicate that there is still a lot of area to cover about the functioning of patients with ABI and neuropsychiatric symptoms in relation to the association between their cognitive and self-reported functioning.

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