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Functional outcome 10 years after traumatic brain injury: Its relationship with demographic, injury severity, and cognitive and emotional status

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Abstract

Previous investigations of long-term outcome following traumatic brain injury (TBI) have yielded mixed results regarding the predictive power of injury severity and demographic factors. Furthermore, there has been limited investigation of the association between long-term outcome and current cognitive functioning and psychiatric state. The aim of this study was to investigate the association of injury severity, demographic factors, and concurrent cognitive and psychiatric functioning with functional outcome 10 years following mild to severe TBI. Outcome was rated using the Extended Glasgow Outcome Scale (GOSE) for 60 participants, who also completed neuropsychological measures of attention, speed of processing, memory and executive function and the Hospital Anxiety and Depression Scale (HADS). Outcome on the GOSE ranged from upper good recovery (32%) to lower severe disability (2%). Participants showing poorer outcome on the GOSE had significantly longer posttraumatic amnesia duration; less education; performed more poorly on cognitive measures of information processing speed, attention, memory, and executive function; and showed higher levels of anxiety on the HADS.
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Keywords: Closed head injuries, Assessment, Patient outcomes, Glasgow Outcome Scale

INTRODUCTION

Traumatic brain injury (TBI) may cause significant impairment of cognitive, behavioral, and emotional functioning. As it occurs predominantly in young people, these changes can have a profound impact on capacity for independent living, relationships, leisure activities, study, and employment (Olver et al., 1996). The ability to perform these activities may be termed "functional outcome." However, outcome following TBI in these domains has been found to be highly variable (Dikmen et al., 1995a; Ponsford et al., 1995). This variability has led to a focus on identifying factors predicting or indicating functional outcome. Studies conducted up to 3 years after injury have found that outcome may be influenced by injury severity, as measured by Glasgow Coma Scale (GCS) scores or duration of posttraumatic amnesia (PTA), demographic factors, including age, gender, and preinjury education and employment, as well as postinjury cognitive and social factors (Brown et al., 2005; Cattelani et al., 2002; Dikmen et al., 1995b; Fleming et al., 1999; Godfrey et al., 1993; Gollaher et al., 1998; Ip et al., 1995; Levin et al., 1990; Pastorek et al., 2004; Ponsford et al., 1995; Rothweiler et al., 1998; Van der Naalt et al., 1999; Van Zomeren & Van den Burg, 1985).

The nature and prediction of functional outcome over 10 years or more after injury remains far less clear. Given the youth of those injured, developing an understanding of factors predicting longer-term outcomes is important as a basis for planning for their future needs. Only a few studies have investigated factors predicting outcome more than 10 years after injury (Dawson & Chipman, 1995; Himanen et al., 2006; Hoofien et al., 2002; Johnson, 1998; Tate et al., 2005;

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Wood & Rutterford, 2006a). Findings from these long-term studies have been mixed, partly due to use of variable outcome measures. In a study of a very severely injured patient group, Tate et al. (2005) found that PTA duration accounted for a significant proportion of variance in psychosocial outcome. On the other hand, Hoofien et al. (2002) reported that injury severity, as measured by length of coma, was only predictive of psychiatric symptoms, accounting for 16% of the variance in this area. Wood and Rutterford (2006a) found that PTA duration was not significantly associated with most outcome measures, except for satisfaction with life, accounting for just 7.8% of variance. They suggested that the predictive power of injury severity may decline over time.

Regarding the influence of demographic variables, studies by Dawson and Chipman (1995), Hoofien et al. (2002), Johnson (1998), Tate et al. (2005), and Wood and Rutterford (2006a) have found no significant association between either age or gender and outcome. However, higher preinjury education has been associated with better long-term outcome in employment, social functioning, and community integration, both alone and in combination with injury severity, age, gender, and/or relationship status (Dawson & Chipman, 1995; Hoofien et al., 2002; Wood & Rutterford, 2006a). Tate et al. (2005) found that more skilled preinjury employment was associated with better outcome in living skills, relationships, and employment.

Few studies have investigated cognitive functioning and psychiatric state 10 years or more after injury or their influence on functional outcome. Whereas Tate et al. (2005) demonstrated a relationship between early cognitive impairment, assessed at rehabilitation discharge and long-term psychosocial outcome, they did not assess cognitive or psychiatric functioning at follow-up. Hoofien et al. (2002) did assess long-term cognitive functioning, in terms of IQ, and psychiatric state, but did not examine their association with functional outcome measures. Wood and Rutterford (2006a) found in their mild–moderately injured TBI group that working memory was the only concurrently measured cognitive function associated with outcome, measured by self-reported community integration, life satisfaction, and depression. They did not investigate the relationship between psychiatric state and functional outcome measures. Given the high incidence of cognitive and emotional problems following TBI, it would be useful to understand their relationship with functional outcome.

The aims of the present study were as follows: (1) To document the functional outcome of TBI survivors 10 years after injury. Hypothesis 1: TBI participants will show functional limitations 10 years after injury. (2) To examine the association between TBI survivors' preinjury sociodemographic status and injury severity and their functional outcome 10 years later. Hypothesis 2: That education and PTA duration would be significantly related to functional outcome 10 years later. (3) To describe the relationship between concurrent cognitive and emotional status and functional outcome 10 years after injury. Hypothesis 3: Poorer functional outcome will be associated with poorer cognitive performances on tests of speed of information processing, attention, memory, and executive function and higher levels of emotional distress, which will also be evident relative to matched healthy controls. (4) To examine, using multivariate analyses, which variables, in combination, are predictive of functional outcome. Hypothesis 4: With regard to sociodemographic and injury variables, we expected both education and PTA to be related to outcome. With regard to cognitive functions, we expected impairments of information processing speed, attention, memory, and executive function to be related to functional outcome. With regard to emotional status, we expected both anxiety and depression to be related to outcome. Finally, we expected both emotional and cognitive variables to be related to outcome when comparing them in one analysis.

METHOD

Participants

Participants were patients with TBI recruited through Epworth Hospital, where they had received rehabilitation following their injury between 1992 and 1995. TBI participants were excluded from the study if they were under 16 years of age at the time of injury ($n = 5$); had sustained a subsequent head injury ($n = 2$); been diagnosed with a neurological illness; been hospitalized for psychiatric illness ($n = 2$); had hearing, vision, cognitive, or physical impairments that prevented them from participating in neuropsychological testing ($n = 24$); or could not speak or read sufficient English ($n = 10$).

Of the 302 patients admitted to the program between 1992 and 1995, 219 were either unable to be contacted ($n = 132$), living interstate or overseas ($n = 44$), or did not meet inclusion criteria ($n = 43$, see above). Of the 83 eligible and contactable participants, 23 declined to participate, leaving 60 TBI participants. Independent samples t tests and χ^2 analyses revealed no significant differences in age, gender, or injury severity in terms of either PTA duration or lowest GCS between the study sample and the patients who were not contactable, living overseas or interstate, or who refused to participate.

TBI participants were seen at an average of 10.58 years after injury ($SD = 0.72$; range = 10–12 years). There were 33 (55%) male TBI participants, and the majority (95%) had been involved in motor vehicle accidents. At the time of injury, the group had a mean age of 31.37 years ($SD = 13.17$; range = 16–64) and 83% were employed (full- or part-time) or engaged in full-time study. There was a wide range of injury severity within the TBI group. GCS was only available for 45 of the TBI participants; the mean GCS was 7.38 ($SD = 4.29$; range = 3–15), with 20% scoring 13–15, 13% scoring 9–12, and 67% scoring 3–8. PTA duration, determined prospectively using the Westmead PTA Scale, was available for all TBI participants; the mean PTA duration was 26.25 days ($SD = 24.73$; range = 0.1–99).

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To examine whether the cognitive abilities and emotional status of patients with different functional outcomes were related to their brain injury, a group of healthy control participants was included in the study (n = 43, 56% men, mean age = 42.30 years, SD = 12.54, mean length of education at time of study = 11.47 years, SD = 1.80). Subgroups of the control participants were matched to each functional outcome group (see Table 2) on age, gender, and education at follow-up. Control participants, who were recruited from acquaintances of the injured participants or the general community, had no history of head injury, other neurological disturbance, or psychiatric illness.

Measures

The Extended Glasgow Outcome Scale (GOSE; Wilson et al., 2000) was used to assess outcome at 10 years after injury. It provides a global rating of functioning and disability in a range of domains following TBI. Information about consciousness, independence in the home and community, employment, social and leisure activities, family and friendships, and return to normal life was obtained by means of structured interview and used to rate outcome into one of the following categories: upper good recovery, lower good recovery, upper moderate disability, lower moderate disability, upper severe disability, lower severe disability, vegetative state, or dead. The GOSE has shown high inter-rater reliability, with a kappa value of 0.92 and moderate-to-strong correlations with PTA duration (−0.52) and other disability scales, such as the Disability Rating Scale (−0.89; Pettigrew et al., 2003; Wilson et al., 2000).

Demographic variables investigated were age at time of injury, gender, education, preinjury employment status, and preinjury relationship status. Education was defined as number of years spent in formal education and was recorded separately at the time of injury and at follow-up, the latter including educational achievements after injury. Participants were classified as employed if they were working (full- or part-time) or studying (full-time) at the time of injury. Preinjury relationship status was defined as either married or defacto, if the participant was married or living in a marriage-like relationship at the time of the injury, or single if not. The injury severity variables investigated were coma depth as indicated by lowest preintubation GCS score recorded in the first 24 hr, obtained from the medical file, and duration of PTA in days, as determined prospectively using the Westmead PTA Scale (Shores et al., 1986).

Current cognitive abilities were assessed with a range of neuropsychological measures. Measures of attention and information processing speed used were raw scores for Digit Span Forwards and Backwards subtests from the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III; Wechsler, 1997), completion time on the Trail Making Test Part A (TMT; Reitan & Wolfson, 1988), mean reaction time on the Sustained Attention to Response Task (SART; Robertson et al., 1997), and total items correct on the Symbol Digit Modalities Test oral version (SDMT; Smith, 1973) and Digit Symbol Coding (DSC) subtest from the WAIS-III. Measures of memory were total words recalled on the five trials of the Rey Auditory Verbal Learning Test (RAVLT; Lezak, 1976; Rey, 1958) and total recall scores on the Doors, People, Names, and Shapes subtests from the Doors and People Test (Baddeley et al., 1994). Measures of executive function were total error scores from the TMT Part B, SART, Hayling and Brixton Tests (Burgess & Shallice, 1997), Porteus Maze Test–Vineland Revision (Porteus, 1965), and Controlled Oral Word Association Tests (COWAT; Benton et al., 1994), as well as total score on the COWAT.

Emotional state was assessed with the Hospital Anxiety and Depression Scale (HADS; Snaith & Zigmond, 1994). The HADS comprises two separate scales for anxiety and depression. Scores range from 0 to 21, with scores from 0 to 7 representing a "normal," 8–10 a "mild," 11–14 a "moderate," and 15–21 a "severe" level of anxiety or depression. The HADS has been widely used to assess anxiety and depression following TBI (Medd & Tate, 2000; Powell et al., 2002; Wood & Rutterford, 2006a,b).

Procedure

Ethics approval was obtained from Epworth Hospital and Monash University ethics committees, and all participants provided informed consent before participating in the study. TBI participants were interviewed and assessed either at home or at Epworth Hospital. A semistructured interview was conducted to obtain pre- and postinjury demographic, employment, and medical information and responses to questions for determination of GOSE scores. The questionnaires previously posted to the TBI participant and a nominated relative were checked for completeness. Participants then completed the cognitive assessment, with the order of test randomly selected from five predetermined orders. Injury information, including date of injury, education at time of injury, GCS score, and PTA duration, were obtained from hospital records.

Data Analysis

Descriptive statistics were used to analyze the sample characteristics. Because of the skewed distribution of TBI participants' GOSE scores, the GOSE scale was recoded into two categories for use in bi- and multivariate analyses (Table 1): The outcomes upper and lower good recovery were merged to create the first category, denoted "Good outcome" and the outcomes upper moderate disability–vegetative state formed the second category, denoted "Poor outcome." The bivariate split used on the GOSE has been used in other studies (e.g., Levin et al., 2001; Rapoport et al., 2003), separating those independent and capable of employment and other aspects of their previous lifestyle from those who are not. Pearson χ^2 analysis was used to analyze the relationships between Good/Poor outcome and gender, preinjury employment status, and preinjury rela-

Table 1. Number of TBI participants in each GOSE category

GOSE category	*N*	%
Upper good recovery	19	32
Lower good recovery	12	20
Upper moderate disability	19	32
Lower moderate disability	7	12
Upper severe disability	2	3
Lower severe disability	1	2

Note. GOSE = Extended Glasgow Outcome Scale.

tionship status. Because of the limited sample size and the skewed distribution of many predictor variables, Mann–Whitney *U*-tests were used to compare performances of those in the Good *versus* Poor GOSE outcome categories according to age, years of education, PTA, GCS the cognitive tests, and HADS. Logistic regressions were then conducted to establish (1) which preinjury demographic and injury-related variables, (2) which measures from each cognitive domain, (3) which measures of emotion, and (4) which of the strongest predictors of outcome from each cognitive and the emotional domain, best differentiated the Good *versus* Poor outcome groups on the GOSE. Only measures that were significantly related to GOSE in the bivariate analyses were entered into these regressions (with regard to education, education at time of injury was chosen). Individuals with Cook's distance values larger than 1 were treated as outliers in the regression analyses by comparing regression results with and without the inclusion of outliers. A significance level of .05 (two-tailed) was chosen. Bonferroni corrections for multiple comparisons were then applied separately for each set of statistical tests. This strategy resulted in significance levels of $p = .007$ for the bivariate comparisons of demographic and injury variables with outcome; $p = .008$, .008, and .007 for the comparison of attentional, memory, and executive tests, respectively, with outcome; and .008 for the logistic regressions predicting outcome.

RESULTS

Functional Outcome According to the GOSE

As can be seen in Table 1, half of the TBI participants were rated as having an upper or lower good outcome on the GOSE. A third of participants fell in the upper moderate disability category, and only a small number fell into the poorer outcome categories on the GOSE. At the time of assessment, 62% of TBI participants were engaged in full-time or part-time employment or full-time study ($n = 2$), 35% were unemployed or retired, and the remaining 3% were engaged in casual employment. Sixty-four percent were living with a spouse/partner or child, 28% were living alone or with flatmates, and 8% were living with their parent/s. Sixty-two percent were married or in a defacto relationship, 30% were single, and 8% were separated or divorced.

Association Between Sociodemographic Status, Injury Severity, and Functional Outcome

Pearson χ^2 analysis indicated no significant relationship between GOSE outcome category and gender, preinjury employment, or preinjury relationship status. Mann–Whitney *U*-tests revealed no statistically significant difference in GOSE outcome category according to age. They did, however, reveal a significant relationship between GOSE outcome and education, that is, those with less education were more likely to have Poor outcomes. Education at follow-up tended to be more closely related to GOSE than education at time of injury. Furthermore, those with good GOSE outcome had significantly shorter PTA duration (Table 2). There was no significant difference in outcome according to GCS scores.

Association Between TBI Participants' Functional Outcome and Their Cognitive and Emotional Status

Mann–Whitney *U*-tests revealed significant differences in performances on several cognitive measures according to GOSE outcome category (Table 2). In the domain of information processing speed and attention, Poor outcomes were associated with significantly longer completion taken on the TMT Part A, fewer items completed on the SDMT and DSC subtest, and fewer trials correct for Digit Span Backwards. In the domain of memory, Poor outcomes were associated with fewer items learnt on the RAVLT and People, Names and Shapes tasks. In the domain of executive function, the difference was evident on the Porteus Maze Test, those with Poor outcomes making more errors, and on the COWAT, those with Poor outcome producing fewer words.

With regard to the relationship between functional outcome and emotional status, there was a highly significant difference between those with Good *versus* Poor outcomes according to HADS anxiety scores, those with Poor outcome showing significantly higher levels of anxiety (Mann–Whitney *U*-tests; Table 2). The difference for depression was not statistically significant but approached significance, with $p = .06$ (Mann–Whitney *U*-test, two-tailed) and moderate effect size (Cohen's $d = .5$).

A comparison of the cognitive test results of the Good and Poor outcome patient group with the age, gender, and education-matched healthy control groups (Table 2) shows that each of the patient groups revealed greater cognitive and emotional difficulties than the healthy controls. However, the differences were not always significant and were strongest between the Poor GOSE outcome group and the matched control group.

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Table 2. Relationships of the dichotomized GOSE scale with sociodemographic and injury-related variables, cognitive tests, and emotional state

	Patient GOSE outcome groups								Demographically matched control groups					
	Upper/lower good outcome			Disability/poor outcome					Match to upper/lower good outcome group			Match to disability/poor outcome group		
Demographic/injury/test variable	Mean	Median	*SD*	Mean	Median	*SD*	d[a]	*p*	Mean	Median	*SD*	Mean	Median	*SD*
Education (years) at injury	12.3	12	2.4	10.9	11	1.6	0.7	.04						
Education (years) at follow-up	13.3	12	2.9	10.7	11	1.6	1.1	<.001	12.6	12	1.8	10.5	11	1.2
PTA (days)	17.4	9	16.6	35.8	31	28.5	0.8	.007						
TMT A (seconds)	26.2	25	8.8	40.1	33	18.6	1.0	<.001	25.1	22.5	9.6	28.7	28*	9.4
SDMT (no. correct)	56.5	56	12.0	44.0	44	12.2	1.0	<.001	62.2	63*	8.1	53.8	56**	7.9
DSC (no. correct)	77.6	73	16.9	54.5	56	16.5	1.4	<.001	80.8	79.5	15.1	66.6	63**	11.0
Digit Span Forward	10.8	10	2.6	9.4	9	2.4	0.6	.046	12.2	13	2.7	10.3	11	1.9
Digit Span Backwards	7.8	7	2.8	5.6	5	2.0	0.9	<.001	7.8	8	2.8	6.7	7*	2.0
RAVLT (total)	51.8	50	8.4	42.9	44	11.8	0.8	.002	57.8	57.5**	5.7	50.6	51**	6.6
Doors (total)	18.7	19	3.6	16.2	17	4.0	0.6	.02	20.6	20.5*	2.1	19.0	19*	3.2
People (total)	27.5	28	4.6	20.5	20	7.8	1.1	<.001	29.4	30	4.4	25.7	27*	5.5
Shapes (total)	33.3	34	3.4	26.5	30	8.9	1.0	.001	33.3	36	4.2	29.7	33	8.3
Names (total)	20.4	21	2.6	17.3	18	3.1	1.1	<.001	19.6	19	2.7	19.3	19*	2.1
Porteus Mazes (errors)	2.0	1	2.1	4.8	2	4.7	0.8	.01	1.6	1.5	1.1	2.5	2	2.5
COWAT (total)	42.1	42	12.4	31.6	29	12.3	0.9	<.001	44.4	43.5	9.0	38.7	35*	9.2
HADS Anxiety	3.6	3	2.6	6.5	6	4.4	0.8	.01	2.5	2	1.7	1.9	2***	1.3

Note. Data given reflect only variables whose relationship to the GOSE was significant at the $p = .05$ level (Mann–Whitney U-tests, two-tailed). All predictors except Digit Span Forward and Doors Test are significantly related to GOSE when applying Bonferroni corrections for each family of predictor variables. GOSE = Extended Glasgow Outcome Scale; PTA = Westmead Posttraumatic Amnesia Scale; TMT A = Trail Making Test Part A; SDMT = Symbol Digit Modalities Test oral version; DSC = Digit Symbol Coding; RAVLT = Rey Auditory Verbal Learning Test; COWAT = Controlled Oral Word Association Tests; HADS = Hospital Anxiety and Depression Scale.
[a]Cohen's *d* for the comparison of the GOSE outcome groups.
*Difference between patient and control group is significant (Mann–Whitney U-test; $p < .05$).
**Difference between patient and control group is significant (Mann–Whitney U-test; $p < .01$).
***Difference between patient and control group is significant (Mann–Whitney U-test; $p < .001$).

Examination of Which Variables, in Combination, Are Predictive of Functional Outcome

Education at time of injury and PTA were entered as independent variables in a logistic regression analysis with the dichotomized GOSE scale as the dependent variable. A significant model emerged [$\chi^2(2, N = 59) = 16.5$; $p < .001$, 70% correct classification of good outcome, 69% correct classification of poor outcome, 69.5% overall correct classification; all Cook's distances $<.5$]. Education and PTA were not significantly correlated (Table 3). Both education (B = −.37; SE = .16; Wald = 5.2; $p = .02$) and PTA (B = .04; SE = .02; Wald = 6.9; $p = .009$) were significantly related to GOSE, with PTA tending to be the stronger predictor.

Logistic regression analysis with the tests of attention/processing speed that were significantly related to GOSE in the bivariate analyses (TMT A, SDMT, DSC, and Digit Span Backwards) as independent variables and the dichotomized GOSE scale as the dependent variable was computed. The full model was significant [$\chi^2(4, N = 60) = 26.6$, 83.9% correct classification of good outcome, 79.3% correct classification of poor outcome, 81.7% overall correct classification, $p < .001$; all Cook's distances $< .8$]. Correlations between the independent variables ranged from −.39 between Digit Span Backward and TMT A to .84 between SDMT and DSC. DSC was significantly correlated with GOSE outcome (B = −.08; SE = .04; Wald = 5.2; $p = .02$). A logistic regression analysis with the memory tests that were significantly related to GOSE in the bivariate analyses (RAVLT and People, Shapes, Names) as independent variables and the dichotomized GOSE scale as the dependent variable was computed. The full model was significant [$\chi^2(4, N = 60) = 25.4$, 80.6% correct classification of good outcome, 69% correct classification of poor outcome, 75% overall correct classification, $p < .001$]. None of the tests, individually, had a significant relationship with outcome, the Shapes test having the lowest p value (B = −.12; SE = .07; Wald = 3.1; $p = .08$). After removing one case with a critical Cook's distance of 1.3, the correct classification did not change. However, the p value of the Shapes test dropped to $p = .05$. Logistic regression analysis with the tests of executive function that were significantly related to GOSE in the bivariate analyses (Porteus Maze test, COWAT) showed a significant full model [$\chi^2(2, N = 60) = 14.1$, 74.2% correct classification of good outcome, 65.5% correct classification of poor outcome, 70% overall correct classification, $p < .001$; all Cook's distances $< .5$]. The correlation between the Porteus Maze test and COWAT was −.42. COWAT was a significant predictor of GOSE outcome (B = −.05; SE = −.03; Wald = 4.1; $p = .04$). Because HADS depression was not significantly related to GOSE, a logistic regression comparing HADS anxiety and depression in their relationship to GOSE was not computed.

To establish which cognitive and emotional variables, in combination, were the strongest indicators of outcome on the GOSE, the variables most strongly differentiating patients from within each category of cognitive tests (DSC, Shapes test, COWAT), as well as HADS anxiety, were included in a Logistic regression analysis. A significant model emerged [$\chi^2(4, N = 56) = 38.9$; $p < .001$, 89% correct classification of good outcome, 79% correct classification of poor outcome, 83.9% overall correct classification]. Table 3 shows that the cognitive tests in this analysis were weak-to-moderately correlated with each other, with the HADS anxiety scale and with length of education and PTA. Anxiety as rated on the HADS was only related to shorter education at time of follow-up, but not to PTA. DSC and HADS anxiety were the only significant predictors in this model (Table 4). The removal of one outlier with a Cook's distance of 1.2 from the analysis changed the classification rates slightly (overall classification rate 83.6%), but otherwise did not affect the results of the regression analysis.

DISCUSSION

The first aim of this study was to describe functional outcome 10 years after TBI. The majority of the TBI participants showed a good outcome or only minor disabilities

Table 3. Correlations between predictors of the dichotomized GOSE scale (final regression analysis) and between the predictors and education and PTA

	PTA	DSC	Shapes	COWAT	HADS Anxiety
Education at time of injury (years)	−.11	.52***	.44***	.40**	−.24
Education at follow-up (years)	−.31*	.65***	.46***	.48***	−.32*
PTA (days)		−.38**	−.33**	−.30*	.09
DSC (no correct)			.43**	.52***	−.10
Shapes (total)				.26*	−.25
COWAT (total)					−.05

Note. GOSE = Extended Glasgow Outcome Scale; PTA = Westmead Posttraumatic Amnesia Scale; DSC = Digit Symbol Coding; COWAT = Controlled Oral Word Association Tests; HADS = Hospital Anxiety and Depression Scale
*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).
***Correlation is significant at the 0.001 level (two-tailed).

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Table 4. Summary of logistic regression analysis combining psychiatric and cognitive tests predicting outcome on the dichotomized GOSE scale

Variable	B	*SE*	Wald statistic	*p* value
DSC (no correct)	−.09	.04	7.03	.008
Shapes (total)	−.15	.09	3.08	.08
COWAT	−.04	.03	1.34	.25
HADS Anxiety	.41	.16	6.52	.01
Constant	10.42	3.59	8.45	.004

Note. GOSE = Extended Glasgow Outcome Scale; DSC = Digit Symbol Coding; COWAT = Controlled Oral Word Association Tests; HADS = Hospital Anxiety and Depression Scale.

according to the GOSE. Although no previous studies have used the GOSE to measure outcome at 10 years after injury, the rates of return to work and marital relationships compare favorably with those of other long-term TBI follow-up studies (Franulic et al., 2004; Hoofien et al., 2001; Koskinen, 1998; Tate et al., 2005; Thomsen, 1984, 1992; Wood & Rutterford, 2006b). However, the lack of detail regarding rehabilitation received by these other groups and variability in injury severity across studies precludes direct comparison and comment on impact of rehabilitation on outcome.

The second aim of this study was to investigate the impact of sociodemographic and injury related factors on functional outcome. As expected, those with Poor outcome had significantly longer PTA duration and less education. Studies by Hoofien et al. (2002), Tate et al. (2005), and Wood and Rutterford (2006a) also found these variables to be associated with outcome. GCS, used as the other measure of injury severity, did not significantly differentiate those with good from those with poor outcomes. Previous studies have also reported PTA duration to be a stronger predictor of outcome than GCS (Cattelani et al., 2002; Doig et al., 2001; Fleming et al., 1999; Sherer et al., 2002; Van der Naalt et al., 1999).

The third aim of the present study was to examine the relationship between functional outcome and concurrent cognitive and emotional status. This study was only the second to investigate the relationship between current cognitive functioning and outcome at a period of 10 years or more after injury. As expected, we found that performances on a range of tests of information processing speed, attention, memory, and executive function significantly differentiated those in the Good outcome category from those in the Poor outcome category on the GOSE. Most statistical effect sizes were large, indicating strong relationships between cognitive status and functional outcome. Slow processing speed, as measured on the Digit Symbol Coding subtest, was the cognitive variable most strongly associated with Poor GOSE outcomes. In a separate, controlled study based on the same sample (Draper & Ponsford, manuscript submitted for publication), we demonstrated that impairments in the domains of information processing speed, memory, and executive function were evident on a range of measures 10 years after injury. The findings of the current study indicate that these impairments contribute to ongoing handicap. Wood and Rutterford (2006a) found that working memory was the only cognitive function associated with outcome, measured according to community integration, life satisfaction, and depression. The majority of their sample had mild to moderate injuries and a substantial proportion were accident litigants. The use of different outcome measures in these studies makes it difficult to directly compare the results. However, the results of the present study suggest that, in a sample with a higher proportion of individuals with moderate to severe injury, working memory is only one of a range of cognitive functions that are associated with continuing disability even at periods of 10 years or more after injury.

This study was the first to investigate the relationship between current psychiatric state and functional outcome at 10 years after injury. The hypothesis that psychiatric state would be significantly associated with functional outcome was partially supported by the results, which showed that the presence of anxiety on the HADS was strongly associated with poorer outcomes. The relationship between greater depression and poorer outcome on the GOSE in this study was weaker and only approached significance. The lack of statistical significance could be due to the relatively small sample size, resulting in a post hoc statistical power of only 45% for this comparison (at $\alpha = 5\%$, two-tailed; power-computation with G*POWER; Faul & Erdfelder, 1992). In this sample, whereas anxiety was most evident in those with the more severe injuries, the levels of depression tended to be somewhat higher in those with milder injuries, suggesting the possibility that poor self-awareness in those with severe injuries reduced the likelihood of depression, at least in some cases.

It is arguable that anxiety, and possibly also depression, may be caused by trying to cope with significant cognitive disability, including reduced speed of information processing. Alternatively, anxiety and depression may be a more direct result of the injury and contribute to avoidance of participation in certain activities, thereby reducing functional outcome levels. It should be noted that our research design does not allow us to draw conclusions about causal relationships between cognitive and emotional status on the one hand and functional outcome on the other. It may be that the relationships are reciprocal rather than unidirectional. For example, poorer functional outcome in terms of difficulties with activities of daily living and social integration may lead to social isolation, resulting in emotional distress. A more comprehensive assessment of psychiatric state with a larger sample could provide further insight into the relationship between outcome and anxiety, depression, and other psychiatric states. This insight may provide a basis for the design of intervention programs, which might inoculate against development of future problems in these domains or be made available to those in need following their return to the community. Individuals who experience anxiety may not report or even identify it as a problem. Therefore, those providing longer-term support to individuals with TBI need to be cognizant of the possible presence of anxiety that may exacerbate social integration difficulties.

As expected, TBI participants tended to have lower scores on the cognitive tests and more emotional distress than healthy controls. Those with poor functional outcome showed significantly greater cognitive difficulties and emotional distress than their healthy controls, again indicating the significance of cognitive and emotional status for long-term functional outcome. Because the controls were matched on education, the findings also indicate that TBI participants' cognitive and emotional difficulties, as well as their relationship with functional outcome were not solely caused by length of education.

The final aim of the present study was to determine how the variables studied, in combination, could predict functional outcome. Both lower preinjury education and longer PTA were associated with poorer functional outcome. The regressions also showed that concurrent speed of information processing (DSC) and anxiety, together, showed the strongest relationship with functional outcome. Given the limited statistical power and the correlations between the cognitive tests, the logistic regressions should, however, be interpreted with caution. The strength of the bivariate relationships we found between cognitive tests and functional outcome (Table 2) suggest that performances in a range of cognitive domains, including attention, speed of information processing, memory, and executive function, as assessed on several measures, are significantly associated with functional outcome.

It should be noted that in some studies, cognitive performance and psychiatric state have been considered outcomes in themselves. Whereas this finding may be a wide practice among psychologists in particular, we would argue that performance on a neuropsychological test should not be considered as a variable that reflects the experience of an individual in coping with a disability in the context of their daily life, which is what is meant by "functional outcome" in the context of this study. Similarly, symptoms of anxiety and depression would represent just one component of an individual's inner experience but should not be considered an outcome in itself. What this study is trying to achieve is to identify the variables that contribute to functional outcome following TBI.

We have drawn our conclusions on the basis of a study with a relatively small and heterogenous sample, which creates some methodological problems, limiting statistical power and the reliability of the coefficients in the regression analyses. The intercorrelations evident between the predictors leads to the same problem. The results of the regression analyses should, therefore, be interpreted with caution. The study had a relatively low recruitment rate, with 58% of potential participants unable to be contacted or living far away. We cannot rule out the possibility that this introduced some selection bias into the sample.

Use of a single, dichotomized global measure of functional outcome such as the GOSE also has its limitations. It brings together in one score changes in several domains of an individual's life, which may be differentially affected by the consequences of TBI. Furthermore, some information is lost by the dichotomization of the scale. The results of our study show to which variables functional outcome is related, but not how these variables are related to different aspects of functional outcome. Future studies should, therefore, incorporate more detailed measurers of functional outcome as well as a broader range of predictors, such as premorbid personality, coping skills, cultural influences, and social support.

Despite these limitations, this study has nevertheless added to our understanding of the factors contributing to ongoing disability following TBI. It has thereby provided some guidance to clinicians advising relatives in the early stages after injury. Although one must always be cautious in making predictions about future recovery in individual cases, this study has provided evidence that severity of brain injury has an impact on a person's functional status even 10 years later. It tells us that when the injured person has a long period of PTA, lasting several weeks, the brain injury may lead to cognitive impairments in the domains of attention, processing speed, memory, or executive function that are present even 10 years after the injury. These impairments may be associated with ongoing functional limitations affecting, amongs other things, capacity for work, leisure, and/or social activities. Therefore, it would be important to seek as much rehabilitative support as possible, as the injured person moves through different life phases. The importance of relatives understanding the implications of cognitive impairments cannot be overemphasized. Given the high likelihood of the presence of symptoms of anxiety and/or depression 10 years after injury and the association between emotional status and functional outcome, it would be advised that the family seek psychological support for their injured relative to minimize these problems. The significance of PTA and length of education for functional outcome even at this long time after injury indicates the importance of accurately measuring these in the early stages of recovery, as a basis for early prediction of outcome. Moreover, identification of the significance of ongoing cognitive and psychiatric problems would suggest that these need to receive greater focus during rehabilitation. Understanding the complex interrelationships between these and other factors and their influence on outcome is an important aspect of understanding recovery following TBI and may aid in the direction of early rehabilitation and determination of long-term needs of individuals with TBI.

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