BRAIN INJURY, 2002, VOL. 16, NO. 1, 9–27

Comparison of the predictive power of socio-economic variables, severity of injury and age on long-term outcome of traumatic brain injury: sample-specific variables versus factors as predictors

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(*Received 26 November 2000; accepted 24 July 2001*)

The primary objective of this study was to measure the predictive power of pre-injury socio-economic status (SES), severity of injury and age variables on the very long-term outcomes of traumatic brain injury (TBI). By applying a within-subjects retroactive follow-up design and a factor analysis, the study also compared the relative power of sample-specific predictors to that of more commonly used variables and conceptually based factors. Seventy-six participants with severe TBI were evaluated at an average of 14 years post-injury with an extensive neuropsychological battery. The results show that pre-injury SES variables predict long-term cognitive, psychiatric, vocational, and social/familial functioning. Measures of severity of injury predict daily functioning, while age at injury fails to predict any of these variables. Sample-specific predictors were more powerful than more commonly used predictors. Implications regarding long-term clinically based and conceptually based prediction, and those regarding comparisons of predictors across samples are further discussed.

Introduction

Prediction of outcome following severe TBI has important theoretical, epidemiological, and clinical implications and has, therefore, been the subject of numerous studies over the past 30 years. The Glasgow Coma Scale (GCS) [1] was the first widespread clinical and research tool that aimed at the prediction of post-injury survival and daily functioning. Further efforts were later directed at unfolding additional outcome predictors, effective for the prediction of various functional domains and aimed at covering longer time spans. A literature review of the last decade reveals a substantial number of at least 25 prediction studies, which may be classified according to the functional domain that they aimed to predict as well as according to their prediction period. Four major functional domains were the focus

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Brain Injury ISSN 0269–9052 print/ISSN 1362–301X online © 2002 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/02699050110088227

of prediction: survival and daily functioning, vocational functioning, social integration, and cognitive abilities. With regard to the period of prediction, most studies encompass the time span of 1-year post-injury, and very few extend their prediction to longer periods, up to 5 years or more post-injury.

A review of the more frequently used predictors for each of the above-mentioned domains and the time periods of their prediction is discussed in the following sections.

Survival and daily functioning

Nearly three decades after its development, the GCS is still subject to continuous research as a predictor of functioning shortly after injury. Zafonte *et al.* [2] found low but significant correlations ($r = 0.16–0.37$) between GCS scores at admission to an emergency room and outcome measures at discharge from an inpatient rehabilitation unit in a group of 501 patients with TBI. Signorini *et al.* [3] found that a multiple logistic regression model, composed of age, GCS, severity of injury, pupil reactivity, and presence of haematoma, when measured at admission to an emergency room, predicted survival of patients 1 year later. In an attempt to improve the reliability of the GCS, Diringer and Edwards [4] deleted several items from the scale and found it to have a better predictive power of functional outcome within 1 year post-injury. Spettell *et al.* [5] used severity indices other than the GCS, namely length of coma (LOC) and duration of acute hospitalization, and found them to be significant predictors of the Glasgow Outcome Scale (GOS) [6]. Length of stay at a rehabilitation unit was best predicted in that study by severity of the initial brain injury, by the length of acute hospitalization, and by gender. All studies cited above predicted outcome at 1-year post-injury. Putnam and Adams [7] suggested that LOC and age at injury were the best single predictors of outcome among 100 patients with traumatic brain injury (TBI). Age at injury was also reported to be a strong predictor of outcome by Katz and Alexander [8], who found that at 1 year post-injury recovery was mediated by age. Asikainen *et al.* [9] studied the predictive power of severity of injury on the very long-term outcomes of TBI (mean of 12 years post-injury) in a group of 508 Finnish patients. GCS at admission to hospital predicted functional outcome, as measured by the GOS. A differential effect of age-at-injury on the predictive power of severity of injury was also noted. These effects distinguished between two extreme age groups of >40 and <7 years old at injury on the one hand, and 8–16 and 17–40 years old on the other hand. Hanks *et al.* [10] reported that the functional outcome several months post-injury was predicted by measures of executive functioning that were recorded at admission to the rehabilitation hospital. Thus, survival and daily functioning have been predicted mostly by measures of severity of injury and age, and most studies have looked at prediction within the first year post-injury.

Vocational functioning

The vocational outcomes of TBI bear prominent clinical, economic, and litigation implications and are, hence, investigated extensively in prediction studies. Various kinds of predictors were identified, including socio-economic status (SES) and pre-morbid variables, measures of severity of injury, and post-injury cognitive predictors. Gollahar *et al.* [11] studied the efficiency of various SES and disability variables in the prediction of vocational productivity at 1–3 years post-injury. Level of functioning at discharge from treatment, pre-injury productivity, and education were found to contribute significantly to prediction power, in contrast to age and severity of injury, which failed to do so. Ip *et al.* [12] found age, substance abuse, and Performance IQ scores to be predictors of employability at 3–5 years post-injury. They also found that severity of injury and disability ratings failed to predict the vocational status of their TBI patients. Sherer *et al.* [13] reported a similar finding of a significant contribution of pre-injury substance abuse to the prediction of post-injury vocational functioning at 1–2 years post-injury. Prior occupation was identified also as a predictor of employability at longer time spans, between 2–5 years following the injury [14].

In addition, Flemming *et al.* [14] reported a significant contribution of several severity of injury variables, including duration of Post Traumatic Amnesia (PTA), level of disability, LOC, and length of acute hospitalization, to the prediction of vocational status. Ponsford *et al.* [15] and Asikainen *et al.* [9] provided further support to this finding in reporting GCS, PTA, LOC, disability scores, and age as predictors of employability 2 years and 12 years post-injury. However, as mentioned earlier, these findings were not confirmed by Gollahar *et al.* [11] and Ip *et al.* [12], who found that measures of severity of injury failed to predict the long-term vocational status.

Several studies examined the predictive power of post-injury cognitive measures on the ensuing vocational status. Ip *et al.* [12] looked at TBI patients 3–5 years post-injury and reported that, of all the prediction variables studied, only WAIS-R PIQ scores remained after a cross-validation procedure of an empirically pre-defined prediction formula. Other cognitive predictors of vocational status were reported by Ryan *et al.* [16], who used reading comprehension, verbal memory, and dysphasic symptomatology 2 years post-injury, by Vilkki *et al.* [17], who used cognitive flexibility and mental planning 1 year post-injury, and by Little *et al.* [18], who used neuropsychological test scores. Cognitive abilities were also among the significant predictors in Flemming *et al.*'s [14] study.

Thus, vocational functioning is effectively predicted, according to the reviewed studies, by pre- and post-injury SES variables, by post-injury cognitive variables, and less consistently by severity of injury variables. Most of these studies attempted to predict functioning at 1–5 years post-injury, with one exception of up to 12 years post-injury [9].

Psychosocial and family functioning outcomes of TBI

Several studies have used cognitive and neuropsychological parameters in order to predict psychosocial and family functioning after TBI. For example, Milles *et al.* [19] and Ross *et al.* [20] used the Trail Making Test and the Rey AVLT total learning scores, as well as age, as predictors of social integration in 59 persons with TBI 1 year post-injury. Vilkki *et al.* [17] reported that tests of cognitive flexibility and mental planning were better predictors of psychosocial outcome 1-year post-injury, as compared to measures of intelligence. In Flemming *et al.*'s [14] study, age, level of disability and cognitive functioning predicted social integration 2–5 years post-injury. Psychosocial evaluation scores given by a social worker at discharge from a rehabilitation unit also predicted social integration at the 1-year post-injury term [21]. The needs of families of persons with TBI, 2 years after the injury, were best predicted by measures of neurobehavioural functioning [22]. Thus, cognitive and neuropsychological abilities, as measured immediately after the injury, were the most frequently used predictors of social integration 1–5 years later. Additional effective predictors were psychosocial and neurobehavioural evaluations.

Cognitive abilities

Of all outcome measures of TBI, the least frequently investigated domain was that of cognitive abilities. Karzmark [23] found that brief cognitive tests delivered shortly after the injury predicted the cognitive functioning 6 months later at least as accurately as PTA. Haslam *et al.* [24] reported that post-coma disturbances served as predictors of memory functioning, and that PTA served as a predictor of processing speed 1 year post-injury.

In summary, two conclusions may be drawn from this review of the literature. First, substantial knowledge has been accumulated regarding the variables that predict the immediate and post-acute sequelae of TBI. Much less is known, however, about prediction of the very long-term outcomes. Most of the studies reviewed above aim at prediction up to the first and second years post-injury, with very few studies covering the 3–5 years period, and only one study going beyond that time period. However, rehabilitation of brain injury is often a lengthy process [25], and the average life expectancy of persons with severe TBI is 50 years post-injury [26]. Thus, more prediction studies that will span longer time periods are essential, both from the epidemiological and the rehabilitative and clinical points of view. Such knowledge bears at least the same significance as that of prediction to the immediate post-injury period; its scarcity seems to spring from a lack of available resources, rather than from a lack of appreciation of its importance. Hence, the first goal of the present study was to extend the scope of prediction to longer time periods, beyond the first decade after the injury.

Secondly, there appears to be a great variability in the specific measures used as outcome predictors, a variability that renders the comparison across studies and across prediction models quite difficult. However, the various outcome predictors that have been used may be conceptually divided into fewer and more parsimonious categories. Of these, the four most salient ones are pre-injury SES predictors (i.e. education and vocational achievement), severity of injury variables (i.e. LOC, GCS), post-injury cognitive and neuropsychological measures (i.e. IQ, executive functioning), and time-related variables (i.e. age at injury). Although specific outcome predictor variables are used in different studies, they are chosen to represent these four main predictive categories. What the researchers seem to share is a general concept of a few certain potential predictive categories, which are frequently represented by different variables in each study. The choice of specific variables is probably influenced by data availability, relevance, and expected validity for the research sample, its epidemiological, aetiological, cultural, and SES background. Thus, while single predictor variables may be more applicable, measurable, and effective for parochial use, they are also culturally-bound, sample-specific, and difficult to generalize across studies. Furthermore, due to aetiological and socio-economic differences, variables found to be effective predictors in one study may prove to be ineffective in another study that investigates a different TBI population, even though they represent the same conceptual domain. On the other hand, while using a factorial approach may be more complicated and less clinically applicable, it is more conceptually representative and allows a better comparison across different studies.

The idea of combining predictive variables into factors has previously been studied by Ezrachi *et al.* [27]. In their study, Ezrachi *et al.* compared the predictive efficacy of specific variables to that of factors that were generated by grouping the same predictive variables together to conceptually cohesive factors. Along with the innovative use of the factorial methodology in this field, Ezrachi *et al.* investigated only very specific aspects of outcome prediction, i.e. awareness and acceptance of disabilities that were presumably gained during a day-centre programme. Vilkki *et al.* [17] grouped their cognitive predictors into three factors: cognitive skills, episodic memory, and mental programming. However, their grouping and scoring were based solely on conceptual similarity between the variables and were not empirically validated. A similar procedure was also adopted by Serio *et al.* [22]. Haslam *et al.* [24] made an attempt to group the dependent variables, rather than the predictors, into two empirically based factors: memory and speed of processing. To the best of the authors' knowledge, no further attempt has yet been made to combine single predictors to factors and to compare the predictive efficacy of these factors to that of single variables. Such an attempt may facilitate data comparison across studies, as it allows a comparison of the conceptual aspect of prediction and is, thus, less affected by the predictive efficacy of sample-specific predictors. Therefore, the second goal of this study was to compare the predictive power of single variables to that of factors that will be empirically generated by grouping these variables to conceptually cohesive factors.

Three groups of predictor variables were studied: pre-injury SES, severity of injury, and age at time of injury. The predictive power of these three groups of predictors was tested, both as single variables and as empirically generated factors, in predicting functioning in five life domains at the very long term of 10–20 years post-injury. The five life domains consisted of cognitive abilities, psychiatric symptomatology, vocational status, social/family integration, and daily functioning.

Method

Participants

Seventy-six individuals (63 males) with severe TBI, and 34 of their family members (eight parents and 26 spouses), participated in the study after signing an informed consent to do so. This group was drawn from a larger group of 99 subjects with various kinds of brain injuries and brain diseases who participated in an extensive long-term outcome study that was performed by the National Institute for the Rehabilitation of the Brain-Injured in Israel [28]. The selection procedures, inclusion criteria, and description of the 76 persons with TBI were given in detail elsewhere [29], their demographic and severity of injury data are presented in table 1.

Vehicular accidents accounted for the injuries of 48 (64%) of the participants, 18 (25%) were wounded in war, most of them suffering penetrating injuries, and nine (11%) were injured in the workplace, mostly in falls.

Forty-seven (62%) of the participants were comatose for more than 1 week. Fifty subjects (66%) suffered two, three, or four major neurological symptoms such as aphasia, hemiplegia, etc. at the time of the injury. Only 31 subjects (41%) suffered

Table 1. Demographic, time and severity of injury data of the participants ($n = 76$)

	M	SD	Range	*n*	%
Age at injury	24.9	7.6	17–50	76	100
Age at study	38.6	8.5	23–62	76	100
Years since injury	13.7	5.5	5.4–25.5	76	100
Education (in years)	12.0	2.1	8–19	76	100
Aetiologies of brain injury:					
Motor vehicle accidents				48	64
War injuries				19	25
Work accidents				9	11
Duration of coma:					
30 days and more				21	27.6
8–30 days				26	34.2
1–7 days				13	17.1
Less than 24 hours				9	11.8
No coma				5	6.6
No available data				2	2.7
Frequencies* of neurological symptoms:					
Sensory disabilities (impaired hearing, impaired vision, hemi-anopsia)				61	80
Motor disabilities (hemiplegia, quadroplegia, hemiparesis, apraxia, ataxia)				59	77
Epilepsy				19	25
Aphasia				10	13

* Percentages do not add to 100% since patients often exhibit more than one symptom.

such symptoms at the time of the study. Data on GCS scores were not available for many of the patients who had been injured before the scale was used in Israel.

Tests and measurements

Predictors

As part of an extensive long-term outcome study conducted by this group [28], various measures of SES, severity of injury, as well as short and long-term post-injury functioning were collected. Out of these measures, seven variables were chosen as predictors: three SES variables, three measures of severity of injury and age. The three SES predictors were:

(1) Education prior to injury in terms of years of education, beginning at grade one.
(2) Number of siblings. The number of children in the family is considered to be a strong SES indicator in Israel, with low level SES strata having more children on average [30].
(3) Index of quality of service in the military, constructed for the purpose of this study. Quality of military service is also considered a strong socio-demographic parameter in Israel. Placement in officer courses and service in more demanding, important and prestigious units are determined in part by the conscript's pre-recruitment SES data [31]. The additive result of three parameters constitutes the index: length of service, i.e. full, partial or none at all

(1–3 points); matching selection criteria for officer rank (Yes/No, 0–1 points); and rank at discharge (1–9 points). These three elements are typical quality parameters of compulsory military service in Israel. The range of this index was 1–13 points, with higher scores indicating lengthier, more successful and higher quality service in the army, i.e. higher SES.

The three severity of injury predictors were:

(1) Length of coma. In order to overcome problems of reliability resulting from inaccurate medical and personal history, this measure was classified with an ordinal scale of 5 points (1 = no coma, 2 = less than 24 hours, 3 = 1–7 days, 4 = 8–30 days, and 5 = more than 30 days).
(2) Length of hospitalization in a rehabilitation hospital measured in months and based on medical files.
(3) Number of disabilities related to brain injury at the time of the injury. This index was constructed for the purposes of the present study. Based on the participant's medical file, the four most prominent neurologically related disabilities were counted for each subject. As part of the collection of medical data, each subject answered a 'Yes–No' questionnaire of 10 possible brain-injury related disabilities: (e.g. R/L hemiplegia and hemiparesis, ataxia, agnosia, aphasia, epilepsy, etc.). Each marked disability was assigned one point, with five points or more collapsed to four points in order to lessen the effect of less prominent disabilities. The average score was 2.33 (SD 1.32), with 8.7% of the participants reporting no disabilities, 23.2%, one disability; 20.3%, two disabilities; 21.7%, three disabilities and 26.1%, four or more disabilities.

The age predictor consisted of only one measure: age at injury, measured in years. Age at injury was chosen over age at the time of the study and over the interval between injury and study because it is more commonly used in the researches cited above.

All predictors were collected from the participants' medical files. Means and standard deviations of the predictors, as well as their inter-correlations, are presented in Appendices A and B.

Dependent variables

Cognitive abilities were assessed by the Wechsler Adult Intelligence Scale-Revised (WAIS-R, Hebrew version) [32], full-scale IQ (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ).

Psychiatric symptomatology was assessed by the Psychiatric Symptoms Checklist-90, Revised (SCL-90-R) [33], a 90-item psychiatric symptom checklist that produces a Global Severity Index (GSI), reflecting the clinical severity of all symptoms. Psychiatric symptomatology was also assessed by the Post-Traumatic Stress Disorder (PTSD) questionnaire [34], a questionnaire that consists of 13 statements describing the DSM-IV symptom clusters of PTSD. A probable diagnosis of PTSD was assigned to a person who fulfilled the four DSM criteria for PTSD. The questionnaire was validated against other psychiatric inventories and clinical interviews of a sample of 114 Israeli soldiers 1 year after the 1982 Lebanon War [35].

Vocational Status was measured by three indices. The Index of Employment (Yes/No) at follow-up assigned a 'Yes' score to a person who, at the time of the study, and at least 3 months prior to it, worked either in a regular job, in a family business, in sheltered employment, or as a volunteer. Hence, a 'No' score was assigned to those who manifested no occupational activity whatsoever.

The Index of Level of Employment at follow-up classified employed participants according to Roe's [36] professional, skilled, and unskilled employment categories.

The Index of Stability at Work since Injury was calculated as a function of the potential work period since discharge from hospital, the actual time spent at various jobs, and the number of jobs held during that period. The index ranged from 0.0–1.0, with 1.0 indicating maximum stability.

Social and family integration was assessed by the social activities sub-scale of the Extended ADL questionnaire [37, 38]. This sub-scale includes eight questions about the subject's active social involvement (e.g. Do you entertain friends at your home?). Answers are scored on a scale from 1 (Not at all) to 5 (Very frequent), with 5 indicating high involvement in social life as perceived by the individual. The same sub-scale was also completed by a family member, who provided his or her evaluation of the patient's social involvement. Relatives' evaluation on the family functioning sub-scale of the Extended ADL Questionnaire was also used. This sub-scale includes four questions concerning the subject's involvement in his or her family life (e.g. Does he or she take part in the family's decisions?). Answers are also scored on a scale of 1 (Not at all) to 5 (Very frequent), with 5 indicating high involvement in family life. In addition, the Family Burden Questionnaire was used [39], assessing family members' feelings of burden by 25 Yes/No questions about their reactions to their role as caregivers.

Daily functioning was assessed by the Home Activities sub-scale of the Extended ADL questionnaire [37]. This questionnaire includes 11 questions (e.g. Do you cook by yourself?) scored on a scale of 1 (Not at all) to 5 (Very frequent). In addition, the Independence in Mobility sub-scale of the same questionnaire was also used, consisting of 10 questions (e.g. Do you manage climbing up the stairs?). Both the participant and a family member filled these two sub-scales.

Subjects' socio-economic background, medical history, education and vocational data were collected by questionnaires and structured interviews, constructed especially for the purpose of the current study. These included 192 informative questions to which the subject, as well as his or her family member, responded. Further information was collected directly from the subject's medical file.

Results

Single variables as predictors of long term functioning

The predictive power of single independent variables was studied by correlating each independent variable with the 16 dependent variables (see table 2) and by regressing the six-predictor variables on five dependent variables, which, for the sake of brevity, were chosen to represent the five dependent functional domains (see table 3). With the use of these two analyses, the predictive power of each independent variable by itself was compared to its predictive power when partialized out of that of the other six. Due to the large number of analyses that were conducted,

Table 2. *Correlations between the seven predictor-variables and the dependent variables in the five domains*

		Predictors						
		Pre-injury socio-economy status			Severity of injury			
Domains	Dependent variable	Educ	Nsib	Imilitary	Coma	Nrehab	Ndis	AgeI
Cognitive	WAIS-R FSIQ	0.161 (57)	−0.463 (58)***	0.442 (52)***	−0.039 (55)	−0.047 (46)	−0.122 (52)	0.047 (58)
	VIQ	0.231 (58)	−0.507 (59)***	0.441 (53)***	0.014 (56)	−0.019 (47)	−0.235 (53)	0.107 (59)
	PIQ	0.065 (58)	−0.271 (59)	0.396 (53)**	−0.039 (56)	−0.074 (46)	−0.004 (53)	−0.074 (59)
Psychiatric	SCL-90 GSI	−0.165 (60)	0.353 (60)**	−0.381 (53)**	−0.400 (58)**	−0.102 (44)	−0.015 (54)	−0.149 (60)
	PTSD	−0.157 (67)	0.341 (67)***	−0.213 (59)	−0.267 (65)	−0.051 (50)	0.072 (61)	−0.114 (68)
Vocation	Employ. (Y/N) (P. bis. cor.)	0.221 (75)	−0.114 (75)	0.131 (66)	−0.022 (73)	−0.093 (57)	0.127 (69)	0.012 (76)
	Employ. Level (Spearman)	−0.152 (46)	0.450 (45)***	−0.388 (41)	0.022 (44)	0.252 (37)	0.321 (40)	−0.035 (46)
	Stability at work	0.240 (61)	−0.378 (61)***	0.399 (54)**	−0.147 (59)	0.197 (46)	−0.107 (55)	0.219 (62)
Soc. Fam.	ADL at social activities	0.344 (62)**	−0.080 (63)	−0.085 (56)	0.151 (60)	−0.116 (46)	0.013 (57)	−0.072 (63)
	ADL at social by relative	0.121 (34)	−0.482 (34)***	0.099 (30)	0.275 (33)	0.058 (25)	0.025 (31)	−0.179 (34)
	ADL at family by relative	0.402 (34)**	−0.433 (34)**	0.220 (30)	0.283 (33)	0.052 (25)	−0.052 (31)	−0.146 (34)
	Burden by relative	−0.104 (34)	0.505 (34)***	−0.297 (30)	−0.216 (33)	−0.195 (25)	0.069 (31)	0.291 (34)
ADL	ADL at home	0.075 (62)	0.192 (63)	0.033 (56)	−0.136 (60)	−0.543 (46)***	−0.073 (57)	−0.228 (63)
	ADL at home by relative	−0.209 (34)	−0.386 (34)**	0.423 (30)	0.038 (33)	−0.395 (25)	−0.054 (31)	−0.191 (34)
	ADL in mobility	−0.064 (62)	−0.149 (63)	−0.031 (56)	−0.023 (60)	−0.420 (46)***	−0.116 (57)	−0.115 (63)
	ADL in mobility by relative	0.164 (33)	−0.316 (33)	0.423 (29)	0.025 (32)	−0.289 (25)	−0.338 (30)	−0.179 (33)

** $p < 0.01$; *** $p < 0.001$.

Note: Educ = Years of education; Nsib = Number of siblings; Imilitary = Index of military service; Coma = LOC; Nrehab = Length of hospitalization in rehabilitation unit; Ndis = Number of disabilities; AgeI = Age at injury; Employ. (Y/N) = Index of employment at present; P. bis. cor. = Point biserial correlation; Employ. Level = Level of employment at follow-up; Spearman = Spearman Rho.

Table 3. Regression analysis of the predictor variables on five dependent variables

Dependent variable	Variables entered	R	R^2	SEE	R^2 change	F change	df1	df2	Sig. F change
WAIS-R FSIQ	1. Nsib	0.463	0.215	11.30	0.215	12.0	1	44	0.001
	2. Imilit	0.541	0.293	10.85	0.078	4.7	1	43	0.035
GSI	1. Coma	0.400	0.160	0.67	0.160	8.0	1	42	0.007
	2. Nsib	0.528	0.279	0.62	0.119	6.8	1	41	0.013
Stability at work	1. Imilit	0.399	0.159	0.23	0.159	8.3	1	44	0.006
ADL at social	1. Educ	0.344	0.118	0.88	0.118	5.9	1	44	0.019
ADL at home	1. Nrehab	0.543	0.294	0.91	0.294	18.4	1	44	0.000
	2. AgeI	0.630	0.397	0.85	0.103	7.3	1	43	0.010
	3. Educ	0.687	0.472	0.80	0.075	6.0	1	42	0.019

Note: Nsib = Number of siblings; Imilit = Index of military service; Coma = LOC; Educ = Years of education; Nrehab = Length of hospitalizsation in rehabilitation unit; AgeI = Age at injury.

only 0.01 levels of significance or lower were regarded as an indication of an above chance correlation.

The number of siblings appears to be the most powerful predictor, with significant correlations with at least one, and more frequently two or three dependent variables in each life domain. Its power is also evident in that it was one of the two variables that entered the prediction regression on WAIS-R FSIQ and on GSI (see table 3). Second to it is the index of military service with significant correlations with intelligence, psychiatric symptomatology, and stability at work. Here again, the power of this index is evident in the regression analysis, as it was found to be the second predictor (out of two) of WAIS-R FSIQ and the only predictor of the index of stability at work. When measured by itself, years of education prior to injury predicted the social-family functioning of the participants (see table 2) and was found to be the only predictor of this domain in the regression analysis. In addition, the variable of years of education prior to injury was the third one to enter the regression analysis on the ADL functioning at home score. A more general view of the data in table 2 shows the three SES variables to be the strongest, and in most cases the only predictors of the cognitive, psychiatric, vocational, and social/family functioning.

Of the predictors of the severity of injury, length of hospitalization at a rehabilitation unit was found to have a major loading in the prediction of ADL, both as a single variable and when partialized in the regression analysis. Length of coma predicted the SCL-90 GSI scores and had the heaviest loading in the regression equation of this variable. Number of disabilities failed to predict any of the dependent variables, both as a single variable and in the regression analysis. Age at injury appears also to have no predictive power in any of the five life domains when presented singly. Age at injury was second in contributing to the prediction of ADL functioning at home in the regression analysis.

When looking at the dependent variables (the rows in table 2), it is evident that the cognitive, psychiatric, vocational, and social/family domains are predicted to a much greater degree by SES variables and to a lesser degree by the severity or age variables. The ADL domain is nearly equally predicted by the SES and the severity variables, but not by the age variable. A most interesting finding is the unpredictability of the index of employment. None of the predictors differentiated (in a point biserial correlation) between the employed and the unemployed subjects. Other methods of differentiation between these two groups (*t*-tests and discriminant analysis) revealed the same results.

Factors as predictors

The seven predictor variables, representing three conceptually driven factors—pre-injury SES, severity of injury, and age—were entered into a principal component factor analysis, in a varimax rotation method with Kaiser normalization. As expected, three factors showed up clearly: (1) A socio-economic factor with loadings of −0.803 by number of siblings, 0.779 by the index of military service, and 0.453 by years of education; (2) A severity of injury factor with loadings of 0.753 by number of disabilities, 0.732 by LOC, and 0.626 by length of hospitalization in a rehabilitation unit; and (3) An age factor with only one loading of 0.857 by age at injury. The three factors explained 27.5%, 21%, and 16.1% of the variance, respectively, amounting to a total of 64.6% of explained variance. A complete list of these loadings is presented in table 4.

Each subject was assigned a 'SES regression factor score' and a 'severity regression factor score', that expressed his or her pre-injury SES status and severity of injury, respectively, by means of standardized regression scores. These two scores were then correlated, as factorial predictors, together with age at injury, with the dependent variables in the five domains (see table 5). In this correlational analysis, age at injury scores were not transformed to regression factor scores, since no other variable constituted the age factor. Nevertheless, the correlations between age at injury and the dependent variables are presented here in order to show the full factorial picture.

The SES factor score predicted intelligence, psychiatric symptomatology, level of employment, and stability at work. It also predicted the family burden scores

Table 4. Loadings of the predictor variables in the socio-economic, severity of injury, and age factors

Component	1	2	3
Nsib	−0.803	—	—
Imilitary	0.779	—	—
Educ	0.453	—	—
Ndis	—	0.753	—
Coma	—	0.732	—
Nrehab	—	0.626	—
AgeI	—	—	0.857

Note: Nsib = Number of siblings; Imilitary = Index of military service; Educ = Years of education; Ndis = Number of disabilities; Coma = LOC; Nrehab = Length of hospitalization in rehabilitation unit; AgeI = Age at injury.
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations. Missing values excluded pair-wise. Empty cells present loadings below the 0.400 limit.

Table 5. Correlations between predictor factors and dependent variables in the five life domains (n in brackets)

		Predictors		
Domains	Dependent variable	SES Factor	Severity factor	AgeI
Cognitive	WAIS-R FSIQ	0.569 (40)***	−0.252 (40)	0.047 (58)
	VIQ	0.620 (41)***	−0.250 (41)	0.107 (59)
	PIQ	0.393 (40)**	−0.262 (40)	−0.074 (59)
Psychiatric	SCL-90 GSI	−0.485 (37)**	0.007 (37)	−0.149 (60)
	PTSD	−0.320 (43)	0.049 (43)	−0.114 (68)
Vocation	Employment (Y/N) (p. bis. cor.)	0.215 (49)	−0.006 (49)	0.012 (76)
	Employment level (Spearman Rho)	−0.564 (32)***	0.263 (32)	−0.035 (46)
	Stability at work	0.520 (40)***	0.025 (40)	0.219 (62)
Soc. Fam.	ADL at social activities	−0.069 (40)	−0.149 (40)	−0.072 (63)
	ADL at social by relative	0.256 (20)	−0.246 (20)	−0.179 (34)
	ADL at family by relative	0.413 (20)	−0.216 (20)	−0.146 (34)
	Burden by relative	−0.488 (20)	0.199 (20)	0.291 (34)
ADL	ADL at home	−0.153 (40)	−0.469 (40)**	−0.228 (63)
	ADL at home by relative	0.330 (20)	−0.534 (20)	−0.191 (34)
	ADL at mobility	−0.065 (40)	−0.423 (40)**	−0.115 (63)
	ADL at mobility by relative	0.414 (20)	−0.684 (20)***	−0.179 (33)

** $p < 0.01$, *** $p < 0.001$.
Note: AgeI = Age at injury; P. bis. cor. = Point biserial correlation.

and the patients' ADL functioning in the family and in the mobility domains, as evaluated by a family member. These last three correlations, though, failed to reach significance due to the small size of the family member sample who completed the relevant questionnaires. The severity factor score predicted mainly the ADL domain. Here, again, a general inspection of the results leads to the conclusion that the SES factor is a better predictor of the cognitive, psychiatric, vocational, and social/family domains, whereas the severity factor is more effective in predicting the ADL domain.

Discussion

The high prevalence of TBI in early adulthood, the length of rehabilitation, as well as the probability of normal life expectancy of TBI survivors, all strengthen the clinical and epidemiological importance of the very long-term prediction of TBI outcome. The large number of studies that attempted to predict outcome in the immediate and medium ranges of time and the scarcity of long-term prediction research seem to reflect practical difficulties in long-term data collection rather than a conceptual bias. Thus, the first goal of the current study was to extend the period of prediction and then to determine the most effective outcome predictors at the second decade post-injury.

The present study suggests that 10–20 years after the injury, SES variables predict mostly the mental (cognitive and psychiatric), vocational, and social/familial outcomes, severity of injury and SES variables predict the ADL functioning, and age at injury is virtually not an effective predictor of outcome. SES variables were significantly correlated with nearly all the dependent variables at the cognitive, psychiatric, vocational, and social/family domains, whereas of the severity variables only one, LOC, was significantly correlated with a dependent variable in these domains, namely the SCL-90 GSI. A more balanced picture is revealed in the prediction of the ADL domain in which a severity variable (e.g. length of hospitalization in a rehabilitation unit) was significantly correlated with two dependent variables, and a SES variable (e.g. number of siblings) was significantly correlated with one dependent variable.

This general trend is only slightly changed when the single variables are partialized from each other in the regression analysis. Cognitive abilities are predicted by number of siblings and by the index of military service. Psychiatric symptomatology is predicted by the combined regression of LOC and number of siblings. The index of stability at work and the ADL in social activities are predicted by SES variables. ADL at home is predicted by a combination of a severity variable, a SES variable, and age at injury.

The results are in accordance with previous prediction reports of the short, intermediate, and long-term outcomes of TBI. SES variables predominated the prediction of the vocational status, whereas severity variables and age failed to do so in Gollahar *et al.*'s [11] study, a finding that was supported by Ip *et al.* [12] and by Sherer *et al.* [13]. On the other hand, this trend was not supported by Flemming *et al.* [14] or Ponsford *et al.* [15]. Daily functioning was repeatedly and effectively predicted by severity of injury variables, including GCS, LOC, and PTA [2, 3, 5, 7, 9]. To the best of the authors' knowledge, no results are reported regarding the prediction of daily functioning by SES variables.

The strong relationship between SES variables and late psycho-social and vocational functioning is probably related to enhanced availability of social and financial resources, social support networks, health and rehabilitation services, as well as personal assets acquired before the injury, etc. A question might be raised, though, regarding the lack of predictive power of the severity of injury variables in these domains. The answer to this question may be found in the fact that these severity of injury variables are better in predicting the late ADL outcomes. When compared to the mental, vocational, and social domains, the ADL domain, including both mobility and home activities, relies more heavily on physical abilities. It is, therefore, more influenced by the long-term physical disabilities that were caused by the TBI, and thus to the severity of the injury. In contrast, the mental, vocational, and social domains are much less influenced by the physical aspects of the injury, are more prone to social and economical influences of the survivors' social surroundings, and are hence less affected by the severity of the injury.

The current results differ from the results of Asikainen *et al.* [9], who found that severity of injury, defined by PTA and LOC, was predictive of long-term vocational outcome of TBI patients. Although Asikainen *et al.*'s [9] study and the present one examined the outcomes of TBI at the same time period post-injury, two methodological differences between the two studies must be considered. Firstly, Asikainen *et al.* assigned an 'Employed' score to currently unemployed patients if these patients had the potential capability to be employed as determined by a neurological examination, whereas in this study only actual employment granted such a score. Thus, it could be the case that the inconsistency in results stems from a difference in the definition of employment. Their finding may be interpreted as indicative of the predictive power of LOC and PTA regarding the capability for employment, but not regarding employment *per se*. Secondly, comparison of the LOC of the 196 participants in the age group of 17–40 years in the Asikainen *et al.* study to the LOC of participants in the present study shows that the sample suffered a much lengthier durations of coma, i.e. that the severity of injury of these patients was greater. Approximately 62% of the participants suffered LOC for longer than 1 week (see table 1), in contrast to 39% of the Asikainen *et al.* group, while 60% of their sample suffered LOC at the 24 hours range, compared to 38% in this sample. Thus, the fact that the range of severity of injury in the present study was restricted to the more severely injured may have also contributed to the differences between the two studies.

A second question that arises from these results concerns the lack of predictive power of age at injury. At shorter post-injury time periods, age was found to predict functional outcome in several studies [7, 8, 12, 15]. Why is it that after a longer time period, within the second decade post-injury, age at injury fails to do so? One possible answer to this question may be found in the range of ages at injury of the participants. Although the sample includes a wide range of ages, spanning 33 years, from 17–50 years of age, this range is still limited in the sense that it still constitutes the most productive phases of life. Differences in age-at-injury within this range did not cause differences in long-term outcomes, as might have been the case had the sample included children and elderly adults. Although stemming from a sampling/methodological limitation, the conclusion that age-at-injury has little predictive power is still important in view of the high prevalence of TBI in these age ranges. The lack of a simple linear relation between age-at-injury and outcome is also exemplified by Asikainen *et al.*'s [9] finding of an interaction effect between age, severity of injury, and outcome. In that study, mild GCS was related to good outcome in all age groups but less so at the youngest and oldest age groups. Severe GCS was found to be related to negative outcomes in the same extreme age groups and again less so in the intermediate ages (i.e. 8–17 and 18–40 years).

A third question that arises from the current findings concerns the inability to predict the employed/unemployed dichotomy in the group by any of the variables. The reason for this unexpected result may lie in the criteria that granted an 'Employed' or 'Unemployed' score to the participants. Following previous outcome studies, an 'Unemployed' score was assigned only to participants who demonstrated no occupational behaviour whatsoever, i.e. to those who stayed at home permanently as part of the regular routine of their lives. An 'Employed' score was assigned, on the other hand, to all those who reported any occupational behaviour as an integral part of their daily routine, including those who were employed on a part time basis in sheltered workshops. A previous report [29] analysed the vocational behaviours of the employed/unemployed subjects in more detail and specified that although 46 (60.5%) of the 76 participants were assigned an 'Employed' score, 34 (73%) of them were employed in low-level, unskilled jobs, and 18 of those had non-competitive employment.

The clinical experience in the rehabilitation of these persons further indicates that there are no clear SES, severity of injury, or age differences between many of those employed at low level, unskilled, or non-competitive jobs and those who are unemployed. In many cases, the differences between the employed-at-low-level and the unemployed clients seem to depend on other aspects of their lives, such as opportunity for employment, current motivation for work, or other health variables that were not studied as predictors here. The lack of difference between employed and unemployed subjects was further supported by a post-hoc analysis of the results, in which additional SES and severity of injury parameters also failed to distinguish between the two groups. For example, 50 participants (66%) in this sample were military veterans. These participants usually receive compensatory allowance from the Israeli Ministry of Defence, which is matched to the average Israeli salary. The other 34% of the participants were referred by the Israeli National Insurance Institute, and their compensatory allowances were mostly equal to or lower than the minimum wage in Israel. This difference in income between the two populations could have led to a difference in employment outcome, but no such differences were found. This finding may be applicable also in other countries in which welfare laws ensure an income equal to at least minimum wages.

The other two vocational-status indices, level of employment and stability at work, were effectively predicted by pre-injury SES variables, indicating that SES differences among the employed subjects are related to subsequent level of employment and stability at work. The higher the SES status of the participant, the higher will be his or her level of employment and stability at work one-to-two decades after the injury.

The second goal of the present study was to compare the relative efficacy of single variables to that of factorial prediction, and to examine the differences in the prediction power between the variables in each factor. As expected, this comparison showed that the constant general trend of the predictive relations was preserved across the two analyses, revealing only minor differences. When combined to a factor, pre-injury SES variables predicted current cognitive abilities, psychiatric symptomatology, and vocational status, and failed to reach significance, due to small sample sizes, in two of four social/family and ADL variables. The severity factor, on the other hand, predicted mainly the ADL domain. Thus, combining single variables into a factor leads, at least in this sample, to the same general trend of prediction, and may provide an effective route for comparisons across studies that use different specific single variables. Together with this seemingly obvious conclusion, a close inspection of the relative predictive power of each variable within the factors and their weightings in the factors raises an interesting issue with regard to sample-specificity of predictors. Within the SES factor, the number of siblings and the index of military service were the most powerful predictors, whereas education was the weakest. While number of siblings and the index of military service are more culturally-specific and may not show the same strong predictive power in other communities, education, whose significance is less culturally-specific, at least in the western hemisphere, failed to show predictive power of the same magnitude in this sample.

The findings regarding the severity of injury variables exemplify this point further. Of the three severity of injury variables (e.g. LOC, length of hospitalization, and number of disabilities), length of hospitalization in a rehabilitation unit, a variable which is greatly influenced by local health laws and regulations, showed the highest predictive power (of the daily independence variable). Length of coma, a well accepted predictor worldwide, predicted only one dependent variable, and number of disabilities showed no correlations with the dependent variables whatsoever (but had the highest loading in the factor).

Thus, within the two factors of SES and severity of injury, the two more locally dependent predictors (i.e. number of siblings and length of hospitalization) were the strongest outcome predictors, whereas the less sample-specific and more widely used predictors (i.e. education and LOC) showed a lower predictive power.

These within-factor differences are very important and may lead to the conclusion that the study of prediction has two distinct aspects, with two distinct methodologies. Studies that aim at clinical application of prediction formulae may be better off using culturally specific predictors. Using powerful predictive variables that proved reliable in other cultures or countries may lead to different results and wrong clinical interpretations, as might have happened if one had used only education as a pre-injury SES predictor or only LOC as a severity predictor in this study.

Studies that aim at cross-sample comparable predictions may be better off, on the other hand, by combining specific variables into cohesive factors and measuring their predictive power. Combining culture- or sample-specific predictors into factors and measuring their predictive power may enable a more general theoretical discussion regarding the predictive power of conceptually driven factors, and may help in overcoming the problem of comparison of sample specific variables.

Summary

In the current study, measures of pre-injury socio-economic status were found to be effective predictors of mental, vocational, and social functioning of persons with TBI more than a decade after their injury. Measures of severity of injury failed to predict these domains and were found more effective in predicting independence in daily functioning. Similar results were previously reported in several studies that investigated shorter post-injury outcome. The current study extends previous reports to one or two decades post-injury. As expected, the general trend of prediction is preserved when single variables are combined into factors. However, the advantage of factors over single variables for cross-sample comparisons is emphasized by the finding that culture- or sample-specific variables are better predictors of outcome than more universally used predictors. Thus, sample-specific variables may be more accurate predictors for clinical applications, whereas factors that are generated from the same variables may serve for the comparison across samples drawn out of different populations.

Further research is needed in order to replicate and cross-validate these findings and in order to measure the long-term predictive power of cognitive and functional variables recorded next to the injury that were not examined in the present study.

Acknowledgements

This study was supported by research grants from the Rehabilitation Department at the Ministry of Defence and from the National Insurance Institute in Israel. The authors gratefully acknowledge Gitit Kave' and Jacqueline Teitelbaum for editing the manuscript.

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Appendix A: Means, standard deviations and ranges of the predictor variables

	Mean	SD	Range	*n*
Nsib	3.81	2.79	0–9	75
Educ	11.86	2.40	8–19	75
Imilitary	6.19	2.15	3–11	66
Coma	3.66	1.22	1–5	73
Nrehab	9.14	7.64	1–39	57
Ndis	2.3	1.32	0–4	69
AgeI	24.9	7.6	17–50	76

Note: Nsib = Number of siblings; Educ = Years of education; Imilitary = Index of military service; Coma = LOC; Nrehab = Length of hospitalization in rehabilitation unit; Ndis = Number of disabilities; AgeI = Age at injury.

Appendix B: Inter-correlations between the predictor variables

		Nsib	Educ	Imilitary	Coma	Nrehab	Ndis
Nsib	*r*	1.000					
	n	75					
Educ	*r*	−0.175	1.000				
	n	74	75				
Imilitary	*r*	−0.402***	0.355***	1.000			
	n	66	66	66			
Coma	*r*	−0.020	0.169	0.216	1.000		
	n	72	73	64	73		
Nrehab	*r*	−0.174	0.152	0.107	0.308**	1.000	
	n	57	57	51	57	57	
Ndis	*r*	0.138	0.141	−0.102	0.302**	0.234	1.000
	n	69	68	61	67	54	69
AgeI	*r*	−0.061	0.159	0.249*	0.017	−0.137	0.077
	n	75	75	66	73	57	69

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Note: Nsib = Number of siblings; Educ = Years of education; Imilitary = Index of military service; Coma = LOC; Nrehab = Length of hospitalization in rehabilitation unit; Ndis = Number of disabilities; AgeI = Age at injury.