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Executive function and coping at one-year post traumatic brain injury

Katherine M. Krpan,[1,3] Brian Levine,[2,3,6] Donald T. Stuss,[2,3,5,6] and Deirdre R. Dawson[1,4,5]

[1]Kunin-Lunenfeld Applied Research Unit, Baycrest, University of Toronto
[2]Rotman Research Institute, Baycrest, University of Toronto
[3]Department of Psychology, University of Toronto
[4]Department of Occupational Science & Occupational Therapy, University of Toronto
[5]Graduate Department of Rehabilitation Science, University of Toronto
[6]Department of Medicine (Neurology), University of Toronto

The purpose of this study was to examine the relationship between executive function and coping at one-year-post traumatic brain injury (TBI). TBI and matched control groups completed a coping questionnaire and a neuropsychological test series. In the TBI group, better executive performance was related to the use of problem focused coping (considered more adaptive). Conversely, lower executive performance was related to the use of emotion focused coping (considered more maladaptive). Planned hierarchical regression showed that executive function contributed significantly to the use of problem focused coping above and beyond pre-morbid intelligence and injury severity. Implications for cognitive rehabilitation are discussed.

INTRODUCTION

Medical and technological advances have dramatically increased the survival rate of people suffering brain injuries secondary to serious accidents. As a consequence, more individuals are living with permanent disabilities that affect their productivity and quality of life (Crepeau & Scherzer, 1993; Dikmen, Ross, Machamer, & Temkin, 1995; Jennett, Snoek, Bond, & Brooks 1981; Rappaport, Herrero-Backe, Rappaport, & Winterfield, 1989). In the United States, every year there are approximately 1.5 million new cases of traumatic brain injury (TBI) (National Center for Injury Prevention and Control, 1999). It is estimated that 5.3 million Americans are currently living with disabilities resulting from TBI, at an estimated annual cost of almost 50 billion dollars (Kraus & McArthur, 1996). The long-term economic impact is most striking because TBI occurs most commonly in young adults (Thuraman, Alverson, Dunn, Cuerrero, & Sniezek, 1999). These prevalence and incidence data present clinical and experimental challenges to understand, and eventually to treat, the effects of TBI.

The purpose of this study was to examine the relationship between two factors that have been related to poor outcomes following TBI: executive function and coping style. Advancing the understanding of this relationship may have applications to rehabilitation, and ultimately improve quality of life for people with TBI.

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Address correspondence to Deirdre R. Dawson, Ph.D., OT Reg (ON), Kunin-Lunenfeld Applied Research Unit, Baycrest, 3560 Bathurst Street, Toronto ON M6A 2E1 (E-mail: ddawson@klaru-baycrest.on.ca).

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TBI and executive function

The prefrontal regions of the brain are particularly vulnerable to TBI. The acceleration-deceleration forces arising from motor vehicle crashes, falls and so on, result in diffuse axonal injury that may affect many brain structures and tracts, specifically affecting the frontal lobes (Levin & Eisenberg, 1991; Nevin, 1967; Stuss & Gow, 1992; Levine, Katz, Dade, & Black, 2002). Due to the tissue strains against the ridges of the anterior and middle fossa, the prefrontal regions of the brain are also particularly vulnerable to focal cortical contusions (Courville, 1937; Gentry, Godersky, & Thompson, 1988; Ommaya & Gennarelli, 1974). Moreover, diffuse damage can affect executive functioning through reduction in the efficiency of information processing, even when the prefrontal cortex is not specifically affected. Since the frontal lobes are accepted as the primary brain region responsible for executive functions (comprising a variety of processes such as initiation, planning, hypothesis generation, cognitive flexibility, decision-making, regulation, judgment, and feedback utilization) (Anderson & Tranel, 2002; Stuss & Benson, 1986; Stuss & Levine, 2002), there is a high probability that people with TBI will experience executive dysfunction, with consequences for outcome (Dawson, Catanzaro et al., 2004; Levin et al., 1990; Temkin, Holubkov, Machamer, Winn, & Dikmen, 1995). Executive deficits following TBI include, but are not limited to: impaired mental flexibility, poor adaptation to unique tasks (Dikmen, Reitan, & Temkin, 1983), poor judgement (Prigatano, 1987), reduced capacity for self-evaluation of abilities, impaired monitoring, and impaired ability to regulate impulses and formulate realistic plans of action (Levin et al., 1987).

TBI and coping

Among other factors that have been related to outcomes following TBI, coping has received considerable attention (Curran, Ponsford, & Crowe, 2000; Moore & Stambrook, 1994; Moore & Stambrook, 1995; Moore, Stambrook, & Peters, 1989). Coping is defined as a person's "constantly changing cognitive and behavioral efforts to manage specific external or internal demands that are appraised as taxing or exceeding the resources of the person" (Lazarus & Folkman, 1984, p. 141). The ability to cope with stressors is critical to attaining and maintaining a good quality of life (Moore & Stambrook, 1995). In a model put forth to account for negative outcome following TBI, coping was identified as the final common pathway leading to negative outcome (Moore & Stambrook, 1995).

The literature has conceptualized coping in two ways: problem focused and emotion focused (e.g., Carver, Scheier, & Weintraub, 1989; Curran et al., 2000; Finset & Andersson, 2000; Lazarus & Folkman, 1984; Milia, Powell, & Torode, 1995; Moore et al., 1989). *Problem focused coping* has been characterized as managing stress by actively seeking a solution to the problem. This may include defining the problem, generating alternative solutions, weighing the alternatives, choosing among the alternatives and acting upon them (Lazarus & Folkman, 1984). *Emotion focused coping* has been characterized as managing stress through emotion. Emotion focused coping may include avoidance, minimization, distancing, positive comparisons, and gaining positive value from otherwise negative events (Lazarus & Folkman, 1984). Emotion focused coping does not refer to coping by using emotional control, but rather to coping strategies that are less cognitive and more avoidant in nature (e.g., wishful thinking, sleeping, ignoring a problem, etc.). Lazarus and Folkman (1984) have suggested that emotion-focused coping, particularly denial, may be adaptive in the acute stages of stress (i.e., early in recovery from TBI), but these strategies are not adaptive in the long term.

The few investigations of coping post TBI have indicated that there are no measurable differences in coping style between TBI and matched control participants at several years post-TBI (Curran et al., 2000). However, Dawson and colleagues (2006) recently reported that emotion focused coping (specifically emotional preoccupation and escape avoidant coping) increases in the first 6 months post TBI, and that this increase is related to reduced productivity. Furthermore, the use of emotion focused strategies such as focus on worry, wishful thinking, self-blame, ignoring a problem and keeping to oneself have been related to increased psychosocial distress, depression and anxiety in TBI samples (Curran et al., 2000; Finset & Anderson, 2000; Lubosko, Moore, Stambrook, & Gill, 1994). Conversely, less use of these types of strategies related to better psychosocial outcome (Milia et al., 1995). Since emotion focused coping has been repeatedly linked to poor outcome following TBI in the post-acute stages, we consider it a maladaptive coping style.

Executive function and coping following TBI

Although the relationship between executive function and coping has not been examined in a TBI sample, we surmised that TBI-related deficits in

executive function would interfere with the ability to effectively select and employ flexible, adaptive coping strategies. Specifically we hypothesized that (1) problem focused coping requires executive processes, such as foresight, planning, and putting problems in perspective; (2) when problem focused coping is compromised by executive dysfunction, emotion focused coping may be used by default, in inappropriate contexts. As mentioned before, emotion focused coping does *not* refer to emotional control, but rather to coping strategies that are less cognitive and often more avoidant in nature. Thus, we hypothesized a direct relationship between higher levels of executive function and use of problem focused coping, and an indirect relationship between lower levels of executive function and use of emotion focused coping where emotion focused coping would be used because the ability to employ problem focused strategies had been compromised by executive impairment.

Support for a relationship between executive function and effective coping is garnered from studies investigating psychological and neuropsychological contributions to self-awareness and self-regulation following TBI, and from other patient populations. Among people with TBI, neuropsychological factors have been directly linked to deficits in self-awareness and self-regulation, where psychological factors (e.g., coping-related and personality-related denial) have been indirectly linked (Ownsworth, McFarland, & Young, 2002). The implications of these findings are that people with executive dysfunction who utilize avoidant coping strategies (denial) may under-report TBI related problems in clinical settings, thus impeding rehabilitation (see Ownsworth & McFarland, 2004). Among people with schizophrenia, a relationship between executive function and coping has also been reported (Wilder-Willis, Shear, Steffen, & Borkin, 2002). Independent of intelligence, Wisconsin Card Sorting Test performance (indicative of executive capacity) has been related to the use of 'active coping strategies' such as recovery through personal challenges and help seeking (Wilder-Willis et al., 2002). This type of coping is problem focused. In addition, there is a relationship between cognitive deficits and the use of emotion focused coping, where poor cognitive performance was associated with avoidant coping style (van den Bosch & Rombouts, 1997). The purpose of this study was to examine the relationship between executive function and both problem focused (specifically, planful problem solving) and emotion focused coping (specifically, escape avoidant) in a TBI sample. As previously stated, we hypothesize that executive performance will be related to both problem focused and emotion focused coping. We predict that higher executive performance will be related to the use of problem focus coping, and lower executive performance will be related to the use of emotion focused coping. We also predict that executive function will carry unique variance in the prediction of coping styles over and above other variables such as intelligence and injury severity (which have previously been related to outcomes, e.g., Dawson et al., 2004; Levin et al., 1990; Temkin et al., 1995).

METHODS

Design and participants

This study employed a cross-sectional design. Twenty-one TBI participants (14 male and 7 female) and 15 control participants (10 male and 5 female) were studied. The TBI participants were tested at approximately 12 months post injury (mean = 14.0, SD = 2.8) as a part of a larger prospective study. The larger study was concerned with the stability of particular psychological factors following TBI, and involved participants completing a number of questionnaires regarding coping, locus of control, life attitude, and community integration (Dawson et al., 2004; Dawson et al., 2006). TBI participants were recruited consecutively over 11 months (February 2002 – January 2003) immediately post injury (in-hospital) following admission to the largest medical trauma centre in Canada, Sunnybrook and Women's College Health Science Centre. Inclusion criteria were: English speaking, non-penetrating traumatic brain injury and at least 16 years of age. Patients were considered to have a brain injury if one or more of the following criteria were met: Glasgow Coma Scale score of less than 15, documented loss of consciousness, documented post traumatic amnesia, positive imaging results on a CT scan (Jennett & Teasdale, 1981; Jennett et al., 1981; Levin, Benton, & Grossman, 1982). Patients exhibiting a pre-trauma history of neurological disease, systemic disease, psychiatric disorder, substance abuse, or developmental disorders were excluded. In order to ensure that factors secondary to TBI were not contributing to coping style, patients with co-morbid spinal cord injury, serious burns, and serious facial disfigurement and/or amputations were also excluded. Control participants were drawn from friends and family members of the TBI participants in order to control for sociodemographic factors specific to TBI. Control participants were English speaking and did not have any serious

medical, psychiatric or substance abuse problems, and had no history of sustaining a brain injury or other neurological condition.

At the time of this study, fifty TBI participants met the inclusion criteria. Of these, 18 were not available for various reasons (10 lived too far away, 4 were too busy, 1 had serious medical problems, 1 had recently had a baby and 2 were advised against participation by their neuropsychologist or lawyer). Of the remaining 32, 21 agreed to participate in the present study.

The sample used in this study closely resembled the prospective sample. With respect to age, sex and years of education, there were no differences between the sample reported in this study and the larger sample used in the prospective study. Participants in this study were more severely injured ($p < .05$).

Measures

Two memory tests that emphasize the central executive (Baddeley, 1986) and control over interference (Stuss, Floden, Alexander, Levine & Katz, 2001b; Stuss et al., 1999) were selected. During the *alpha span* (see Craik, 1990), participants are initially verbally presented with two words and asked to verbally alphabetize them according to the first letter in each word. The number of words in the lists increases every second trial to a maximum of eight words. The primary measures of the alpha span are 1) the alpha score, that is the number of completely correct trials (maximum 14) and 2) the alpha span, that is the longest list giving at least one completely correct trial (maximum 8). The Brown-Peterson Procedure (Brown, 1958; Peterson & Peterson, 1959) was also administered to assess components of working memory and control over interference. Initially, participants are required to recall a verbally presented three consonant trigram with no delay period. Following five zero-delay trials, participants are presented with 20 more trigrams and required to count backwards by threes for 3, 9, or 18 seconds before recalling the trigram. The primary scores obtained from the Brown-Peterson are the number of correctly remembered letters following each of the 4 delay periods.

The Stroop Test was used to asseses the ease of shifting perceptual set to meet changing demands and the ability to suppress automatic responses in favour of unusual ones (Spreen & Strauss, 1998). Stimuli, administration and scoring were in concordance with the Comalli, Wapner, & Werner (1962) version (see also Stuss et al., 2001b). The Trail Making Test (TMT) parts A and B (Army Individual Test Battery, 1944) were used to assess speed of attention, visual search and motor function, and mental flexibility (Spreen & Strauss, 1998). The primary scores on the TMT are time to completion on parts A, B, B-A (difference score) and (B-A)/A (proportional score) (see also Stuss et al., 2001a). The Wisconsin Card Sorting Test (WCST) was administered to assess the ability of individuals to think abstractly, maintain and shift attention appropriately and to utilize feedback in problem solving. The WCST was administered according to the Grant and Berg (1948) criteria, and scored as specified by Stuss et al., (2000). Scores reported in this paper include perseveration to previous response (ppr), perseveration to previous category (ppr), total correct, categories complete, and set loss. The Revised Strategy Application Test (R-SAT) (Levine, Dawson, Schwartz, Boutet, & Stuss, 2000a; Levine et al., 1998) is a measure of self-regulation sensitive to the effects of moderate to severe TBI. The R-SAT is a paper and pencil test in which participants are required to trace figures, copy sentences, and number sets of shapes across a 10-minute time period in an attempt to accumulate maximum points. Items are worth either 0 or 100 points, and vary from extremely simple, to quite complex (these taking more time to complete). Healthy control participants usually employ a strategy of completing the small simple items and avoiding large or more complicated items in order to maximize points. [See Levine et al., 2000a, for detailed description of the test, scoring and administration.]

The Ways of Coping Questionnaire–Revised (WOC-R) (Folkman & Lazarus, 1988) was designed to assess strategies that people use in order to cope with stressful life events. Participants are asked to recollect a stressful event that has occurred within the last week, and respond using a 4-point Likert-type scale (0 indicating 'not applicable or not used', to 3 indicating 'used a great deal') to a series of 66 statements as to how they dealt with the stressful occurrence. The WOC-R has been used with TBI populations (e.g., Moore & Stambrook, 1994; Moore & Stambrook, 1992; Moore, Stambrook, & Peters, 1989) and has acceptable reliability and validity.

The WOC-R generates scores relating to eight coping styles: confrontive coping, distancing, self-controlling, seeking social support, accepting responsibility, escape-avoidant, planful problem solving, and positive reappraisal. This study focused on two coping styles in particular, 'planful problem solving coping' and 'escape avoidant coping'. We selected the escape avoidant subscale because it has been related to negative outcomes in earlier research (e.g., Dawson et al., 2006), and because the items on this scale are reflective of

avoidant, maladaptive coping. We selected the planful problem solving subscale because the items on this scale were most reflective of deliberate, instrumental coping behaviors that likely involve a number of executive functions in order to be executed effectively.

Pre-morbid intellectual functioning was assessed with the vocabulary subtest of the Shipley Institute of Living Scale (Zachary, 1982).

Procedure

Participants in this study (control and TBI) were recruited by telephone. Demographic and health related data, as well as coping data, were obtained from structured face-to-face interviews conducted by a trained research assistant and by chart extraction. Neuropsychological tests were administered by the primary author (KMK). Ethics approval for this study was obtained through the Ethics Review Board at Baycrest, Toronto, Ontario, Canada, and the University of Toronto, Ontario, Canada. Participants provided written consent prior to becoming involved in the study.

RESULTS

Classification of injury severity was based on 6-hour GCS scores. According to standard criteria (Teasdale & Jennett, 1974), 6 of the TBI participants had mild TBI (GCS 13–15), 11 had moderate TBI (GCS 9–12) and 4 had severe TBI (GCS 8 or less). There were no significant demographic differences between TBI and control participants. See Table 1 for participant characteristics.

To assess the differences between TBI and control groups with respect to memory, executive function and coping style, one-way ANOVAs were employed. Analyses were first conducted between controls and the entire TBI group, and then between controls and the two TBI groups composed according to injury severity (mild, and moderate to severe). As this was an exploratory study, p values were set at $p < .05$. There was considerable variation in neuropsychological performance in both control and TBI samples. However, no scores fell outside of three standard deviations of the mean (i.e., there were no outliers in this sample). Controls performed better then the mild TBI group on the alpha span ($p < .05$) and on overall recall on the Brown Peterson Procedure ($p < .05$). However, both the mild and moderate-severe TBI groups performed better than controls on the Stroop Test Word Naming ($p < .05$). No other significant differences were found on the neuropsychological measures used. There were no significant differences among the TBI groups or between the TBI group and the controls on the WOC-R (see Table 2) although trends show that the control participants used more coping strategies in each category.

TABLE 1
Demographic characterization of sample

	TBI *(n = 21)*	*Control* *(n = 15)*
Sex		
Male	14	10
Female	7	5
Mean Age in years (*SD*)	33.8 (± 12.5)	26.6 (± 7.6)
Mean Years of Education (*SD*)	14.1 (± 2.26)	14.6 (± 1.40)
Mean verbal score on the Shipley (*SD*)	28.3 (± 5.62)	29.8 (± 5.25)
Injury Severity		
6 hour GCS		
Mild (13–15)	6	n/a
Moderate (9–12)	11	
Severe (<9)	4	

For the correlational analyses, the relationships between variables were assessed separately within the TBI and control groups using Spearman's *rho*. Non-parametric correlations were used because of the small sample size and the amount of variability within groups. Correlations were performed between escape avoidant and planful problem solving coping, the demographic variables, and the neuropsychological variables reflective of executive functioning.

There were no significant relationships between coping and injury severity, age, years of education or gender in the TBI or control groups (see Table 3). There was a marginally significant ($p = .08$) positive relationship between planful problem solving coping and pre-morbid intellectual abilities (as measured by the Shipley) in people with TBI. A significant negative correlation ($p = .003$) was noted between intellectual abilities and escape avoidant coping in the TBI group. In control participants, there was a *negative* relationship ($p = .03$) between intellectual abilities and problem focused coping.

Turning to the relationships between neuropsychological test scores and coping (see Table 4), a number of significant relationships were evident, all in the directions hypothesized. Among the TBI participants, increased neuropsychological performance related to the use of planful problem solving coping, and decreased performance related to the use of escape avoidant coping. These relationships were not seen in the control group, with

TABLE 2
Mean (SD) score on Ways of Coping Questionnaire – revised

	Control (n = 15)	*TBI (n = 21)*	*Mild (n = 8)*	*Mod/Sev (n = 13)*
Confrontive	5.4 (3.7)	4.3 (3.6)	4.5 (3.6)	4.2 (3.8)
Distancing	6.2 (3.1)	4.9 (3.5)	6.0 (4.0)	4.5 (3.4)
Self-controlling	8.8 (4.1)	8.3 (3.7)	10.0 (4.0)	7.6 (3.5)
Seeking social support	8.0 (4.2)	5.9 (4.5)	5.1 (3.4)	6.2 (4.9)
Accepting responsibility	4.3 (3.4)	3.1 (2.9)	4.1 (1.7)	2.7 (3.2)
Escape-avoidant	7.0 (4.4)	5.0 (5.4)	6.6 (5.9)	4.4 (5.3)
Planful problem-solving	9.0 (4.5)	8.2 (4.4)	8.1 (3.7)	8.2 (4.7)
Positive reappraisals	6.3 (5.2)	5.6 (4.7)	5.8 (6.4)	5.5 (4.1)
Total score	8.9 (3.5)	7.3 (3.5)	8.1 (2.6)	6.9 (3.8)

Note. No significant differences between groups ($p < .10$). Higher scores mean more use of that strategy.

TABLE 3
The relationships between coping and participant characterization

	Planful Problem Solving		*Escape Avoidant*	
	TBI	*Control*	*TBI*	*Control*
Gender	–0.28 ($p = .22$)	–0.28 ($p = .31$)	0.11 ($p = .63$)	0.30 ($p = .28$)
Age	0.36 ($p = .11$)	–0.11 ($p = .68$)	–0.10 ($p = .65$)	0.05 ($p = .87$)
Education	0.32 ($p = .15$)	–0.31 ($p = .26$)	–0.18 ($p = .43$)	–0.09 ($p = .74$)
Shipley	0.39 ($p = .08$)	–0.57 ($p = .03$)	–0.62 ($p = .003$)	–0.19 ($p = .49$)
6 hour GCS	–0.21 ($p = .93$)	na	0.06 ($p = .80$)	na

Note. Correlation coefficient is Spearman's *rho.*

TABLE 4
The relationships between coping and neuropsychological performance

	Planful Problem Solving		*Escape Avoidant*	
	TBI	*Control*	*TBI*	*Control*
Brown Total Recall§	0.47 ($p = .05$)	0.10 ($p = .73$)	–0.60 ($p = .008$)	0.01 ($p = .96$)
Alpha Span§	0.09 ($p = .71$)	–0.34 ($p = .22$)	–0.66 ($p = .003$)	0.01 ($p = .98$)
Stroop Errors (INT)«	–0.39 ($p = .11$)	–0.22 ($p = .44$)	0.549 ($p = .02$)	–0.43 ($p = .11$)
Trails B-A«	0.06 ($p = .78$)	0.01 ($p = .96$)	0.30 ($p = .18$)	–0.10 ($p = .72$)
WCST Total Correct§	0.34 ($p = .12$)	–0.31 ($p = .26$)	–0.37 ($p = .09$)	–0.17 ($p = .53$)
WCST Categories§	0.26 ($p = .26$)	–0.47 ($p = .07$)	–0.22 ($p = .34$)	–0.13 ($p = .63$)
WCST PPR«	–0.25 ($p = .27$)	0.21 ($p = .44$)	0.46 ($p = .03$)	0.21 ($p = .45$)
WCST Set Loss«	–0.20 ($p = .39$)	0.26 ($p = .35$)	0.16 ($p = .48$)	0.19 ($p = .48$)
RSAT Proportion Easy§	0.48 ($p = .01$)	0.28 ($p = .31$)	–0.38 ($p = .086$)	–0.39 ($p = .15$)

Note. §higher score indicates better performance.
«lower score indicates better performance.

the exception that controls who scored marginally lower on the WCST (categories complete) used more escape avoidant coping. More specifically, performance on the Brown-Peterson task was significantly positively related ($p = .05$) to planful problem solving coping in people with TBI. Performance on both the Brown Peterson and Alpha Span tasks was negatively related to escape avoidant coping ($p = .008$, $p = .003$, respectively). Among tests of executive functioning, R-SAT performance was positively related ($p = .01$) to planful problem solving coping strategies in the TBI group. Correct responses on the WCST showed a marginally ($p = .09$) significant positive relationship to planful problem solving coping among people with TBI. Also in the TBI group, escape avoidant coping was positively related to Stroop (errors on interference) and WCST perseverations to the preceding response ($p = .02$, $p = .03$, respectively), with WCST correct responses and

the RSAT showing non-significant trends in a negative direction.

To help control for conducting multiple analyses using a small n, all the executive measure scores were transformed into *z*-scores, and summed to make a general executive composite score. This score was then correlated with escape avoidant and planful problem solving coping. The same patterns of correlations seen between individual executive function scores and coping were observed when using the general composite executive score. In the TBI group executive function (general executive composite score) was positively correlated with planful problem solving coping ($r = .621$, $p = .003$), and negatively correlated to escape avoidant coping ($r = -.501$, $p = .021$). There were no significant relationships between the general executive composite score and coping in the control group.

To determine if executive function contributed unique and significant variance to the use of planful problem solving and escape avoidant coping post TBI, planned hierarchical regression analyses were performed. Only three variables were entered into the regression to reduce confounds related to sample size. To ensure that executive function contributed uniquely to the models, pre-morbid intelligence and GCS were the first variables entered. To reduce the number of variables being entered into the models, a second set of composite scores of executive function were computed for each type of coping. Composite scores were computed based on the correlational analyses. All executive scores that correlated with coping where p was equal or less than .2 were transformed into *z*-scores and summed. Under these criteria, the composite score of executive function for planful problem solving coping consisted of Brown Peterson total recall, stroop errors on interference, WCST total correct and RSAT proportion easy. The composite score of executive function for escape avoidant coping consisted of Brown Peterson total recall, alpha span, Stroop errors on interference, Trails B-A, WCST total correct, WCST ppr, and RSAT proportion easy. These composite executive scores were the last variables to be entered into the model.

In the TBI group, executive function contributed unique and significant variance to the use of planful problem solving coping above and beyond injury severity and intelligence. In the first model, pre-morbid intelligence accounted for 26% of the variance in planful problem solving coping. Injury severity accounted for no additional variance. The third model included the composite executive function score, and was highly significant accounting for an additional 29% of the variance in the use of planful problem solving coping following TBI (see Table 5).

In the first model related to escape-avoidant coping, pre-morbid intelligence accounted for 35% of the variance. The second model included injury severity and was also significant, although the increase in variance accounted for by GCS was not significant (12%). The third model included the composite score of executive function and was also significant. However, the increase in variance accounted for was not significant with executive function accounting only for an additional 3.2% of the variance (see Table 5).

DISCUSSION

This is the first study we are aware of that examines the relationship between executive function and both problem focused (planful problem solving) and emotion focused coping (escape avoidant),

TABLE 5
Hierarchical regression analyses

Dependent measure	*Model & Variables*	*Model F-Value (p-value)*	*R-Square*	*Increase in R-Square Significance (p-value)*
Planful problem solving Coping	1. Shipley	5.64 (0.030)	0.26	
	2. Shipley + GCS	2.69 (0.100)	0.26	Model 2 to 1: 0.4% ($p = .78$)
	3. Shipley + GCS + Executive	5.81 (0.009)	0.55	Model 3 to 2: 29.0% ($p = .009$)
Escape avoidant coping	1. Shipley	8.62 ($p = .010$)	0.35	
	2. Shipley + GCS	6.69 ($p = .008$)	0.47	Model 2 to 1: 12.0% ($p = .08$)
	3. Shipley + GCS + Executive	4.72 ($p = .018$)	0.50	Model 3 to 2: 3.2% ($p = .361$)

Note. Shipley = Estimate of pre-morbid IQ.
GCS = 6 hour Glasgow Coma Scale.
Composite score of executive function for planful problem solving coping = Brown Total Recall, Stroop Errors on Interference, WCST total correct, RSAT proportion easy.
Composite score of executive function for escape avoidant coping = Brown Total Recall, Alpha Span, Stroop Errors on interference Trails B-A, WCST total correct, WCST ppr, RSAT proportion easy.

following TBI. As hypothesized, in the TBI group, better executive performance (working memory and strategy application) was related to greater use of planful problem solving coping strategies. Conversely, lower executive performance (speed of attention, sequencing, mental flexibility, inhibition, perseveration and working memory) was related to the increased use of escape avoidant coping strategies. There were no relationships between executive function and coping in the control group.

In addition to the relationships investigated between executive function and coping, relationships between pre-morbid intelligence, injury severity and escape avoidant coping were examined. In the TBI group, lower intelligence was associated with using more escape avoidant coping strategies. In this study, injury severity was not associated with coping. However, injury severity has been shown to be related to and predictive of outcomes in other studies (e.g., Dikmen et al., 1995; Dikmen et al., 2003). Thus, in order to ensure that intelligence, as well as injury severity, could not account for the relationships between executive function and coping, hierarchical regression was performed.

Executive function contributed significant variance to the use of planful problem solving coping, above and beyond injury severity and pre-morbid intelligence. This relationship emerged in spite of a lack of significant differences in the types of coping strategies being used by the TBI and control groups, and is consistent with work done by Wilder-Willis et al. (2002) who found a similar pattern in people with schizophrenia. Thus, our hypothesis that executive function would relate to planful problem solving coping, independent of other factors, was supported. Like people with schizophrenia, people with executive dysfunction following TBI may lack the cognitive capacity to implement coping strategies that require problem solving.

In contrast, executive function did not significantly add to the model explaining the use of escape avoidance coping. This was somewhat surprising as this type of relationship has been found in people with schizophrenia (van den Bosch & Rombouts, 1995). In the schizophrenia literature, it has been hypothesized that cognitive deficits interfere with patients' abilities to access adaptive (i.e., planful problem solving) coping strategies and thus, they engage in maladaptive coping (i.e., emotion focused) (Wilder-Willis et al., 2002, see also Nicholson & Neufeld, 1992). That is, emotion focused coping strategies may be the 'default' solution, rather than strategies that were consciously selected under the appropriate circumstances. The posited indirect nature of this relationship between the use of emotion focused coping and executive dysfunction may provide the explanation for the lack of significant findings in our study. In other words, it is possible that people with TBI are less able to use problem focused coping strategies such as making a plan of action and following through on it, or coming up with several solutions to a problem, and by default use emotion focused strategies such as wishful thinking, denial and taking out frustrations on other people. In this case, executive dysfunction following TBI does not directly affect variability in coping, but rather the application of effective, contextually adaptive coping strategies (likely to be most pronounced in unstructured, novel and stressful situations). This hypothesis helps to explain why executive function did not significantly contribute to emotion focused coping in our regression analyses and why emotion focused coping is related to negative outcomes following TBI. It may be that executive function is indirectly influencing emotion focused coping by compromising the ability to utilize problem focused strategies. In turn, emotion focused coping may be used by default in inappropriate situations, contributing to negative outcomes.

No relationships were found between coping and executive function in the control group. This finding is intriguing because there were no statistical differences in self-reported coping behavior and few differences in executive function found between the groups. We hypothesize that people with TBI must actively engage executive processes to implement effective coping strategies whereas healthy people (our controls) may be able to utilize effective coping strategies more automatically (with less executive control). Our data suggests that people with TBI are reliant on executive processes to engage in planful problem solving coping, whereas the people in the control group seem to be selecting coping strategies relatively independently of their executive function scores. Furthermore, even those controls with lower executive function appear to have adapted.

Implications for rehabilitation

Had we restricted our analysis to a simple group comparison of coping styles, we would have erroneously concluded that TBI does not affect coping (see Table 2). Rather, we found that among patients with TBI, variability in coping can be explained in part by variability in executive functions. As coping can be understood to be the final pathway between the sequelae of TBI and outcomes (Moore & Stambrook, 1995), these preliminary data provide evidence that suggests the choice of coping strategies is

influenced by cognitive status. This in turn, suggests coping should be explicitly considered in the rehabilitation process. For example, a rehabilitation protocol might involve teaching people to use a conscious process to select adaptive coping strategies, how to effectively use emotion focused coping strategies, and perhaps even how to decode and adaptively respond to emotional, or stressful stimuli (i.e., affective regulation). Rath, Simon, Langenbahn, Sherr, and Diller (2003) postulated that reducing problems in emotional self-regulation would aid in the development of efficient problem solving strategies. Supporting their hypothesis, they showed that a holistic rehabilitation program focused on emotional self-regulation and problem solving in simulated real-world situations (thus including a psychosocial component to their program) improved performance on a variety of measures of problem solving. Ownsworth and McFarland (2004) found that while patients with executive dysfunction showed clinical improvement on measures of awareness, strategic behaviour and psychosocial functioning following group rehabilitation, patients who utilized avoidant coping were less likely to improve. Based on previous literature, and the data presented in this paper, it appears that patients who utilize emotion focused coping strategies, specifically escape-avoidant strategies, should be identified, and rehabilitation programs more explicitly tailored to meet the special needs of this group. It seems most likely that a rehabilitation program incorporating training on systematic problem solving skills and affective regulation in the context of real-world situations would most benefit this group of patients. To what degree such rehabilitation would be efficacious, and whether it should be done in a context/task-specific fashion or using a metacognitive type of approach, are questions that can only be addressed through future research.

Limitations and suggestions for future research

There are a number of limitations to this study that point to areas for future research. The inclusion of tests sensitive to affective processes may have added more predictive power to our model. Although we have hypothesized the use of emotion focused coping is used as a default, it is possible that damage to the parts of the brain responsible for affect may underlie our findings. Future work may address the relative contribution of damage to cognitive and emotional brain regions to coping (a distinction made by Stuss & Levine, 2002) which was beyond the scope of this study. The sample size is small, thus limiting generalization to the larger population of people with TBI. Small sample size may have also contributed to some of the unexpected relationships found within the control group (e.g., negative relationship between intelligence and problem focused coping among controls). Nevertheless, these data provide a starting point for future investigations of these relationships. A third limitation of this study relates to our exclusion criteria. It order to isolate coping that is TBI specific, we excluded people that had a premorbid history of mental illness or substance abuse (these factors may have altered coping style). It is likely that excluding this group of people eliminated the individuals who are most challenging in a clinical setting, and whose maladaptive coping strategies may be most pronounced. Future studies should address the complexity of this subset of people with TBI, so that findings may be applied in a clinical setting. A fourth limitation relates to the coping style measure (WOC-R) which is a self-report questionnaire. People with TBI have also been reported to have poor insight/self-awareness and underestimate their impairments relative to their caregiver (Burgess & Robertson, 2002). This may have impacted the accuracy of the data reported. We are now electing to include data from significant others of TBI participants (Dawson, Catanzaro, Firestone, Schwartz, & Stuss, 2006). Ultimately it may be that some composite scores between TBI participants and their significant other proxies may provide the most accurate reflection of their true coping behaviors.

Conclusion

Coping is determined by multiple cognitive, social, and emotional processes. Cognitive processes are necessary to hold elements in working memory and attend to relevant features. Emotional processes are necessary to bias decision-making (on gambling tests, for example; Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, & Damasio, 2000), but even here, intact executive processes are necessary for successful performance (Bechara, Damasio, Tranel, & Anderson, 1998; Levine et al., 2005). Although causality is not proven in this study, our data suggest that executive dysfunction due to TBI-related brain damage affects coping mechanisms, likely contributing to psychosocial dysfunction, and thus negative outcomes.

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