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Indices of Impaired Self-Awareness in Traumatic Brain Injury Patients with Focal Frontal Lesions and Executive Deficits: Implications for Outcome Measurement

Jacoba M. Spikman^{1,2} and Joukje van der Naalt²

Abstract

In patients with moderate to severe traumatic brain injury (TBI), impairments of self-awareness are frequently found and associated with worse functional outcome and poor compliance with rehabilitation. The aim of this study was to investigate whether indications of impaired self-awareness could be found in TBI patients with frontal lesions and executive function deficits. Twenty-two TBI patients with focal frontal injuries were compared to 29 TBI patients without focal frontal injuries visible on neuroimaging. No differences were found on several outcome measures, including the Glasgow Outcome Scale-Extended (GOS-E), the Differential Outcome Scale (DOS), and return to work (RTW), although the frontal injury patients were more severely injured as indicated by the Glasgow Coma Scale (GCS) and duration of post-traumatic amnesia (PTA), and had impaired performance on a neuropsychological test of executive functioning. Even more so, the frontal injury group had a significantly lower score on the Sickness Impact Profile (SIP), indicating that they had fewer complaints than the patients without frontal injury, and scored significantly higher on the percentage of recovery (PoR) score, which expresses the extent of recovery as a percentage of their previous level of functioning. In contrast to the non-frontal-injury group, their PoR scores were not related to RTW, reflecting an erroneous perception of their actual working status. The positive results on these different outcome measures, which are partly or entirely self-reported, were seen as an indication of an impaired self-evaluative ability in the frontal injury patients. To determine outcome in a patient with frontal injuries and executive dysfunction, the judgment of several relevant other persons in the patient's life (e.g., partners, therapists, and employers) of the patient's daily life functioning should be sought.

Key words: executive functions; frontal lesions; impaired self-awareness; outcome; traumatic brain injury

Introduction

TRAUMATIC BRAIN INJURY (TBI) of at least moderate severity often results in chronic cognitive, emotional, and behavioral sequelae that negatively affect patients' abilities to function on their previous social and vocational level (Crepeau and Scherzer, 1993; Engberg and Teasdale, 2004; Ponsford et al., 2008; Wood and Rutherford, 2006). The most frequently occurring cognitive sequelae after TBI involve mental slowness, attentional deficits, memory impairments, and executive problems (Azouvi et al., 2009; Millis et al., 2001; Rios et al., 2004; Ruttan et al., 2008; Spikman et al., 2000). To determine to what extent these cognitive deficits are related to long-term outcome, reliable assessment of both deficits as well as outcome is crucial.

Cognitive sequelae of brain injury can be validly, reliably, and objectively assessed with neuropsychological tests. Outcome is the term used to determine final recovery status, which can have several dimensions. Neurological and psychosocial outcome after TBI can be measured with different scales and questionnaires, most of them with good psychometric properties. Well-known neurological outcome scales include the Glasgow Outcome Scale (GOS; Jennett and Bond, 1975), and its extended version (GOS-E; Jennett et al., 1981). Van der Naalt and colleagues (1999b) developed the Differential Outcome Scale (DOS), which allows a more detailed assessment of outcome in four categories (neuropsychological, cognitive, behavioral, and social). A more specific indication of outcome in terms of daily life recovery is vocational status. Another indication of psychosocial outcome is quality of life

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in terms of behavioral and social well-being, which can be assessed with the Sickness Impact Profile (SIP; Bergner et al., 1981). In a range of studies, indications of injury severity (e.g., GCS score or duration of post-traumatic amnesia [PTA]), as well as cognitive deficits in several domains, were found to be significantly associated with worse functioning according to these aforementioned outcome measures (Boake et al., 2001; Felmingham et al., 2001; Klonoff et al., 1986; Mazaux et al., 1997; Ponsford et al., 2008; Spikman et al., 1999).

Nevertheless, a general drawback of these outcome measurements is that they are, albeit to differing extents, self-report based and therefore at least partially subjective. This is no problem when patients are able to provide an honest and objective report of their abilities and performance in daily life. However, a complicating factor is that TBI of at least moderate severity frequently results in impaired self-awareness (ISA), also referred to as lack of insight or anosognosia (Abreu et al., 2001; Hart et al., 2004; Sherer et al., 2003). According to McGlynn and Schacter (1989), ISA is an impaired ability to accurately perceive one's deficits, and to understand the impact of these deficits on real-world functioning. ISA is associated with worse functional outcome and poor compliance with rehabilitation (Wise et al., 2005).

ISA results in diminished self-evaluative accuracy and hence obscures the reliability of self-report-based measures of outcome. Patients will tend to rate their functioning more optimistically than justified by reality, even when there are salient cues that things are not as good as perceived by the patient. For this reason, it is important to identify those patients who have self-awareness deficits, because this might prevent them from getting the care they actually need. However, ISA cannot be measured directly. The most commonly used method is comparison of patient self-ratings with ratings by relatives or staff on the same questionnaires (Fleming et al., 1996). Some studies comparing patients' own ratings of their functioning with those of others, showed awareness deficits in TBI patients (Abreu et al., 2001; Sherer et al., 2003). Another option for measuring self-awareness is to compare patient self-ratings of functioning with their actual task performance. Allen and Ruff (1990) compared self-rating of learning and memory of TBI patients with their neuropsychological test performance, and found severe TBI patients to be less accurate in their prediction than mild to moderately injured patients.

Theoretically, self-awareness can be conceived as an aspect of executive functioning, because it involves the executive abilities to monitor and evaluate one's own behavior. In a range of studies, strong links were found between ISA and impaired executive function (EF; Bivona et al., 2008; Bogod et al., 2003; Hart et al., 2005), although in a study by Bach and David (2006) this relationship could not be demonstrated. Deficits in EF are associated with damage to prefrontal systems (Fork et al., 2005), which is common after TBI, either because of focal lesions or because of diffuse axonal injury (DAI; Wallesch et al., 2001a, 2001b). Problems with EF have been extensively documented in TBI patients (Bamdad et al., 2003; Bennett et al., 2005), with evidence of more severe problems in those with focal frontal damage (Fontaine et al., 1999; Lehtonen et al., 2005; Spikman et al., 2000). Since the majority of findings point to a strong connection between impaired EF and ISA, and since impaired EF is linked to frontal damage, it is plausible that ISA is also related to the

presence of frontal damage in TBI. However, there is no conclusive evidence to confirm this assumption. Some studies (Prigatano and Altman, 1990; Sherer et al., 2005) demonstrated that ISA was related to injury severity in general, as indicated by the number of brain lesions, but not to the presence of frontal lesions in particular. On the other hand, Murrey and associates (2005) found that TBI patients with focal frontal lobe damage had a worse score on a self-awareness measure than patients without such damage. To date, there are no studies in TBI patients in which ISA was connected to frontal damage, as well as impaired EF.

The present study was conducted to investigate whether TBI patients with frontal lesions and EF deficits are less accurate in judging their own functioning than patients without frontal lesions. We compared TBI patients with and without focal frontal lesions visible on neuroimaging on an scientifically valid test of EF, as well on different outcome measures. In addition to assessment of outcome with standard measures, the patients were asked to explicitly rate their extent of recovery as a percentage of their previous level of functioning. This was conceived as a direct indication of self-evaluation, and therefore as a measure of self-awareness.

Methods

Subjects

The patient group was a part of a TBI group that was described in a previous paper (Spikman et al., 2000). Inclusion criteria for this study were: age at trauma between 15 and 60 years, no history of previous neurological or psychiatric disturbance, and at least primary school education level. Minimum duration of PTA was 1 day and maximum duration was 60 days (indicating moderately severe to very severe injury according to Russell's classification, 1971).

Fifty one patients participated in this study. The mean time since injury for this group at follow-up was 40.6 months (SD = 12; range 25–66 months). Mean PTA duration was 9.7 days (SD = 10.7 days; range 1–51 days). The mean age at the time of injury was 29.3 years (SD = 12.3 years; range 15–59 years), and at follow-up was 32.2 years (SD = 12.0 years; range 18–61 years). Educational and professional level at the time of injury were both rated on a 7-point scale; the highest of both scores was taken as an indication of the highest achieved level of functioning (LOF; see also Spikman, 1996). The mean score was 5.0 (SD = 1; range 3–7). Males accounted for 61% of the group. The patient group was divided into two subgroups based on the absence or presence of focal frontal pathology on neuroimaging in the first 6 months post-injury. MRI scanning was the primary diagnostic tool, but when no MRI was available, CT results were used (15 patients). The scans were rated by an experienced neuroradiologist. The frontal group consisted of 22 patients, and the non-frontal group of 29 patients.

The control group consisted of 45 healthy subjects (Spikman et al., 2000) with a mean age at follow-up testing of 31 years (SD = 12.5; range 17–64 years), and a mean LOF of 5.1 (SD = 1; range 3–7). Statistical testing revealed no differences with the patient group, indicating that the two groups were well matched.

Procedure

All patients in the study underwent several neuropsychological and neurological assessments in the first year post-

injury. At 1 year post-injury, the neurologist determined an outcome score with the GOS-E and the DOS. In the follow-up study, which took place at 2–5 years post-injury, a new test for executive functioning was administered. Also, assessment of vocational status, number of complaints, and the patient's own rating of recovery was done.

Test measure

Executive Route-finding Task (Boyd and Sautter, 1993; 2–5 years post-injury). This executive task is extensively described in Spikman and colleagues (2000). In that study it appeared to be sensitive to the effects of TBI and of focal frontal lesions. It is a real-life planning and problem-solving indoor task, in which the subject has to find the best route to a specific destination. Patient performance was judged on three scales, namely "adequacy of information seeking," "error detection," and "error correction." The observers were blinded to whether the patient had frontal lesions or not. A standardized sum score of these scales forms the variable "Route."

Outcome measures

GOS-E (1 year post-injury). The Glasgow Outcome Scale-Extended (Jennett et al., 1981) consists of eight categories (the original GOS codes are added between parentheses). The scores are: 1 = death (1), 2 = vegetative state (2), 3 = severe disability, completely dependent on others (3), 4 = severe disability, for some activities dependent on others (3), 5 = moderate disability, work at a lower level of performance (4), 6 = moderate disability, return to previous work with some adjustments (4), 7 = good recovery with minor physical or mental deficits (5), 8 = good recovery (5). This variable was called "GOS-E."

DOS (1 year post-injury). The Differential Outcome Scale (DOS; Van der Naalt et al., 1999b) consists of four domains: neurophysical, cognitive, personality/behavior, and social. The scores range from 4 (persistent vegetative state) to 20 (complete or good recovery in each domain). Outcome was determined with the DOS at 1 year post-injury by an experienced neurologist who had not seen any of the patients before. This variable was called "DOS."

RTW (2–5 years post-injury). Return to work was rated on a 6-point scale, which was a modification of the 5-point scale of van Zomeren and van den Burg (1985). The categories were as follows: (0) former work or study resumed without any changes; (1) former work resumed without any objective changes, but requiring more mental exertion; (2) former work resumed but with lower demands, for example part-time, at a lower rate, or with more structure; (3) former work not resumed: working at a lower level; (4) working in a socially sheltered environment; and (5) not working. This variable was called "RTW." By taking scores 0–2 as well as 3–5 together, the variable was dichotomized in order to distinguish between "former work resumed" and "former work not resumed." This variable was called "WORK."

POR (2–5 years post-injury). For subjective percentage of recovery, each patient was asked to express the extent to which they had recovered to their pre-trauma level as a per-

centage, with the pre-trauma level set at 100%. This variable was called "PoR."

SIP (Jacobs, 1993; 2–5 years post-injury). For the Dutch version of the Sickness Impact Profile, only those categories of the SIP assessing psychosocial functioning were administered. These were the following: Home Management, Mobility, Work, Recreation and Pastime activities, Emotional Behavior, Alertness/Intellectual Behavior, and Social Interaction. A weighted sum score based on these scales was calculated according to Jacobs (1993), and formed the variable "SIP." A low score indicates few complaints.

Statistical analysis

All analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 16.0 (SPSS, 2007). Differences between the groups were tested with *t*-tests in cases of variables of interval or ratio level. In cases for which Levene's test for Equality of Variances was significant, the corrected *t*-value was taken. Univariate covariance analyses were applied in cases for which there were covariates to be controlled for. Furthermore, nonparametric tests (Mann-Whitney *U* test) were applied in cases of ordinal variables, and a chi-square test in cases for which the variable was dichotomous. To detect whether the variables were statistically dependent, nonparametric Spearman correlation coefficients were calculated.

Results

Severity of injury

Table 1 shows the results of injury-related variables as well as the demographic data of the frontal and the non-frontal groups. Of the injury-related variables, the significantly lower GCS scores, as well as the significantly longer PTA durations, show that the frontal group was more severely injured than the non-frontal group. Although the frontal group was somewhat older on average with a slightly higher educational level, the differences between the two groups did not reach statistical significance, nor was there a difference with respect to time since injury at follow-up.

TABLE 1. *t*-TESTS ON DIFFERENCES BETWEEN MEANS OF NON-FRONTAL AND FRONTAL TRAUMATIC BRAIN INJURY PATIENTS ON INJURY-RELATED AND DEMOGRAPHIC VARIABLES

<i>Injury-related and demographic data</i>	<i>Non-frontal M (SD)</i>	<i>Frontal M (SD)</i>	<i>t</i>	<i>p Value</i>
GCS	11.7 (2.5)	9.6 (2.9)	2.7	0.010
PTA	6.3 (8.1)	14.0 (12.2)	-2.6	0.010
TSI	40.4 (12.0)	40.9 (12.7)	-0.49	n.s.
Age	27.5 (10.6)	30.7 (13.8)	-0.95	n.s.
LOF	4.8 (.88)	5.1 (1.12)	-1.1	n.s.

GCS, Glasgow Coma Scale score; PTA, post-traumatic amnesia duration in days; TSI, time since injury in months at follow-up; Age, age at time of injury; LOF, level of functioning, the highest of educational or vocational functioning on a 7-point scale; SD, standard deviation.

TABLE 2. DIFFERENCES BETWEEN THE NON-FRONTAL AND FRONTAL GROUP ON THE OUTCOME INDICATIONS

Outcome measures	Non-frontal n = 29 M (SD)	Frontal n = 22 M (SD)	t	p Value
GOS-E	7.1 (.8)	7.0 (1.1)	.3	n.s.
DOS	18.7 (1.3)	18.5 (1.8)	.3	n.s.
PoR	84.5 (17.3)	92.8 (10.8)	-2.1	.040
SIP	112.8 (130.3)	52.7 (71.7)	2.1	.041
			χ^2	
WORK	86%	68%	2.4	n.s.

t-Tests on differences between the means of the frontal and non-frontal group on the outcome indications.

GOS-E, Glasgow Outcome Scale-Extended; DOS, Differential Outcome Scale; PoR, percentage of recovery score; SIP, Dutch version of the Sickness Impact Profile.

Also shown are the percentages of former work resumed (WORK), as well as a chi-square test of the differences between the frontal and non-frontal groups.

Test of executive functioning (Route)

The difference on the test of EF (Route) between the frontal and non-frontal group was analyzed. Because in a previous study (Spikman et al., 1999), age and LOF appeared to be significant covariates in a range of test measures, a univariate covariance analysis was performed to control for their possible influence. The analysis revealed that both covariates had no significant influence on the Route score, and that the difference between the mean score of the frontal group (mean 5.4, SD=1.9) and of the non-frontal group (mean 6.9, SD=1.8) was significant ($F=7.8$; $df=1,50$; $p=0.007$). In addition, the frontal and non-frontal groups were separately compared to the healthy control group (mean 7.3, SD=1.8). *t*-Tests revealed no significant difference between the healthy controls and the non-frontal group ($t=1.1$, $p=0.26$), whereas the difference between the controls and the frontal group appeared to be highly significant ($t=4.1$, $p=0.000$).

Outcome scores

Table 2 shows the results of both groups on several indications of outcome. As expected, no significant differences were found with respect to the DOS and the GOS-E; mean ratings of patient functioning were similar for the frontal and non-frontal patients. Although the percentage of non-frontal patients having resumed their former work was higher than that of the frontal group, the difference was not significant.

However, the SIP and PoR scores were significantly different in the frontal group, with a significantly lower score on the SIP, indicating a lower number of complaints, and a significantly higher score on the PoR, indicating that they judged their recovery percentage significantly higher than the non-frontal group.

Return to work

Table 3 shows the percentages of patients in each category for RTW for both TBI groups separately. Statistical testing revealed no differences between the frontal and non-frontal group ($Z=-0.65$, $p=0.51$).

Correlation of outcome scores and injury severity

In Table 4, two-tailed Spearman correlations between PTA, Route, and the outcome measures are presented for the non-frontal and frontal groups. In both groups, the correlations between the GOS-E and the DOS were high and significant. However, there were also some striking differences between the groups. In the non-frontal group, PTA duration was significantly related to the DOS and GOS-E, as well as to the SIP score, whereas in the frontal group there were no significant correlations at all of PTA with the other variables. Furthermore, in the non-frontal group the DOS and GOS-E scores were significantly related to RTW. In both groups the DOS and GOS-E scores were related to the PoR score, but to a higher extent in the frontal group. In both groups, the PoR score was significantly related to the SIP score. The PoR score in the non-frontal group was significantly related to RTW, with a high correlation of .83, in contrast to the frontal group. In the frontal group, the DOS and GOS-E scores were also significantly related to the SIP score, but not in the non-frontal group. Strikingly, the Route score, an assessment of EF in a daily life situation, was not significantly related to any of the outcome scores in any of the groups.

Discussion

In this study TBI patients with and without focal frontal lesions visible on neuroimaging were compared to find indications of impaired self-awareness (ISA) in the frontal group. The present study provides, albeit indirectly, evidence for ISA in patients with focal frontal damage and impaired EF.

The first goal of our study was to identify whether differences between the frontal and non-frontal TBI groups regarding injury severity were responsible for the determined outcome. Comparison of indications of injury severity re-

TABLE 3. SCORES OF THE NON-FRONTAL AND FRONTAL GROUPS ON RETURN TO WORK

	Nonfrontal n = 29 M (SD)	Frontal n = 22 M (SD)
Return to work		
0 = former work resumed, no changes	16 (55.2%)	11 (50%)
1 = former work resumed, more mental exertion	4 (13.8%)	3 (13.6%)
2 = former work resumed, lower demands	5 (17.2 %)	1 (4.5%)
3 = former work not resumed, lower level	1 (3.4%)	4 (18.2%)
4 = socially-sheltered work	1 (3.4%)	0
5 = not working	2 (6.9%)	3 (13.6%)

TABLE 4. RELATIONSHIP BETWEEN INJURY SEVERITY, EXECUTIVE FUNCTIONING, AND OUTCOME MEASURES FOR THE NON-FRONTAL (NF) AND FRONTAL (F) GROUPS

	PTA		Route		DOS		GOS-E		RTW		PoR	
	NF	F	NF	F	NF	F	NF	F	NF	F	NF	F
Route	-.15	-.21										
DOS	-.38*	-.08	.15	-.02								
GOS-E	-.46*	-.15	.14	.08	.87*	.94**						
RTW	-.10	.07	-.07	-.07	-.42*	-.09	-.40*	-.19				
PoR	.03	-.12	-.06	.09	.60**	.79**	.55**	.82**	-.83**	-.31		
SIP	-.39*	.11	-.05	.13	-.32	-.52*	-.15	-.59**	.74**	.53*	-.67**	-.80**

* $p < 0.05$; ** $p < 0.01$.

Spearman correlations (two-tailed) between PTA, route, and outcome measures (DOS, GOS-E, RTW, PoR, and SIP) for the NF and F groups.

GOS-E, Glasgow Outcome Scale-Extended; DOS, Differential Outcome Scale; PoR, percentage of recovery score; SIP, Dutch version of the Sickness Impact Profile; RTW, return to work.

vealed that the frontal group was more severely injured, as indicated by their significantly lower mean GCS scores and significantly longer PTA durations. In previous studies, it was extensively demonstrated that this group of TBI patients performed worse on tests of speed of information processing, attention, and executive functioning than healthy controls at 1 month post-injury (Spikman et al., 1996). Despite some recovery in the first year, they still performed worse on attention tests at 1 year post-injury (Spikman et al., 1999), as well as at follow-up 2–5 years post-injury (Spikman et al., 2000), although the differences between the frontal-injured and non-frontal-injured patients on these attention tests were not analyzed here. In the latter study it was also demonstrated that the TBI patients had impaired EF at the chronic stage, as they performed worse than healthy controls on an ecologically valid EF measure, the Route score. It was also found that within the TBI group, the frontal subgroup performed worse on this score than the non-frontal subgroup. In the present study subsequent analyses were performed on this measure. First, the possible influence of age and educational or professional level was controlled for in a covariance analysis. It is known that age affects EF negatively (Salthouse and Siedlecki, 2007; Silver et al., 2009), but also that EF is related to indications of intellectual functioning (Wood and Liossi, 2006). However, the covariance analysis showed that the Route score was not influenced by age or LOF. Because the frontal group was more severely injured, injury severity could be another factor affecting test performance, in addition to the presence of frontal lesions. This was not likely the case, since the correlation analyses showed that in both groups PTA duration was not significantly related to the Route score. Hence the main factor causing the difference between the frontal and non-frontal groups on the Route score must be the presence of frontal lesions. This was corroborated by an additional analysis of the original data, in which the Route scores of the non-frontal and frontal groups were separately compared to the original control group. There was only a significant difference between the frontal and control groups, whereas the non-frontal group and the controls performed at the same level. Thus at 2–5 years post-trauma, only the frontal group demonstrated impaired EF. This could partly explain the lack of significant correlations with the outcome measures in the non-frontal group, because they were not impaired at all on the Route score. However, in the frontal group these

correlations were not significant either, despite the frontal patients having impaired EF, which is known to hamper daily life functioning. We have reason to believe that impaired self-awareness is the crucial factor here.

Therefore, the second goal was to investigate whether and how ISA was reflected in the outcome measures. Injury severity is known to influence social reintegration and return to work negatively, and EF deficits in particular are related to worse outcome in daily life situations (Crepeau and Scherzer, 1993; Hanks et al., 1999; Struchen et al., 2008). Consequently, we would expect the frontal group to have lower scores on outcome measures indicating daily life functioning. But when both EF deficits as well as frontal lesions are accompanied by ISA, this might cause the frontal group to overestimate their own functioning, that is, to rate it more positively than is justified by reality. Hence this would lead to higher scores on self-report-based outcome measures. Therefore, in case of ISA, no differences between frontal and non-frontal patients on outcome scales are expected, although the strong indications of less effective daily life functioning of the frontal patients would suggest otherwise. With the application of routinely used outcome measures, indeed no differences were seen between the frontal and non-frontal groups. However, when RTW was dichotomized, the percentage of non-frontal patients having resumed their previous work was higher (86%) than the percentage of frontal patients (68%), although the difference was not statistically significant. Notably, the scores of the frontal group on the PoR score and the SIP differed significantly from those of the non-frontal group, indicating that at 2–5 years post-injury the frontal-injured patients judged themselves as being better recovered than the non-frontal-injured patients. They also had significantly fewer complaints with respect to their daily life functioning. It is not likely that the frontal group was actually functioning at a higher level in daily life activities than the non-frontal group. Because of the discrepancy between their positive self-ratings on the SIP and PoR on the one hand, and their greater injury severity and worse EF on the other hand, we interpret these findings as an indication of impaired self-awareness in the frontal group. This conclusion is corroborated by the correlations of the PoR score with a more objective measure of outcome, namely RTW. In the non-frontal group, the correlation between PoR and RTW was quite high and significant, indicating that patient judgment of their functioning

corresponded to a more objective criterion. In the frontal group, the correlation was very low. Apparently, a patient's impression of their own recovery status is not related to their actual working status.

The question arises whether the results are influenced by the fact that both RTW as well as the DOS and GOS-E are also partly self-report based. Because they are also rated by an external observer, they are not entirely objective, although they are to a greater extent than the SIP and the PoR. With regard to both the DOS and the GOS-E, the rater forms a personal impression of patient functioning based on a neurological examination, but the rater will also be dependent on the patient's own report. In both groups, the correlations between DOS and GOS-E were high, indicating that both scales to a great extent covered similar aspects of outcome. Evidence that the patient's opinion of their recovery status influences DOS and GOS-E scores is provided by the correlation of these outcome measures with the more subjective measures SIP and PoR, which are administered at follow-up, and not with the more objective RTW score, in the frontal group. In contrast, in the non-frontal group the correlations of DOS and GOS-E with RTW and the PoR score were both significant. The PoR score was also significantly correlated with RTW, which was not the case in the frontal group. Apparently, in the frontal group, the fact of having few complaints and being satisfied with one's own recovery status is closely connected to high DOS and GOS-E scores. However, not having complaints and judging oneself to be fully recovered is a characteristic of ISA. The fact that the DOS and GOS-E scores correlated more strongly with these subjective measures, than to a more objective measure such as RTW, indicates that patients with frontal lesions had unrealistically high positive self-reports. The fact that the RTW, DOS, and GOS-E were significantly correlated in the non-frontal group only, indicates that work status carries more weight in the DOS and GOS-E scores of these patients than in those of the frontal group. However, RTW, a seemingly more objective measure, is also self-report based and allows subjective interpretation of some of its categories. For example, for patients who could not return to their previous job and had to work at a lower level or in a socially-sheltered situation, it will be quite obvious to them that there has been a change. However, for patients that have returned full-time to their previous jobs, this may be less clear. For example, such a patient may indicate on the RTW scale a score of 0 (former work resumed without changes), whereas the employer would indicate that the patient works at a lower level and requires help with some tasks, and thus a more appropriate rating would be a score of 2 (former work resumed but with lower demands). The fact that this may be the case is suggested by the results shown in Table 3, where there is only one frontal patient with a score of 2, as opposed to five non-frontal patients. Thus, it is quite conceivable that patients with ISA are unable to see that they actually require help and more structure at their job, and thus function on a lower level, while they themselves feel that they have fully returned to their previous working level.

It has to be acknowledged that there are limitations to the proposed distinction between frontal and non-frontal patients. As was stated above, this distinction was based on whether focal frontal pathology due to contusions or hemorrhages was visible on the available neuroimaging studies. For the majority of the patients this was an MRI scan. However, at

the time these studies were done, no FLAIR or T2-weighted imaging sequences were yet available, and they might have revealed microscopic non-hemorrhagic lesions. Thus not all focal frontal damage may have been detected. Even more so, for some patients MRI data were not available, so CT data were used. As CT imaging has a lower sensitivity for detecting hemorrhagic and non-hemorrhagic lesions compared to MRI, there is an additional chance that a small proportion of the non-frontal group may have been classified incorrectly, because their focal frontal injuries were too small to be detected. Furthermore, in addition to focal contusions, frontal lobe systems can also be affected by DAI. Studies have demonstrated that it is likely that DAI is present in nearly all moderately to severely injured TBI patients, and is used along with GCS scores to determine injury severity (Levine et al., 2008, Meythaler et al., 2001, Wallesch et al., 2001a). However, Meythaler and colleagues (2001) emphasized that DAI is not as diffuse as the term suggests, because it is more often found in deeper, subcortical brain regions. This explains its significant relationship with indicators of loss of consciousness, which is considered a phenomenon that more accurately reflects the amount of mid-brain and brainstem injury than cortical injury. Still, DAI may affect the frontal network, resulting in problems with EF. This was demonstrated by Fork and associates (2005) and Wallesch and colleagues (2001a). Furthermore, it could be questioned whether small hemorrhagic and non-hemorrhagic lesions contribute significantly to outcome, as a correlation has been found between the volume of lesions and outcomes in earlier studies (Levin et al., 1992; Pierallini et al., 2000), and even up to 25% of patients with MRI lesions show good recovery (Mitchener et al., 1997, Van der Naalt et al., 1999a).

Thus it is likely that both groups had additional frontal damage due to DAI, but it is also true that this was more marked in the frontal group, because of their significantly lower GCS scores. Also, we cannot exclude that in some patients in the non-frontal group, small amounts of focal frontal damage may have been present. This means that the distinction between the frontal and non-frontal groups should not be considered absolutely dichotomous, and that it does not distinguish between a complete lack or not of frontal damage. It should be considered a distinction reflecting clinical practice, to distinguish between patients with clear, marked frontal damage, as opposed to patients with only minor frontal damage.

In conclusion, this is the first study in which evidence was presented of impaired self-awareness in TBI patients with focal frontal lesions and impaired executive function. There are strong indications that impaired self-awareness caused the frontal patients to provide an unrealistically positive report of their own functioning, which can affect the reliability of even seemingly objective outcome measures. In the non-frontal group, there was no compelling reason to doubt that the DOS, GOS-E, and RTW were valuable indicators of outcome, despite our lack of rating data from significant others that might have corroborated this. However, in patients with frontal lesions, scores on these measures should be interpreted with caution, as they may not accurately reflect the patient's actual situation. Not acknowledging an unfavorable situation may result in insufficient care, which might ultimately lead to a worse outcome status. Therefore, other sources of information about the patient's functioning are needed. When

using self-report-based measures in patients with frontal damage, it is sensible to complement patient judgment with the judgment of one or more significant others (e.g., family members, health professionals, and employers). Together, these data may provide a more realistic view of how the patient actually functions in daily life, especially at work.

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