Journal of Clinical and Experimental Neuropsychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ncen20

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Published online: 23 May 2013.

To cite this article: Michal Sela-Kaufman, Yuri Rassovsky, Eugenia Agranov, Yifat Levi & Eli Vakil (2013) Premorbid personality characteristics and attachment style moderate the effect of injury severity on occupational outcome in traumatic brain injury: Another aspect of reserve, Journal of Clinical and Experimental Neuropsychology, 35:6, 584-595, DOI: 10.1080/13803395.2013.799123

To link to this article: http://dx.doi.org/10.1080/13803395.2013.799123

Journal of Clinical and Experimental Neuropsychology, 2013
Vol. 35, No. 6, 584–595, http://dx.doi.org/10.1080/13803395.2013.799123

Premorbid personality characteristics and attachment style moderate the effect of injury severity on occupational outcome in traumatic brain injury: Another aspect of reserve

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The concept of "reserve" has been proposed to account for the mismatch between brain pathology and its clinical expression. Prior efforts to characterize this concept focused mostly on brain or cognitive reserve measures. The present study was a preliminary attempt to evaluate premorbid personality and emotional aspects as potential moderators in moderate-to-severe traumatic brain injury. Using structural equation modeling and multiple regression analyses, we found that premorbid personality characteristics provided the most robust moderator of injury severity on occupational outcome. Findings offer preliminary support for premorbid personality features as another relevant reserve construct in predicting outcome in this population.

Keywords: Traumatic brain injury; Brain reserve; Cognitive reserve; Functional outcome; Personality.

Traumatic brain injury (TBI) has been reported as the most common cause of brain damage (Kurtzke, 1984; Langlois, Rutland-Brown, & Wald, 2006). The Centers for Disease Control and Prevention indicate that an estimated 1.7 million people incur TBI each year, and TBI is a contributing factor to a third of all injury-related deaths in the United States (Faul, Xu, Wald, & Coronado, 2010). Although most individuals sustaining significant brain damage manifest some degree of impairment (Cicerone & Fraser, 2000; Zillmer, Spiers, & Culberston, 2008), numerous reports indicate a lack of direct relationship between the extent of brain pathology and its clinical manifestation (Katzman et al., 1989). In other words, a brain insult of a certain magnitude may result in severe cognitive impairment in one person while having little effect on another.

The concept of "reserve" has been proposed to explain this mismatch between brain pathology or brain damage and the clinical expression of that damage (Stern, 2002). In this sense, the concept of "reserve" has been used as a potential buffer between brain pathology and clinical outcome (Satz, 1993; Stern, 2002, 2006). In the reserve literature, a distinction is typically made between brain

The authors wish it to be known that, in their opinion, the first two authors should be regarded as joint first authors. This study was carried out as part of a MA thesis by Michal Sela-Kaufman at The Academic College of Tel-Aviv–Yaffo, Tel-Aviv–Yaffo, Israel. The authors thank Irene Kopel for her assistance with interviewing participants and data management. No conflicts of interest exist for any of the authors.

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reserve (Satz, 1993) and cognitive reserve (Stern, 2002). Stern (2002) characterizes models of brain reserve as passive models (i.e., the amount of damage that can be sustained before reaching a threshold for clinical expression) and models of cognitive reserve as active models (i.e., differences in processing the relevant task). The former construct is typically indexed with total brain volume, intracranial volume, or ventricle-to-brain ratio, whereas the latter construct is commonly measured by premorbid educational and occupational attainment, IQ, and measures of specific cognitive functions (Bigler, 2007; Levi, Rassovsky, Agranov, Sela-Kaufman, & Vakil, 2013; Rassovsky et al., 2006a, 2006b; Satz, Cole, Hardy, & Rassovsky, 2011).

Despite conceptual utility and broad applications of these constructs, brain and cognitive reserve elements are unlikely to account for the entire variability in post-TBI outcome. For example, according to Prigatano (1992, 1999), emotional and motivational factors, which may largely reflect premorbid personality features, also play an integral role in patients' recovery process following TBI. Along these lines, McCauley et al. (2013) found that measures of psychological resilience and mood predicted severity of anxiety and postconcussive symptoms following mild TBI. Despite their potential predictive utility, there is still a substantial gap in knowledge regarding these factors, mostly due to challenges inherent in measuring premorbid variables (Handle, Ovitt, Spiro, & Rao, 2007; Nelson, Drebing, Satz, & Uchiama, 1998; Prigatano, 1999). Three major aspects of premorbid personality received notable attention in the literature: personality traits, attachment style, and temperament.

Personality traits have been typically studied within the context of resilience and coping with stressful events (Friborg, Barlaug, Martinussen, Rosenvinge, & Hjemdal, 2005). "The Big 5" dimensions of personality (Neuroticism, Extraversion, Openness to Experience, Conscientiousness, and Agreeableness) have been the focus of most of these studies (Costa & McCrae, 1992b). High neuroticism refers to the individual's tendency to experience psychological distress, including aspects of depression and anxiety, whereas high extraversion includes a number of properties such as the tendency to experience positive emotions, sociability, talkativeness, and energy. High openness to experience reflects developed emotional life, sensitivity to art, imagination, intellectual curiosity, and behavioral flexibility. High conscientiousness describes morality, organization, and diligence, whereas high agreeableness reflects the ability to trust others, feel sympathy toward others, and cooperate with others. Each of the five traits also contains a low level of the trait, mirroring its high level. Various studies have shown that high levels of extraversion, openness to experience, and conscientiousness (Davey, Eaker, & Walters, 2003; Riolli, Savicki, & Cepani, 2002), as well as agreeableness (Davey et al., 2003), were positively associated with mental resilience, whereas high neurotic personality traits were found to have the opposite effect (Campbell-Sills, Cohan, & Stein, 2006).

Attachment style is another aspect of premorbid personality thought to predict future adjustment (Svanberg, 1998). According to attachment theory (Bowlby, 1969), the nature and quality of attachment to the primary caregiver in early childhood provides the basis for the subsequent development of interpersonal behavior. Bowlby (1973) maintains that the nature of this early attachment explains individual differences in ability to cope with stressful situations. In this view, individuals who have experienced the attachment figure as available and supportive will believe in their ability to bear distress, whereas those who have experienced the attachment figure as distant and nonsupportive will grow with doubts regarding their coping ability. Based on this theory, Ainsworth, Blehar, Waters, and Wall (1978) defined three major attachment styles: secure attachment, avoidant attachment, and anxious/ambivalent attachment. Using this classification scheme, numerous investigators predicted successful and maladaptive emotional coping responses in a variety of contexts (e.g., Mikulincer, 1998; Mikulincer & Florian, 1995; Mikulincer & Florian, 2000; Mikulincer, Florian, & Tolmacz, 1990; Mikulincer, Horesh, Eilati, & Kotler, 1999; Solomon, Ginzburg, Mikulincer, Neria, & Ohry, 1998; Svanberg, 1998).

The third personality component, temperament, has been defined as an ongoing biological pattern of responsiveness and self-regulation that is affected by heredity, maturation, and experience (Rothbart & Derryberry, 1981). Temperament is thought to surface very early in life, to be influenced by genetics, and to remain stable across the lifespan (Whittle, Allen, Lubman, & Yucel, 2006). Studies have shown that temperamental properties may exert significant influence on adaptive behavior. For example, temperamental emotionality was found to predict behavioral problems, and temperamental sociability and shyness were found to influence the development of social skills (Mathiesen & Prior, 2006; Mathiesen & Sanson, 2000). Temperament then may also offer a unique contribution to the individual's coping and adjustment capabilities.

In the present study, we examined the role of these personality components in the context of reserve. That is, we evaluated whether they

would provide resilience or buffer against the detrimental effects of TBI on adaptive functioning. Prigatano (1987, 1999) proposed a connection between personality and TBI at three levels: (a) neuropsychological disorders, representing personality disorders that arise from neuropathology in brain structures that mediate emotional and motivational responses; (b) responsive disorders, including emotional and motivational responses that reflect a failure to cope with the demands of the environment due to decreased cognitive and personality resources; and (c) premorbid personality, reflecting previous emotional and motivational responses. This research examined how the third level, that of premorbid personality, contributes to the clinical picture following moderate-to-severe TBI. Specifically, we tested the reserve hypothesis by first examining whether premorbid personality factors predicted social, occupational, and psychological functioning that are typically impaired in TBI and subsequently testing whether the relevant variables moderate the influence of injury severity on these outcomes.

METHOD

Participants

The study included 61 individuals (93% male), who sustained moderate-to-severe TBI (82% closed head injury). Mean age of the sample was 37.9 years (SD = 12.2; range = 21–63), and the mean age at the time of injury was 26.1 years (SD = 7.73; range = 19–58). Inclusion criteria were based on TBI severity, defined by the following measures: (a) score of 12 or less in the Glasgow Coma Scale (GCS); (b) loss of consciousness (LOC) of 20 minutes or longer; and (c) posttraumatic amnesia (PTA) of at least 24 hours (Vakil, 2005; Williamson, Scott, & Adams, 1996). We focused on the moderate-to-severe TBI group because the differential diagnosis is much clearer than in cases of mild TBI. Only participants who were at least 18 years old at the time of injury were included in order to avoid potential confounds related to neural plasticity in children. Participants were assessed at least one year post injury, in order to achieve some stability in their neuropsychological status. They were recruited through the day treatment brain injury rehabilitation unit at the Chaim Sheba Medical Center at Tel-Hashomer, Ramat-Gan, Israel, and through the Rehabilitation Center for Veterans After TBI, Jaffa, Israel. In addition to physical rehabilitation, they maintained long-term involvement in a supportive program consisting of social, emotional, and occupational therapies for an average of 11.82 years (SD = 12.86). All participants gave written informed consent after receiving a full explanation of the research according to procedures approved by the Institutional Review Boards at each institution.

Measures and procedure

Injury severity data were extracted from patients' medical records. Questionnaires assessing psychological status and adaptive functioning were administered by trained research assistants. Finally, information regarding patients' premorbid personality was collected using questionnaires completed by their family members, mostly one of the parents or older siblings who grew up with the patient and was familiar with his or her premorbid personality.

Injury severity measures

Glasgow Coma Scale (GCS) score upon arriving to the emergency room was obtained from the medical record. The GCS (Teasdale & Jennett, 1974) is a clinician-rated instrument used to quantify level of consciousness following TBI and ranges from 3 to 15.

Loss of consciousness (LOC) was indexed using an ordinal scale: 1 = no coma, 2 = less than 24 hours, 3 = 1–7 days, 4 = 8–30 days, 5 = more than 30 days (Hoofien, Vakil, Gilboa, Donovick, & Barak, 2002).

Posttraumatic amnesia (PTA), assessed by the rehabilitation physician during hospitalization, was calculated using an ordinal scale: 1 = no PTA, 2 = less than an hour, 3 = 1–24 hours, 4 = 1–7 days, 5 = 8–28 days, 6 = 29–60 days, 7 = more than 60 days.

Premorbid personality measures

Personality traits were evaluated using the Neuroticism–Extraversion–Openness Five Factor Inventory (NEO-FFI), which is a shortened version of the Revised Neuroticism–Extraversion–Openness Personality Inventory (NEO-PI-R) and has a version for completing by family members (Costa & McCrae, 1992a). The questionnaire contains 60 items reflecting five dimensions of personality: agreeableness, extraversion, neuroticism, conscientiousness, and openness. Each item is scored on a 5-point Likert-scale format, from 0 (very irrelevant) to 4 (very relevant). The

questionnaire was filled by family members who were asked to assess the relevance of the item to the participant, based on their acquaintance with him or her prior to the injury.

Attachment style was evaluated using the Attachment Style questionnaire (Mikulincer et al., 1990). The questionnaire includes 15 statements regarding three attachment styles: secure, avoidant, and anxious/ambivalent. Each statement is scored on a 7-point Likert-scale format, from 1 (not at all relevant) to 7 (very relevant). The questionnaire was filled by family members who were asked to assess the relevance of the statement to the participant, based on their acquaintance with him or her prior to the injury.

Temperament was evaluated using the Emotionality–Activity–Sociability–Shyness (EAS) questionnaire (Buss & Plomin, 1984). The questionnaire contains 20 items reflecting four temperament aspects: emotionality—the tendency toward an intensive and rapid emotional reactivity; activity—the preferred level of activity and the speed of acting; sociability—the preference to be around people rather than being alone; and shyness—the tendency to be restrained and feel uncomfortable in new social situations. Each item is scored on a 5-point Likert-scale format, from 1 (not typical) to 5 (very typical). The questionnaire was originally designed to be filled by parents regarding their children's temperament during childhood. Accordingly, in this research parents were asked to assess the relevance of the items to their sons or daughters as young children (age 1 to 9).

Outcome measures

Social functioning was assessed using a Social Activity Questionnaire constructed for this study. This questionnaire contains seven questions examining the frequency of interactions with family members, friends, and acquaintances and is scored on a 5-point ordinal scale: 1 = never, 2 = once a year, 3 = once a month, 4 = once a week up to once in two weeks, 5 = daily. The score was calculated by summing the answers and dividing it by the maximum score the participant could obtain, not including irrelevant questions (e.g., a question regarding spouses for a bachelor, or parents for an orphan).

Occupational functioning was assessed using an Occupation Level Index. This index was largely based on Roe's (1956) categories, with an addition of two other domains to better characterize the present TBI population. The scale included the following levels: 0 = unemployed, 1 = sheltered employment or voluntary work, 2 = unskilled employment, 3 = skilled employment, 4 = executive position/professional occupation.

Psychological symptoms were assessed using the Brief Symptom Inventory (BSI) (Derogatis & Melistratos, 1983). The BSI is a shortened version of the Symptom Checklist-90-R (Derogatis, 1983). The instrument is a self-report symptom inventory that contains 53 items and is used to evaluate levels of psychopathology. It was found to produce three index scores: the General Severity Index (GSI), the Positive Symptom Total Index (PST), and the Positive Symptom Distress Index (PSDI; Gilbar & Ben-Zur, 2002).

Data analysis

The hypothesized underlying structure of personality constructs and the relationship between these constructs and outcome measures were examined using the structural equation modeling (SEM) approach. The latent constructs included injury severity (indexed with duration of LOC, GCS total score, and duration of PTA), personality traits (indexed with scores on the five dimensions of personality—agreeableness, extraversion, neuroticism, conscientiousness, and openness), attachment style (indexed with scores on the three dimensions of attachment—secure, avoidant, and anxious/ambivalent), and temperament (indexed with scores on the four dimensions of temperament—emotionality, activity, sociability, and shyness). The dependent variables included the Positive Symptom Total Index of the BSI and total scores on the Social Activity and Occupation Status measures. Given sample size limitations, separate models were tested for each of the dependent variables. All models were estimated with EQS Structural Equation Package (Bentler, 1996), using maximum likelihood solution. Moderation effects of premorbid personality variables between injury severity and outcome measures were tested using multiple regression analyses. Missing data were handled by first conducting analyses with listwise deletion and then repeating them with maximum-likelihood expectation-maximization (Jamshidian & Bentler, 1999). As the pattern of results from the two methods was virtually identical, only the results obtained using the second method are reported.

RESULTS

Descriptive statistics and factors

The means and standard deviations of the study variables are presented in Table 1. The factorial structure of injury severity and the personality constructs were examined with SEM, using EQS Structural Equation Package with maximum likelihood solution (Bentler, 1996). All independence models, testing whether or not the observed data fit the expected data, were rejected. (The chi-square for the independence model should always be significant, indicating that there is a relationship among the variables.) Standardized path coefficients of injury severity and the personality indicators on their respective latent constructs are presented in Table 1. As can be seen in the table, almost all indicators (except for secure attachment style and agreeableness) were significantly related to their respective latent variables. (Excluding the nonsignificant indicators slightly improved model fit but did not modify the pattern of subsequent predictions.)

TABLE 1
Means and standard deviations for the study variables, and standardized path coefficients of each measured indicator on its respective latent constructs for independent variables

Variable	*M*	*SD*	*Path coefficient*
Injury severity			
Glasgow Coma Scale	6.24	3.21	−0.64*
Loss of consciousness	3.57	1.09	0.95*
Posttraumatic amnesia	6.26	0.85	0.66*
Personality traits			
Neuroticism	17.3	6.87	−0.53*
Extraversion	30.2	6.48	0.29*
Openness	25	5.9	−0.35*
Agreeableness	31.5	7.23	0.26
Conscientiousness	38	6.21	0.99*
Attachment style			
Secure	4.85	0.92	−0.23
Avoidant	2.91	0.95	0.61*
Anxious/ambivalent	2.67	0.95	0.64*
Temperament			
Shyness	2.51	0.94	−0.99*
Emotionality	2.27	0.78	−0.45*
Activity	3.68	0.71	0.64*
Sociability	3.7	0.71	0.66*
Social functioning			
Social Activity Questionnaire	0.75	0.14	
Occupational functioning			
Occupation Level Index	1.69	0.83	
Psychological functioning			
Brief Symptom Inventory (Positive Symptom Total Index)	25.7	14.1	

Note. $^*p < .05$.

Predicting post-TBI outcome

SEM was conducted to test the direct contributions of injury severity and the personality components to the three outcome measures. The first set of models tested whether injury severity predicted each of the outcome measures. As can be seen in Figure 1, all three models provided good fit for the data. A good-fitting model is typically indicated by a nonsignificant chi-square. However, because the chi-square is very sensitive to sample size, it often rejects good-fitting models (Ullman, 2001). Therefore, the Comparative Fit Index (CFI) was also included, with values above 0.90 indicating good fit (Bentler, 1990; Hu & Bentler, 1999). All three standardized path coefficients were significant, indicating that injury severity predicted significant variance in social, occupational, and psychological functioning, respectively. Referring to Table 1 and Figure 1, the direction of path coefficients indicated that longer LOC and PTA and lower GCS scores were, respectively, associated with lower social and occupational functioning and higher psychological symptoms.

In the next set of models, we tested whether each of the personality constructs (personality traits, attachment style, and temperament) predicted

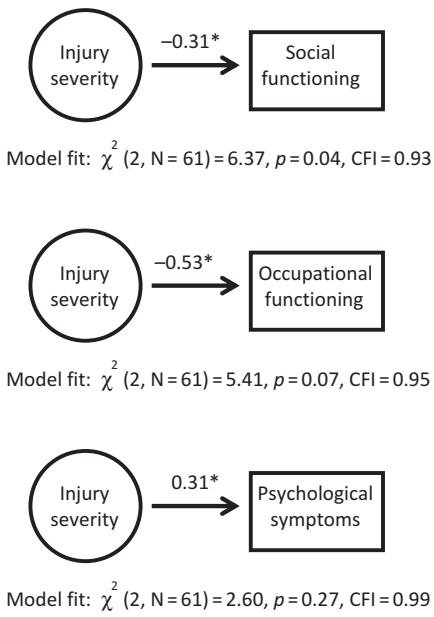

Figure 1. Structural equation models testing prediction between injury severity and outcome. Circles represent latent variables, and rectangles represent measured variables. Values are standardized path coefficients. CFI = comparative fit index. $^*p < .05$.

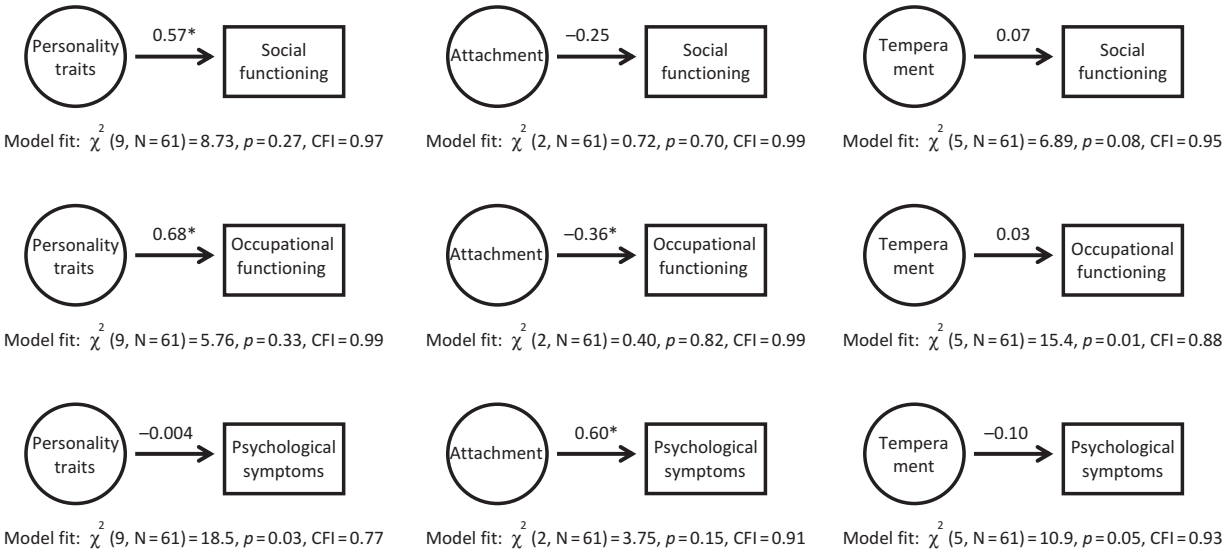

Figure 2. Structural equation models testing prediction between personality constructs and outcome. Circles represent latent variables, and rectangles represent measured variables. Values are standardized path coefficients. CFI = comparative fit index. $^*p < .05$.

post-TBI outcome. As can be seen in Figure 2, although most models provided a good fit for the data, a differential pattern of prediction among the personality constructs has emerged. Whereas personality traits (left column) significantly predicted social and occupational functioning, attachment style (middle column) significantly predicted occupational and psychological functioning. Finally, temperament (right column) did not significantly predict any of the outcome measures (see Figure 2).

Testing moderation of premorbid personality on post-TBI outcome

Given sample size limitations, it was not possible to use the SEM approach for testing moderation effects of entire personality constructs, and collapsing constructs into summary scores is not appropriate (Holmbeck, 1997; Little, Bovaird, & Widaman, 2006). Consequently, we used multiple regression analyses to test whether the different variables that significantly contributed to each of the personality components moderated the impact of injury severity on outcome. Injury severity was represented by LOC, as this measure had the highest loading on the latent construct (see Table 1), and moderation effects were examined for the models that significantly predicted outcome in the previous SEM analyses. Potential multicollinearity was handled by "centering" the predictor and moderator variables (i.e., subtracting the sample mean for the variable from individuals' scores on the variable) and subsequently creating an interaction term by multiplying the centered predictor and moderator variables (Aiken & West, 1991; Holmbeck, 1997). The predictor and moderator variables were entered in the first step followed by the addition of the interaction term. Given the exploratory nature of these analyses, no correction was used for multiple regressions.

The multiple regressions are presented in Table 2. As can be seen in the Table, although most models passed the overall test of significance, only a few measures significantly moderated the effect of injury severity on outcome measures. Specifically, analyses revealed that the personality measures neuroticism, extraversion, and conscientiousness significantly moderated the influence of injury severity on occupational functioning. Similarly, avoidant attachment style also significantly moderated the influence of injury on occupational functioning (see Table 2).

A graphical representation of the four significant interactions is presented in Figure 3. As can be seen in Figure 3a, whereas substantial occupational dysfunction resulted for all individuals with prolonged LOC, individuals low on the trait of neuroticism adapted much better than individuals high on that trait as the duration of LOC became briefer. Figure 3b depicts the moderating effect of extraversion, indicating that mainly for those individuals who scored high on that measure, prolonged duration of LOC adversely affected their occupational functioning, whereas lower LOC durations were associated with more favorable outcome for the high extraverts. Similarly, as can be seen in Figure 3c, for individuals scoring high on

TABLE 2
Regression analyses predicting post-TBI outcome

Regression model	*Variable*	R^2	*F*	*B*	*SE B*	*β*	*t*
1. DV	Social functioning	.13	2.96*				
IVs	LOC			−0.04	0.02	−0.29	−2.36*
	Neuroticism			−0.005	0.003	−0.25	−1.93
	LOC × Neuroticism			−0.001	0.003	−0.04	−0.32
2. DV	Social functioning	.08	1.58				
IVs	LOC			−0.03	0.02	−0.26	−2.04*
	Extraversion			0.001	0.003	0.05	0.35
	LOC × Extraversion			−0.001	0.003	0.08	−0.59
3. DV	Social functioning	.23	5.62**				
IVs	LOC			−0.04	0.02	−0.34	−2.77**
	Openness			−0.009	0.003	−0.37	−3.17**
	LOC × Openness			−0.003	0.003	−0.12	−0.96
4. DV	Social functioning	.24	6.07**				
IVs	LOC			−0.03	0.02	−0.25	−2.09*
	Conscientiousness			0.009	0.003	0.39	3.37**
	LOC × Conscientiousness			0.003	0.003	0.11	0.89
5. DV	Occupational functioning	.41	13.2***				
IVs	LOC			−0.36	0.08	−0.47	−4.57***
	Neuroticism			−0.06	0.01	−0.51	−4.89***
	LOC × Neuroticism			0.03	0.01	0.21	2.05*
6. DV	Occupational functioning	.22	5.49**				
IVs	LOC			−0.29	0.09	−0.38	−3.23**
	Extraversion			0.003	0.02	0.02	0.16
	LOC × Extraversion			−0.04	0.02	−0.27	−2.30*
7. DV	Occupational functioning	.19	4.35**				
IVs	LOC			−0.31	0.10	−0.41	−3.25**
	Openness			0.02	0.02	0.16	1.33
	LOC × Openness			−0.02	0.02	−0.12	−0.97
8. DV	Occupational functioning	.39	11.9***				
IVs	LOC			−0.22	0.08	−0.29	−2.75**
	Conscientiousness			0.06	0.01	0.43	4.05***
	LOC × Conscientiousness			−0.05	0.02	−0.29	−2.73**
9. DV	Occupational functioning	.24	6.05**				
IVs	LOC			−0.29	0.09	−0.38	−3.33**
	Avoidant			−0.13	0.10	−0.14	−1.25
	LOC × Avoidant			0.25	0.11	0.26	2.29*
10. DV	Occupational functioning	.23	5.64**				
IVs	LOC			−0.29	0.09	−0.39	−3.27**
	Anxious/Ambivalent			−0.21	0.10	−0.24	−2.02*
	LOC × Anxious/Ambivalent			−0.14	0.11	−0.14	−1.22
11. DV	Psychological symptoms	.17	3.86*				
IVs	LOC			−3.85	1.57	−0.30	−2.46*
	Avoidant			4.25	1.81	0.28	2.35*
	LOC × Avoidant			−1.19	1.91	−0.08	−0.62
12. DV	Psychological symptoms	.21	5.03**				
IVs	LOC			−4.06	1.55	−0.31	−2.62*
	Anxious/Ambivalent			5.20	1.76	0.35	2.95**
	LOC × Anxious/Ambivalent			1.01	1.91	0.06	0.53

Notes. TBI = traumatic brain injury; LOC = loss of consciousness; DV = dependent variable; IV = independent variable.
*$p < .05$. **$p < .01$. ***$p < .0001$.

conscientiousness, reduced duration of LOC was associated with better occupational functioning. Finally, the moderating effect of avoidant attachment style is depicted in Figure 3d. As can be seen in the figure, it was mainly for individuals who scored low on avoidant attachment that reduced LOC was associated with better occupational functioning.

DISCUSSION

This research constitutes a preliminary attempt to define and characterize premorbid personality constructs within the context of resilience against the detrimental effects of TBI on adaptive functioning and to examine its congruence to the reserve hypothesis. Based on available

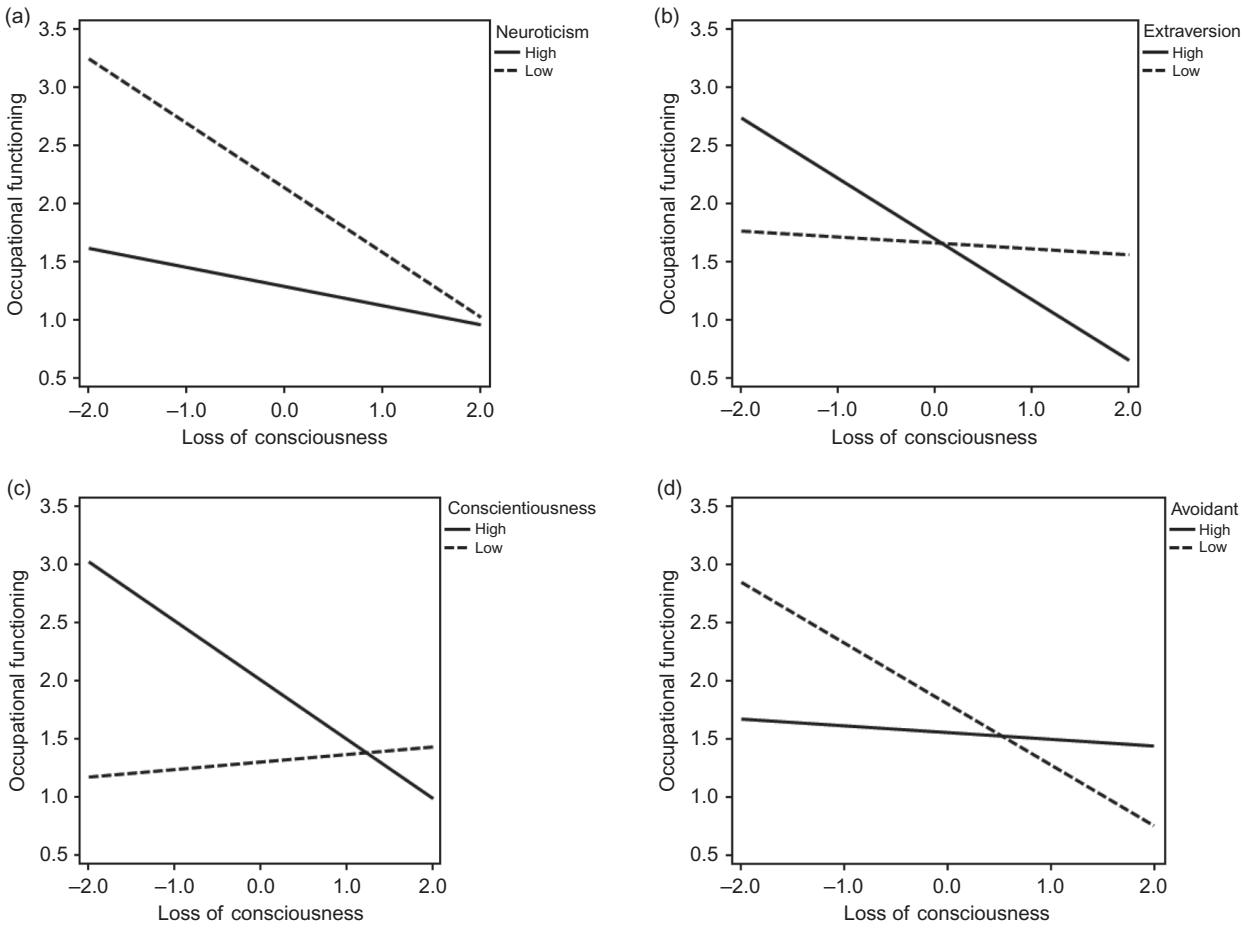

Figure 3. Significant interactions for regression models predicting occupational functioning from loss of consciousness and personality indices: (a) neuroticism, (b) extraversion, (c) conscientiousness, and (d) avoidant attachment style.

literature, three personality constructs were selected a priori, including personality traits, attachment style, and temperament (Costa & McCrae, 1992b; Friborg et al., 2005; Mathiesen & Prior, 2006; Svanberg, 1998). We tested the reserve hypothesis by first examining whether these constructs predicted social, occupational, and psychological outcome following TBI, and subsequently testing whether the relevant variables moderate the influence of injury severity on outcome measures.

Consistent with our hypotheses and prior research (Dikmen, Ross, Machamer, & Temkin, 1995; Levin et al., 1990; Macmillan, Hart, Martelli, & Zasler, 2002; Rassovsky et al., 2006a, 2006b; Ropacki & Elias, 2003; Tate & Broe, 1999), we found that injury severity significantly predicted all outcome measures, such that longer LOC and PTA and lower GCS scores were respectively associated with lower social and occupational functioning and higher psychological symptoms. Furthermore, examining whether each of the premorbid personality constructs predicted post-TBI outcome, results demonstrated a differential pattern of prediction across the outcome measures. Specifically, as can be seen in Figure 2, personality traits significantly predicted social and occupational functioning, attachment style significantly predicted occupational and psychological functioning, and temperament did not significantly predict any of the outcome measures. These findings demonstrate the relevance of certain personality features in influencing postinjury outcome, in addition to the obvious impact of injury severity (Malec, Brown, & Moessner, 2004; Novack, Bush, Meythaler, & Canupp, 2001; Rush, Malec, Brown, & Moessner, 2006; Tate, 2003; Temkin, Corrigan, Dikmen, & Machamer, 2009).

Most notably, the current findings bear relevance for the reserve hypothesis by directly testing whether the relevant personality proxies, identified in the previous step, moderate the impact of injury severity on post-TBI outcome. We found that among the various indices, only four measures (neuroticism, extraversion, conscientiousness, and avoidant attachment style) came out as significant moderators, and that these measures exerted a significant moderating effect only on occupational

functioning. It is of note that the same variables have been previously reported to predict adaptive behavior following TBI and other neurological diseases (Magai, Cohen, Culver, Gomberg, & Malatesta, 1997; Malec et al., 2004; Rush et al., 2006; Schretlen, 2000), although these studies did not directly examine moderation effects. Overall, it appears that among the three potential personality constructs hypothesized to reflect reserve, premorbid personality traits seem most relevant in moderating the impact of injury severity on outcome (although, as noted above, only three traits of the "Big 5" dimensions were found to be significant moderators).

These findings are thus consistent with Prigatano's (1999) argument, suggesting an important role played by premorbid personality in explaining the clinical picture after TBI. Measures comprising this construct constitute pervasive patterns of communication and interpersonal relationships. These personality dimensions provide a framework for connection, profound relationships with significant others, a sense of confidence and organization, and coping capabilities (Bowlby, 1973; Costa & McCrae, 1992b). It is therefore possible that adaptive personality features offer resilience or a protective buffer against the detrimental effects of TBI, whereas certain maladaptive traits may lead to ongoing difficulties in interpersonal relationships, lack of confidence, and a sense of inability to cope, thereby resulting in reduced adaptive functioning.

The pattern of predictions and moderation effects between personality and outcome measures found in the current study underscores the complex influence of premorbid personality features on post-TBI outcome. For example, as can be seen in Figure 3a, whereas substantial occupational dysfunction resulted for all individuals with prolonged LOC, individuals low on the trait of neuroticism adapted much better than individuals high on that trait as the duration of LOC became briefer. The moderating effect of extraversion was somewhat different, indicating that mainly for those individuals who scored high on that measure, prolonged duration of LOC adversely affected their occupational functioning, whereas lower LOC durations was associated with more favorable outcome for the high extraverts (see Figure 3b). These findings then offer additional support for the argument against collapsing constructs into summary scores (Holmbeck, 1997; Little et al., 2006), as such analytical approach would not have been able to detect the differential pattern of moderation effects.

It should be noted that the personality measures used in this study included self-report questionnaires, as well as retrospective family members' reports, and were therefore exposed to bias associated with this method of data collection. Additionally, given the lack of assessment tools designed for this purpose, we utilized available well-standardized measures in a nonstandard manner. Given these limitations, it is necessary to view our effort of conceptualizing and evaluating this construct as preliminary. Future longitudinal studies would be optimally suited to provide a more objective assessment of the impact of premorbid personality features on long-term adaptive functioning in TBI. In parallel, it would be essential to develop and validate additional measures that would index the diverse personality constructs as potential proxies of reserve.

Additionally, due to sample size limitations, we were unable to utilize the SEM approach for testing moderation effects of the personality constructs. Because of the problem of compounding measurement error when computing interaction terms, SEM strategies provide a less biased assessment of the significance of moderator effects (Holmbeck, 1997; Ping, 1996). Therefore, it would be useful to replicate the present findings in larger samples using SEM methods. Given the sample size and the diffuse nature of injuries commonly seen in moderate-to-severe TBI (Bigler, 2007), we were also unable to examine differential functional patterns according to sites of injury. As lesions in different brain regions might influence functional outcome in different ways, it could be informative to examine whether premorbid personality might play a differential moderating role on outcome according to injury patterns. Finally, it should be noted that given the severity of their injuries, participants received long-term supportive intervention, consisting of social, emotional, and occupational therapies. As these and similar forms of intervention could influence functional outcome, it would be informative to test larger models for mediation or moderation effects of various forms of intervention on different outcome domains.

Despite these limitations, this study represents an initial effort to introduce and evaluate an additional, potentially relevant, component of reserve against brain damage. Our findings demonstrate the potential influence of premorbid personality on post-TBI outcome. Nonetheless, given the aforementioned limitations, it would be important to validate this construct in other populations (e.g., healthy aging, Alzheimer's, schizophrenia). Additionally, it remains unknown whether the personality construct is distinct from other, previously described constructs, such as brain and cognitive reserve (Satz, 1993; Stern, 2002, 2006). Indeed, in

a recent study employing the SEM approach, it has been demonstrated that even the cognitive reserve construct itself may not be unitary (Levi et al., 2013). Prior studies have demonstrated a moderating role of brain and cognitive reserve constructs in aging (Brickman et al., 2011), multiple sclerosis (Sumowski, Chiaravalloti, Wylie, & DeLuca, 2009), and TBI (Salmond, Menon, Chatfield, Pickard, & Sahakian, 2006). Therefore, it would be important to examine the relationship between premorbid personality and these other, more established, constructs of reserve. Specifically, it would be informative to evaluate the shared variance among these constructs, as well as the combined and unique contribution and moderating effects of each of these constructs to functional outcome in healthy aging and in various neurological conditions. This line of research would likely improve our understanding of this important, albeit complex, construct of "reserve," which can then be used in designing more effective rehabilitation programs for a host of neurobehavioral conditions.

Original manuscript received 16 December 2012
Revised manuscript accepted 19 April 2013
First published online 21 May 2013

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