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Relation of Executive Functioning and Affect to Psychosocial Outcome After Traumatic Brain Injury

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RELATION OF EXECUTIVE FUNCTIONING AND AFFECT TO PSYCHOSOCIAL OUTCOME AFTER TRAUMATIC BRAIN INJURY

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Abstract

The present study examined the interrelationships between affect and executive functioning and concurrently measured community integration and employability outcomes following traumatic brain injury (TBI). A sample of 227 adults with complicated mild to severe TBI completed neuropsychological measures of executive functioning, the Positive and Negative Affect Schedule, Community Integration Measure, and the Disability Rating Scale during follow-up evaluations that occurred up to 15 years postinjury. Contrary to previous cognitive research in this area, positive and negative affect were only weakly related to tests of executive functioning, with better performance associated with higher levels of positive affect and lower levels of negative affect. Regression analyses indicated that affect and executive functioning were independent predictors of perceived community integration and objectively assessed employability, respectively. However, hypotheses regarding the combined contribution of these variables to psychosocial outcome following TBI were not supported. Implications for measuring mood, executive functioning, and outcome in clinical practice and future research are considered.

Dedication

In loving memory of my grandmother, Alice Loton Blake.

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Introduction

Traumatic brain injury (TBI) constitutes a major health problem and a leading cause of death and disability in North America. An estimated 1.4 million Americans sustain a TBI each year, principally as a result of falls, motor vehicle collisions, and assaults (Rutland-Brown, Langlois, Thomas, & Xi, 2006). Epidemiological studies indicate the overall annual incidence of TBI is approximately 506 per 100 000 population, with adolescents, young adults, and those over age 65 at highest risk for brain injury; males are twice as likely to be injured irrespective of age (Corrigan, Selassie, & Orman, 2010). According to the Centers for Disease Control and Prevention, more than 3.2 million Americans live with TBI-related disabilities (Zaloshnja, Miller, Langlois, & Selassie, 2008). The enormous socioeconomic burden of TBI, in terms of direct medical costs and lost productivity, is estimated at $60 billion annually (Finkelstein, Corso, & Miller, 2006). Moreover, the psychosocial burden endured by survivors and their families due to consequent changes in cognitive, behavioural, emotional, and social functioning is immeasurable.

A review of the literature over the past two decades revealed a wealth of studies examining recovery from TBI and identifying factors that influence or predict psychosocial outcome. From a clinical perspective, outcome prediction is essential for rehabilitation planning, informing prognostic statements, assisting patients and families with adjustment, allocating resources, and assessing the effectiveness of interventions intended to reduce disability after TBI. Despite significant progress in this area, predicting psychosocial functioning following brain injury remains a challenging endeavour. In addition to establishing the significance of various predictor variables, a more complete understanding of the relationships among these variables is needed. Therefore, the primary aim of the current study was to examine the interrelationship between executive functioning and affect after TBI within the theoretical framework of a shared neuroanatomical architecture. The independent and cumulative contributions of these variables to psychosocial outcome were also examined.

Executive Functioning and TBI

Although the concept of executive functioning still awaits a formal definition, it generally refers to “those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior” (Lezak, Howieson, & Loring, 2004, p. 35). Subsumed under the rubric of executive functions are high-level cognitive abilities such as initiation, problem-solving, concept formation, abstract reasoning, planning, cognitive flexibility, and response inhibition that facilitate adaptation to novel or complex situations. While no single theory of executive functioning explains the entire range of these cognitive abilities, several influential models have shaped our current understanding of this multifaceted construct.

Models of executive functioning. Luria (1973) provided an early conceptualization of executive functions largely based on clinical observations of brain damaged patients. According to Luria, the brain is hierarchically organized into three functional units. The first unit is responsible for regulating cortical tone and wakefulness while the second unit is responsible for receiving, processing, and storing information from the outside world. The final functional unit is involved in programming, regulating, and verifying mental activity. This unit essentially represents an ‘executive’ system that allows the individual to formulate plans and programs of action. Luria further proposed that this executive system is dependent on the integrity of the prefrontal cortex. Thus, Luria provided an integrative account of executive control that highlighted the important role of the frontal lobes in “the most complex forms of man’s goal-linked activity” (p. 188).

The hierarchical nature of cognitive functioning is also emphasized in the prominent models of Baddeley (1986) and Norman and Shallice (1986). In Baddeley’s tripartite model of working memory, two separate slave systems (the phonological loop and the visuospatial sketchpad) are responsible for processing and temporarily storing information while the ‘central executive’ component is involved in regulating the distribution of limited attentional resources. More recently, Baddeley (1996) has attempted to specify the capacities of the central executive, namely the ability to carry out two tasks simultaneously, to attend selectively to one stream of incoming information while discarding others, to switch retrieval strategies, and to select and manipulate information in long-term memory.

Baddeley’s early conceptualization of the central executive is largely based on the Supervisory Activating System (SAS) component of Norman and Shallice’s (1986) model of attentional control. The SAS, located in the prefrontal cortex, is a mechanism employed in situations in which more automatic processing is inadequate (Shallice, 2002). Specifically, the SAS modulates a contention scheduling system that is specialized for automatized behaviours such as repetitive routines, procedures, and skills. This system utilizes schemas that channel behaviour into routinized patterns and place minimal demands on the individual’s attentional capacity. The supervisory system comes into play in novel or problematic situations and is capable of overriding habitual response patterns in order to initiate new behaviour (Baddeley, 1996). Shallice and Burgess (1996;

Shallice, 2002) have further fractionated the supervisory attention system into a set of parallel attention processes that work together to manage complex multitask behaviours.

Goldman-Rakic (1987, 1996) proposed a model of working memory in which the central executive is composed of multiple segregated processing domains rather than a central processor served by convergent slave systems. According to this view, different areas of the prefrontal cortex share the common function of 'on-line' processing of information or maintenance of representational information in the absence of the original stimulus; however, each area processes different types of information (Goldman-Rakic, 1996). The interaction of these working memory centres with posterior and subcortical areas within domain-specified cortical networks is held to constitute "a well designed parallel processing architecture for the brain's highest level cognition" (1996, p.1451). While Goldman-Rakic and colleagues based their model on evidence from single-unit recording and lesion studies in nonhuman primates, PET and fMRI findings in humans provide support for the role of focal prefrontal cortex activation in working memory tasks (Cohen et al., 1994; McCarthy et al., 1996).

Fuster (1995, 2001) also believed that the findings from neurophysiological research in animals provided a basis for understanding executive functions in humans. He proposed that the entire prefrontal cortex is dedicated to the memory, planning, or execution of actions. The orbital and medial regions, with extensive connections to the brainstem and limbic system, play a major role in behavioural inhibition whereas the cardinal function of the lateral prefrontal cortex is the "temporal integration of information for the attainment of prospective behavioral goals" (2001, p. 329). That is, the lateral prefrontal cortex integrates temporally separate units of perception, action, and cognition into a sequence toward a goal. In turn, four cognitive functions are said to underlie temporal integration: selective attention, working memory, preparatory set, and response monitoring. Together these retrospective and prospective processes allow for the maintenance of information pertaining to a goal and the preparation to act in anticipation of events (Jurado & Rosselli, 2007).

The field of cognitive science has offered an alternative approach to studying executive functions using neural network models (e.g., Cohen, Dunbar, & McClelland, 1990; Kimberg, D'Esposito, & Farah, 1998). One of the most comprehensive accounts is that of Miller and Cohen (2001) who argue that the prefrontal cortex exerts control over a wide range of processes through the active maintenance of patterns of activity that represent goals and the means to achieve them. In 'top-down' fashion, these patterns of activity provide bias signals throughout the rest of the brain, affecting sensory systems, cortical and subcortical motor systems, as well as limbic and midbrain systems involved in processing internal states such as affect, motivation, and memory retrieval. Collectively, the bias signals guide the flow of neural activity along pathways that establish the proper mappings between inputs, internal states, and outputs needed to perform a given task. Computational modeling studies based on this premise have simulated the behavioural performance of normal and frontally damaged patients on tasks sensitive to executive control, thereby contributing valuable support for the theory.

Lastly, Stuss and colleagues (Stuss, 2007; Stuss & Alexander, 2000) propose a model of executive functioning based upon research in patients with focal frontal lesions. The authors caution against confounding anatomy with a neuropsychological construct, but view their study of the functions of the frontal lobes as a necessary step toward understanding executive functions from a purely psychological standpoint. Specifically, Stuss recently posited four functional distinctions within the frontal lobes that correspond to specific anatomical regions: 1) executive cognitive functions that are involved in the control and direction (planning, switching, and monitoring) of lower-level, more automatic functions; 2) behavioural self-regulatory functions required in situations where cognitive analysis, habit, or environmental cues are not sufficient to determine the most adaptive response; 3) activation regulating functions that provide initiative and energizing behaviour at a level appropriate to the situation and to attain the individual's goals; and 4) metacognitive processes implicated in personality, social cognition, autonoetic consciousness, and self-awareness. The respective prefrontal regions purportedly associated with these functional domains are lateral, ventral (medial), superior medial, and frontal polar. The work of Stuss represents a valuable attempt to dissociate executive cognitive processes using tasks developed in cognitive psychology and calls attention to other important behavioural processes grouped under the term "executive" that are less likely to be tapped by traditional neuropsychological assessment.

Executive dysfunction. Deficits in executive functioning generally manifest as disorganized or poorly controlled behaviour. Specific impairments include, but are not limited to, distractibility, stimulus bound behaviour, perseveration, disorganization, poor response inhibition, impaired judgment and problem-solving, difficulties with planning and anticipating consequences, problems sequencing complex actions, and impaired emotional regulation (McCullagh & Feinstein, 2005).

The theories outlined above offer somewhat disparate explanations for these "dysexecutive" behaviours. For instance, persons with compromised executive functioning often perseverate or fail to modify their behaviour in response to changing environmental demands. According to Goldman-Rakic (1996), damage to the prefrontal cortex or associated cortical networks would result in the failure to suppress a prepotent response due to the inability to use working memory to initiate the correct response. That is, an individual would be rendered unable to form and/or access internal representations to guide behaviour and would therefore be forced to rely solely on external cues. In such circumstances, the individual will likely respond in a manner that has been previously reinforced. Miller and Cohen (2001) offer an alternative explanation in which a prepotent response is represented by a strong pathway between input and output mappings in the brain. In situations requiring the inhibition of a prepotent response in favour of another action, an internal representation of this goal is activated within the prefrontal cortex, which in turn biases signals to guide the flow of activity along a weaker pathway in order to establish the mappings needed to produce the contextually appropriate response. Damage to the prefrontal cortex would disrupt this top-down control mechanism, causing the individual to revert to the more habitual response.

Despite the lack of consensus regarding the nature of executive dysfunction, there is relative agreement among theorists in terms of the involvement of the frontal lobes, especially prefrontal cortices. Compelling evidence suggests that the prefrontal cortex is a vital component of a dynamic cerebral network that subserves executive functioning – a network that involves extensive reciprocal connections to posterior cortical regions and subcortical structures (Alvarez & Emory, 2006; Elliot, 2003). Three frontal-subcortical circuits have been identified as particularly important in this regard: the dorsolateral prefrontal, lateral orbitofrontal, and anterior cingulate circuits (Royall et al., 2002; see

Appendix A). Lesion and neuroimaging studies implicate the dorsolateral prefrontal circuit in planning, goal selection, working memory, set maintenance and shifting, verbal fluency, response inhibition, and self-monitoring; the lateral orbitofrontal circuit is involved in risk assessment and the inhibition of inappropriate behavioural responses; and the anterior cingulate circuit is important for self-monitoring and error correction (Cummings & Miller, 2007; Royall et al.). Importantly, executive dysfunction may result from damage to any of the frontal regions, subcortical structures, and neural pathways that comprise this circuitry.

Measures of executive functioning. The construct of executive functioning has proven as challenging to measure as it is to define. The assessment of executive abilities is complicated by the absence of a formal classification scheme as well as the multidimensional nature of the domain. As a result, the executive capacities of an individual must be inferred from performance on a variety of putative executive tasks in a neuropsychological evaluation. Given the inherent complexity of these tasks, a host of cognitive abilities in addition to executive facility are required for successful performance. Moreover, many of these tests have been validated solely on the basis of their sensitivity to frontal lobe damage and the precise nature of the executive process(es) that are involved is often unclear (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Further difficulties stem from the degree of external structure provided by the testing situation, which may serve to mask impairments in goal-setting, planning, initiation, and self-regulation, among other executive functions (Lezak et al., 2004; Stuss & Alexander, 2000). The fact that patients may perform adequately within the context of a structured testing environment, yet exhibit significant impairment in less structured "real world" situations is often cited as evidence of the limited ecological validity of executive tests.

Despite these challenges, a number of neuropsychological measures have been established as sensitive to executive functioning and are widely used in clinical practice (see Appendix B).

Executive dysfunction following TBI. The frontal lobes are particularly vulnerable to the mechanisms of injury associated with head trauma. In closed head injury, damage to the brain is primarily due to contact (i.e., a direct blow to the head or contact between the brain and the inner table of the skull) and acceleration/deceleration forces which give rise to focal and diffuse lesions (Gennarelli & Graham, 2005).

Focal lesions in the form of cortical contusions and lacerations characteristically occur in the frontal and temporal poles, the orbital surface of the frontal lobes, the inferior lateral surface of the temporal lobes, the gyri on either side of the Sylvian fissure, and beneath or contralateral to the site of impact (coup or contrecoup contusions; Gennarelli & Graham, 2005). The disproportionate susceptibility of ventral and polar frontal and temporal regions to focal lesions largely relates to their proximity to the bony protuberances of the anterior and middle cranial fossa (Bigler, 2007). That is, powerful acceleration/deceleration forces cause the tissue of the frontal and temporal lobes to grate and deform against the ridges and confines of the skull, resulting in contusions and, in the event that the pia is torn, lacerations. Lacerations are often associated with subdural hematomas (due to rupture of bridging veins within the subdural space) and intracerebral hematomas (due to the rupture of blood vessels within the brain parenchyma; Graham, Adams, Nicoll, Maxwell, & Gennarelli, 1995). In particular, disruption of subcortical penetrating vessels may result in deep hemorrhages affecting frontal-subcortical circuitry.

Secondary damage to frontal systems after focal injury may result from delayed neuronal injury, herniation syndromes (especially frontal transfalcine herniation that may compromise medial frontal lobes and anterior cerebral artery perfusion), and hypoxic-ischemic injury.

In addition to focal lesions, traumatic brain injury involves diffuse damage resulting from shear and strain caused by inertial forces present at the time of injury (Graham et al., 1995). Examples of this type of pathology include hypoxic-ischemic brain damage, diffuse brain swelling, diffuse vascular injury, and diffuse axonal injury (DAI; Gennarelli & Graham, 2005). The latter results from acceleratory/deceleratory forces leading to disruption of axonal transport which progresses to axonal disconnection and distal axonal degeneration – a process that occurs over several hours to days following injury (Povlishock & Katz, 2005). A degree of DAI is implicated in every injury involving a loss of consciousness and a direct relationship between the degree of DAI and injury severity has been confirmed (Gennarelli & Graham). The parasagittal frontal white matter, corpus callosum, and the pontine-mesencephalic junction adjacent to the superior cerebellar peduncles have been identified as the predominant sites of axonal damage (Graham et al.; Meythaler, Peduzzi, Eleftheriou, & Novack, 2001). Ultimately, DAI leads to widespread deafferentation of axonal projections throughout the brain, including those of prefrontal systems. In turn, this disconnection phenomenon is thought to be the basis for many of the impairments associated with TBI (Meythaler et al.; Povlishock & Katz).

As noted by Bigler (2007), forces sufficient to damage brain tissue are also sufficient to damage blood vessels such that vascular injury is often seen concomitantly with DAI. Petechial hemorrhages due to the disruption of small blood vessels are often concentrated in frontal regions (Scheid, Preul, Gruber, Wiggins, & von Cramen, 2003). Moreover, DAI is accompanied by a cascade of complex biochemical processes involving the excessive release of excitatory amino acids, disruption of cellular calcium homeostasis, and the production of free radicals, all of which serve to exacerbate the effects of primary damage (Novack, Dillon, & Jackson, 1996; Povlishock & Katz, 2005).

The susceptibility of the frontal lobes and associated neural pathways to the aforementioned mechanisms of brain damage is assumed to underlie the core cognitive and neurobehavioural symptoms of TBI (Bigler, 2007; Cicerone, Levin, Malec, Stuss, & Whyte, 2006). Specifically, a pattern of impairment in executive functioning, attention, processing speed, and learning and memory is frequently reported following TBI (Dikmen, Machamer, Winn, & Temkin, 1995; Levin et al., 1990; Millis et al., 2001; Novack, Anderson, Bush, Meythaler, & Canupp, 2000). In general, the extent of cognitive impairment has been found to vary according to the severity of brain injury, time since injury, and premorbid factors (Dikmen et al.).

With respect to executive functioning, deficits on neuropsychological measures sensitive to reasoning, concept formation, problem solving, cognitive flexibility, set-shifting, initiation and productivity, working memory, and planning have been consistently demonstrated following moderate to severe TBI (Cockburn, 1995; Dikmen et al., 1995; Ferland, Ramsay, Engeland, & O'Hara, 1998; Gansler, Covall, McGrath, & Oscar-Berman, 1996; Greve et al., 2002; Kersel, Marsh, Havill, & Sleigh, 2001; Leon-

Carrion et al., 1998; Levin et al, 1990; Millis et al., 2001; McDowell, Whyte, & D'Esposito, 1997). Studies have further revealed that such deficits may persist for years postinjury, although there is considerable variability among brain injury survivors in terms of level of performance, especially with more severe injuries. This was effectively demonstrated by Millis and colleagues who found that a substantial proportion (>40%) of individuals with moderate to severe TBI exhibited impairment on executive tests (i.e., Trail Making Test – Part B, COWAT, and WCST) 5 years after injury. At the same time, the range of observed test scores indicated significant variability in the extent of residual deficits, ranging from severe to no measurable impairment.

Impairments in executive functioning are also noted in the subjective complaints of TBI survivors and their caregivers (Donnelly, Donnelly, & Grohman, 2005; Marsh & Kersel, 2006; Martin, Viguier, Deloche, & Dellatolas, 2001; van Zomeren & van den Burg, 1985). Ponsford, Olver, and Curran (1995) examined the problems experienced by individuals who had sustained a severe TBI two years prior using structured interviews. From a cognitive standpoint, the majority reported memory problems, slowed thinking, concentration difficulties, and word-finding problems. Almost half of the TBI survivors also endorsed ongoing difficulties with planning and organization, impulsiveness, and reduced initiative. A follow-up study revealed that the profile of reported cognitive and behavioural problems remained relatively unchanged at 5 years postinjury (Olver, Ponsford, & Curran, 1996).

In summary, executive dysfunction is a pervasive and persistent sequela of TBI, presumably due to the vulnerability of frontal systems to injury. Damage to the prefrontal cortex itself or to the extensive interconnections of the frontal cortex with other cortical and subcortical regions has been associated with a vast array of impairments in executive functions, including concept formation, rule detection, problem solving, mental flexibility, planning, anticipation of consequences, working memory, initiation, temporal sequencing, response inhibition, and self-regulation. It stands to reason that compromised executive functioning may represent a significant barrier to functional independence, employment, and social integration following TBI. Indeed, the integrity of executive functions is crucial to the execution of everyday tasks ranging from preparing a meal, to driving a car, to effectively maintaining interpersonal relationships and job responsibilities. The ability of neuropsychological assessment to capture the extent of impairment in executive functions and associated consequences for psychosocial outcome after TBI has been a topic of increasing research interest.

Relation of executive functioning to psychosocial outcome after TBI. The primary role of neuropsychological assessment has gradually shifted away from assisting in the diagnosis of brain pathology to addressing questions about individuals' everyday cognitive abilities and limitations (Chaytor & Schmitter-Edgecombe, 2003). Referral questions often pertain to issues such as the TBI survivor's suitability for rehabilitation programs, ability to work or attend school, live independently, manage finances, and drive. Accordingly, concerns over the degree to which neuropsychological test performance corresponds to real-world functioning (i.e., the ecological validity of neuropsychological test findings) have transpired (Sbordone, 1996).

Notwithstanding methodological limitations of many studies to date (see Sherer et al., 2002), the literature provides empirical support for the utility of neuropsychological measures in the prediction of psychosocial outcome following TBI (Boake et al., 2001;

Hanks et al., 2008; Hart, Millis, et al., 2003; Millis, Rosenthal, & Lourie, 1994; Neese et al., 2000; Ross, Millis, & Rosenthal, 1997; Ruff et al. 1993, Sherer, Sander, et al., 2002). Moreover, there is a modest but growing body of evidence supporting the predictive validity of executive functioning measures, specifically. For instance, in a large-scale review of factors related to employment outcome, Ownsworth & McKenna (2004) identified measures of executive function as the most reliable neuropsychological predictor of return to work. Tests tapping concept formation, divided and selective attention, mental flexibility, mental programming and planning were associated with employment outcome in a number of different studies. Similarly, Hart and colleagues (Hart, Millis, et al., 2003) noted that performance on a comprehensive battery of neuropsychological tests predicted level of caregiver supervision one year postinjury in a large group of TBI survivors. However, only measures of working memory and cognitive flexibility (i.e., digits backward, COWAT, and WCST) successfully differentiated those individuals requiring moderate versus heavy supervision.

While research has typically focused on single or selective measures of executive functioning and individual outcomes such as return to work, several notable studies have employed a broader approach. Hanks and colleagues (1999) investigated the utility of executive functioning measures in predicting functional outcome 6 months after discharge in a mixed rehabilitation sample that included a substantial proportion (50%) of patients with TBI. The authors reported that tests tapping problem solving, abstraction, planning, cognitive flexibility, and working memory skills (i.e., TMT-B, LNS, COWAT, WCST) were strongly associated with outcome upon re-entry to the community as measured by the Community Integration Questionnaire (CIQ; Willer, Rosenthal, Kreutzer, Gordon, & Rempel, 1993) and the Disability Rating Scale (DRS; Rappaport, Hall, Hopkins, Belleza, & Cope, 1982). Additionally, tests of executive functioning and verbal memory were found to predict functional outcome beyond information regarding sensory and motor functioning.

More recently, Stuchen et al. (2008) examined the relationship between executive functioning and concurrently measured occupational and social integration outcomes in 121 individuals with TBI. Participants had all received comprehensive brain injury rehabilitation and were, on average, 6 years postinjury at the time of assessment. In line with the findings of Hanks et al. (1999), performance on measures of response initiation and inhibition, planning, problem solving, and cognitive flexibility (i.e., D-KEFS Color-Word Interference and Sorting Tests, TMT-B, COWAT) contributed to both occupational functioning and social integration. Among the executive functioning measures, better performance on the response inhibition task was associated with increased participation in productive activities while cognitive flexibility, as reflected in faster performance on TMT-B, was associated with increased social integration. These findings offer further support for the ecological validity of executive functioning measures and highlight the importance of the integrity of higher –level cognitive skills for “real world” functioning (Hanks et al.).

The association of executive functioning to outcome after TBI is not surprising considering the complexity of behaviors required for successful integration into home, social, and community roles. Yet, several methodologically sound investigations have failed to demonstrate the value of executive functioning tests in predicting functional outcome (e.g., Malec, Smigielski, DePompolo, & Thompson, 1993). Furthermore, those studies that validate the predictive ability of executive functioning tests also report that a great deal of the variance in outcome remains unaccounted for by performance on these measures. For instance, Struchen et al. (2008) reported that executive functioning variables accounted uniquely for 13% of the variance in occupational functioning and 16% of the variance in social integration in their sample. As such, further research is not only needed to clarify the association between executive test performance and real-world functional outcomes in TBI, but also to identify additional factors that may influence this complex relationship.

Mood and TBI

In addition to cognitive impairment, the TBI literature documents a high incidence of mood disturbance that can impede rehabilitation efforts and influence long-term outcome (Hesdorffer, Rauch, & Tamminga, 2009; Rosenthal, Christensen, & Ross, 1998). Much of the research in this area has focused on depression, which affects 11% to 44% of survivors within the first year postinjury (Rogers & Read, 2007). This estimate rises to 53.1% when assessed more frequently (Bombardier et al., 2010). However, depression is a heterogeneous disorder involving affective as well as somatic and cognitive symptoms, many of which are also common sequelae of TBI. As a result, studies that employ popular measures of depressive symptomatology may overestimate the extent of mood disturbance in TBI populations (Dikmen, Bombardier, Mchamer, Fann, & Temkin, 2004). Moreover, the reliance on such measures does not permit the systematic examination of the affective component of post-TBI depression.

In order to address the limitations associated with assessing mood after TBI in terms of broad constructs such as depression, the present study examined its fundamental affective constituents - positive and negative affect.

Positive and negative affect. A vast body of research on the basic structure of affect has revealed that subjective affective experience is best captured by a two-dimensional circumplex, with mood descriptors arranged in circular space. Watson and Tellegen (1985) proposed such a model based on compelling evidence that positive and negative affect are the dominant dimensions in self-reported mood. According to the authors, "although the terms *Positive Affect* and *Negative Affect* might suggest that these two mood factors are opposites (that is, strongly negatively correlated), they have in fact emerged as highly distinctive dimensions that can be meaningfully represented as orthogonal dimensions…" (Watson, Clark, & Tellegen, 1988, p. 1063; but see also Russell & Carroll, 1999). A depiction of Watson and Tellegen's two-factor model is presented in Appendix C.

Generally speaking, positive affect (PA) represents the extent to which a person feels enthusiastic, active, and alert. High PA is a state of high energy and pleasurable engagement with the environment, whereas low PA is characterized by sadness and lethargy. By contrast, negative affect (NA) is epitomized by subjective distress and unpleasurable engagement and encompasses a variety of aversive mood states including anger, contempt, disgust, guilt, fear, and nervousness; low NA reflects a state of calmness and serenity (Watson et al. 1988; see Appendix C). The Positive and Negative Affect Schedule (PANAS; Watson et al.) was developed to provide a brief measure of PA and NA (see Appendix D).

Notably, Watson and colleagues (Watson, Wiese, Vaiday, & Tellegen, 1999) came to view PA and NA as unipolar constructs that are essentially defined by the activated, high ends of each dimension. That is, the lower ends of each dimension are characterized by the absence of positively and negatively valenced affects, respectively (i.e., low PA is better characterized by the *absence* of enthusiasm and alertness than by the *presence* of sluggishness). The authors further argue these dimensions represent the subjective components of evolutionarily adaptive motivational systems that mediate approach and withdrawal behaviours. Briefly, the approach system facilitates appetitive behaviour and positive emotional states associated with the PA dimension are thought to serve as a source of motivation and reward for this goal-directed behaviour (Watson et al.). In contrast, the withdrawal system facilitates withdrawal from sources of aversive stimuli. NA serves this function inasmuch as the negative emotional states that characterize the NA dimension promote vigilant apprehensiveness (Watson et al.). In keeping with this framework, the authors revised their original assertion that PA and NA are entirely independent of one another; however, they maintained that the dimensions are highly distinct.

Although PA and NA represent affective states, they are closely related to the dispositional dimensions of positive and negative affectivity (i.e., individual differences in positive and negative emotional reactivity). At the trait level, NA reflects stable individual differences in the tendency to experience aversive emotional states such as fear, guilt, sadness, and anger, whereas trait PA corresponds to a predisposition to experience positive states such as enthusiasm, confidence, and cheerfulness (Tellegen, 1985; Watson & Clark, 1984; Watson et al., 1999). Trait NA and PA have been shown to be differentially related to the personality dimensions of neuroticism and extraversion that appear in factor analytically derived models of personality (e.g., Eysenck, 1970; Goldberg, 1993). Specifically, measures of trait NA were strongly correlated with scores on the neuroticism scales, but weakly related to scores on the extraversion scales from the Big Five Inventory (John, Donahue, & Kentle, 1991) and NEO Personality Inventories (Costa & McCrae, 1992). Conversely, measures of trait PA were more strongly related to extraversion than to neuroticism scores (Watson and Clark, 1992).

Researchers have also focused on the relation of NA and PA to psychopathological constructs. Watson and associates (Clark & Watson, 1991; Tellegen, 1985; Watson, Clark, & Carey, 1988) posited that anxiety and depressive syndromes share a common factor of negative affectivity or generalized affective distress (i.e., high NA). However, low PA (akin to the concept of anhedonia) is considered a distinctive feature of depression. Accordingly, researchers have administered the PANAS in clinical samples and found PA to be specifically related to depression and not anxiety, but NA to be highly related to both (Jolly, Dyck, Kramer, & Wherry, 1994; Watson, Clark, & Carey, 1988). Recent research has also emphasized the role of PA in understanding bipolar disorder. For example, Meyer and colleagues (Hofmann & Meyer, 2006; Meyer & Baur, 2009) used the PANAS to demonstrate that individuals at risk for bipolar disorder report higher levels of PA and more fluctuations in PA relative to controls. Thus, the PANAS appears to provide a means to specifically examine the affective component of complex constructs such as depression and mania.

Relation of affect and executive functioning. Advances in the field of affective neuroscience have confirmed that the neural substrates of mood and cognition encompass overlapping networks of cortical and subcortical regions (Phan, Wager, Taylor, & Liberzon, 2002; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). Studies of the functional neuroanatomy of emotion have concluded that the prefrontal cortex plays a crucial role in this circuitry, along with the ventral striatum, amygdala, hypothalamus, and cingulate cortex (Dalgleish, 2004; see Appendix E). Although the exact function of the prefrontal cortex in emotion remains uncertain, several influential hypotheses have been proposed. The orbital prefrontal cortex is considered important for learning the emotional and motivational value of sensory stimuli through reinforcement contingencies (Rolls, 1999) while the ventromedial aspect of this region has been specifically implicated in emotional decision-making (Damasio, 1996). Others argue that the prefrontal cortex sends bias signals to other areas of the brain to guide behaviour toward the acquisition of a more adaptive goal in the face of competition from potentially stronger alternative responses that are linked to immediate emotional consequences (Davidson & Irwin, 1999).

Positive and negative affect appear to be mediated by somewhat independent prefrontal substrates. Both positive and negative induced mood states have been shown to activate orbital and medial prefrontal cortex using PET (Baker, Frith, & Dolan, 1997; Phan et al., 2002), indicating these regions may play a general role in emotional processing. However, Davidson and colleagues used similar techniques to demonstrate that positive affect is predominantly associated with left-sided activity whereas negative affect is associated with right-sided activity (Davidson, 1992). Further, stable differences in prefrontal activation asymmetry were linked to temperamental dispositions toward PA and NA (Tomarken, Davidson, Wheeler, & Doss, 1992; Davidson, 1998).

The increasing appreciation of the role of the prefrontal cortex in both the processing and regulation of mood and executive cognitive functions has prompted an intriguing line of research regarding the reciprocal influence of positive and negative mood on executive functioning. For the most part, evidence for this interrelationship stems from laboratory studies of the effects of induced mood states on executive functioning and research on the cognitive correlates of mania and depression.

Mitchell and Phillips (2007) reviewed studies examining the effects of experimentally manipulated mood on executive control processes in non-clinical samples. In these studies positive (happy) and negative (sad) mood states were induced through reading self-referent statements, listening to classical music, and/or watching film clips designed to evoke affective reactions. In some cases participants were asked to recall and describe an autobiographical memory that has a particular emotional connotation. The authors reported that mild fluctuations in positive mood were found to impair working memory, as measured by a complex reading span task (Spies, Hesse, & Hummitzsch, 1996); planning, as measured by the Tower of London task (Oaksford, Morris, Grainger, & Williams, 1996; Phillips, Smith, & Gilhooly, 2002); and some aspects of set-switching (Phillips, Bull, Adams, & Fraser, 2002; Dreisback & Goschke, 2004).

Regarding the latter, Dreisback and Goschke (2004) found that positive mood impaired switching to familiar information (i.e., reduced perseveration) but enhanced switching to novel stimuli (i.e., increased distractibility), suggesting that positive affect promotes cognitive flexibility by essentially broadening the scope of attentional focus. Rowe, Hirsh, and Anderson (2007) directly tested this hypothesis using a clever design that involved semantic search and visual selective attention tasks. The researchers confirmed that positive affect increases the breadth of attentional allocation by "loosening the reins on inhibitory control" (p. 383). Such findings are consistent with a number of studies demonstrating that positive mood enhances performance on a variety of creative problem-solving, fluency, and decision-making tasks (Bartolic, Basso, Schefft, Glauser, & Titanic-Schefft, 1999; Isen, 1999; Phillips, Bull, et al., 2002). Indeed, the influence of positive affect on cognitive elaboration and flexibility is well documented and has been theoretically linked to concomitant increases in dopamine levels in the brain (Ashby, Isen, & Turken, 1999).

Unexpectedly, mild variations in negative mood were found to have little effect on updating, planning, or set-switching in the studies reviewed by Mitchell and Phillips (2007). The authors caution that the lack of findings may relate to the limited intensity and duration of negative mood manipulations in extant studies. However, two contemporaneous studies (Rowe et al., 2007; Chepenik, Cornew, & Farah, 2007) which used induction procedures designed to sustain sad mood over the course of the testing session also found that negative affect did not influence performance on executive tasks.

Thus, a relatively modest body of experimental evidence suggests that the effects of positive affect on executive functioning depend on the nature of the task, whereas negative affect appears to have little effect on executive functioning. According to Mitchell and Phillips (2007) this pattern of findings is best understood within an affect-as-information framework which proposes that positive affect promotes a more heuristic or global processing style whereas negative affect promotes analytic and more focused processing. Because most executive tasks require careful attentional control they are not well suited to heuristic processing strategies and are, therefore, likely to be impaired under positive mood states. In contrast, positive mood may facilitate performance on tasks that require creative and flexible thinking because these tasks are more amenable to a global processing approach. Further research is needed to validate this theory, especially given empirical support for alternative perspectives which regard the effects of mood on executive functioning in terms of competition for limited cognitive resources (e.g., Drevets & Raichele, 1998; Oaksford et al., 1996).

Contrary to the findings of mood induction studies in healthy participants, the results of neuropsychological studies of bipolar disorder and major depression suggest that more extreme fluctuations in mood have a detrimental effect on executive functioning. It is commonly assumed that the disinhibited behaviour that characterizes mania is reminiscent of the dysexecutive behaviour observed in patients with frontal lobe damage. On formal testing, manic patients performed poorly on set-shifting, planning, and decision-making tasks, although it remains unclear whether these deficits exceed the level of general cognitive impairment associated with mania (Murphy & Sahakian, 2001). Along with more widely recognized impairments in attention and memory, deficits on tests tapping working memory, cognitive flexibility, planning, initiation, and inhibition are frequently (though not invariably) found in individuals diagnosed with major depression (Austin et al., 1999; Marvel & Paradiso, 2004; Rogers et al., 2004). Furthermore, functional neuroimaging studies in depressed samples have documented abnormal activity in prefrontal regions that purportedly govern executive processes (Davidson, Pizzagalli, Nitschke, & Putman, 2002; Shenal, Harrison, & Demaree, 2003). To the extent that major depression is characterized by pervasive negative affect and a lack of positive affect, these findings support the notion that negative affectivity may compromise executive functioning.

Importantly, the relationship between mood and executive functioning is most likely bidirectional. That is, mood potentially influences executive functions, but executive processes likely play an important role in the maintenance and regulation of mood as well. In fact, some theorists argue that emotion regulation is a distinct component of executive functioning (e.g., Stuss, 2007). Others have suggested that executive functioning is linked to coping mechanisms, which in turn, moderate mood. For example, Krpan and associates (Krpan, Levine, Stuss, & Dawson, 2007) found that better performance on executive tests was associated with the use of problem-focused coping strategies, whereas poorer executive performance was related to more maladaptive (i.e., emotion-focused, avoidant) coping strategies in a small group of TBI survivors. Based on their findings, the authors postulated that executive dysfunction interferes with the application of effective, contextually adaptive coping strategies, which likely contributes to post-TBI emotional disturbances. Ochsner and colleagues (Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner et al., 2004) utilized a more direct approach in their work on the neural correlates of cognitive reappraisal. This commonly used coping strategy involves reinterpreting the meaning of affective stimuli as a means of diminishing the negative impact of an aversive event. Functional MRI revealed significant activation of prefrontal cortices when participants were asked to engage in cognitive reappraisal to increase or decrease their affective response to negatively valenced images (Ochsner et al., 2002, 2004). Specifically, up- and down-regulation of emotion 1) activated regions of the lateral prefrontal cortex implicated in working memory and cognitive control; 2) activated regions of the dorsal anterior cingulate implicated in the on-line monitoring of performance; 3) activated regions of dorsal medial prefrontal cortex implicated in self-monitoring and self-evaluation; and 4) modulated amygdala activation. The researchers concluded that effective cognitive reappraisal involves interactions between prefrontal systems that implement cognitive control processes (i.e., executive functions) and systems that appraise the properties of stimuli, such as the amygdala (Ochsner et al., 2004). Taken together, these findings imply that the integrity of executive functions is important for the regulation of negative mood. The role of executive processes in maintaining or modifying positive mood has yet to be investigated, although research to date suggests that the prefrontal correlates of positive and negative emotion regulation may differ considerably (Kim & Hamann, 2007).

In summary, converging evidence suggests that positive and negative affect are not merely opposite mood states that have inverse associations with executive functioning. Rather, positive and negative affect appear to be relatively independent dimensions of mood which are mediated by a distributed neural network that overlaps considerably with that of executive functioning. Consistent with the notion of a shared neural architecture, behavioural studies suggest that positive and negative affect may differentially influence higher-order cognitive skills. Whether positive affect facilitates or disrupts executive functioning seems to depend on the nature of the executive task. The influence of negative affect on executive functioning remains unclear. Lastly, executive processes may also function in the self-regulation of mood, especially the ability to effectively cope with negative affect.

Relation of affect and executive functioning to TBI outcome. As mentioned, few studies have directly examined the role of positive and negative affect in TBI outcome. Rather, research within this population has tended to focus on closely related concepts such as depression or generalized distress. In this regard, it is generally recognized that depression can complicate recovery from TBI. A number of empirical investigations have associated depression with poor psychosocial outcomes, including return to work (Ruff et al. 1993; Felmingham, Baguley, & Crooks, 2001), functional independence (Christensen, Ross, Kotasek, Rosenthal, & Henry, 1994; Rapoport, Kiss, & Feinstein, 2006) role resumption following injury (Fann, Katon, Uomoto, & Esselman, 1995) and subjective quality of life (Hibbard et al., 2004). It has been suggested that early onset depression can diminish individuals' motivation to complete rehabilitation (Prigatano, 1986), limit the development of effective coping strategies (Fleming, Strong, & Ashton, 1998), or exacerbate existing neurological deficits (Silver, Yudofsky, & Hales, 1991), all of which may contribute to poor outcome. Conversely, functional impairments such as unemployment, relationship difficulties, and loss of independence may also contribute to the onset and maintenance of post-TBI depression (Ownsworth & Oei, 1998).

The relationship between depression and cognitive functioning after TBI is less clear. Although depression has been consistently linked to cognitive impairment in psychiatric samples (e.g., Burt, Zembar, & Niederehe, 1995), several studies have failed to find a relationship between depression and neuropsychological test performance in TBI samples (e.g., Burton & Volpe, 1992; Satz et al., 1998). For example, Satz et al. reported that depression status was unrelated to overall performance on a brief battery of neuropsychological measures in a group of 100 moderate to severe TBI survivors.

However, those individuals with depression were found to have poorer functional outcomes relative to their non-depressed counterparts.

Chaytor and colleagues (Chaytor, Temkin, Machamer, & Dikmen, 2007) examined the association of depression, neuropsychological test performance, and functional outcome in a sample of 216 moderate to severe TBI survivors. Measures of memory, processing speed, language, and executive functioning were administered 6 months postinjury. Depression severity was concurrently assessed with the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977), a self-report measure of depressive symptomatology. While depressive symptoms were significantly correlated with performance on all but one of the neuropsychological tests, the researchers noted that the magnitude of the relationships was quite small. Furthermore, the neuropsychological measures accounted for little of the variance (6%) in depression severity. When the sample was divided on the basis of a cutoff score for clinically significant depressive symptoms, the "depressed" and nondepressed groups obtained comparable scores on most of the neuropsychological tests, with the exception of the memory measure. Accordingly, the authors concluded that depression and neuropsychological test performance were only weakly related in their sample. Subsequent analyses revealed that both neuropsychological measures and depressive symptoms were unique and largely independent predictors of everyday functioning, as measured by the Functional Status Examination (Dikmen, Machamer, Miller, Doctor, & Temkin, 2001). However, the presence of depressive symptoms did not reduce the predictive validity of the neuropsychological tests as expected.

The results of Chaytor et al. (2007) suggest that mood is related, albeit weakly, to neuropsychological functioning after TBI. However, the use of the CES-D confounds this interpretation to some extent. The CES-D includes a number of items addressing somatic and cognitive symptoms (i.e., sleep disturbance, concentration difficulties) in addition to affective symptoms of depression. As such, individuals classified as “depressed” solely on the basis of a cutoff score on this measure may not have necessarily endorsed a significant degree of affective symptoms. Although it may be inferred that high depression scores would be strongly correlated with negative affect and inversely related to positive affect, this was not examined directly. Furthermore, this study did not examine the relationship between mood and specific cognitive domains such as executive functioning. On closer inspection, however, TMT-B was significantly correlated with depressive symptomatology and functional outcome, indicating that additional investigation into this relationship is warranted.

Present Study

Few studies have examined the relationship of mood and executive functioning in TBI, despite recent evidence from the fields of cognitive psychology and affective neuroscience to suggest that these two constructs are closely linked. The majority of research in this area has assessed broad psychological constructs rather than basic affective components, with an emphasis on negative mood states. The role of positive affect has rarely been taken into account. Therefore, the present study sought to contribute to the literature by investigating the relationship between affect and measures of executive functioning in persons with TBI. A theory-based measure of mood was used to analyze whether positive and negative affect were differentially related to executive functioning in this population. The independent and joint contributions of these measures to psychosocial outcome were also examined. Of particular interest was whether positive and negative affect added predictive value beyond that provided by performance on executive functioning measures. As noted by Sherer and colleagues (Sherer, Roebuck-Spencer, & Cole Davis, 2010), one of the most important considerations in selecting outcome measures is their relevance to survivors, as well as clinicians and researchers. Individuals' subjective assessments of their life situation may well differ from objective indices of participation. Therefore, subjective and objective assessments of community integration and vocational functioning were used as the outcomes of interest.

Findings from cognitive studies in non-clinical populations suggest that positive affect can have facilitory and detrimental effects on executive functioning, depending on the nature of the task. It was therefore predicted that PA, as measured by the PANAS, would be related to performance on measures of executive functioning in individuals with TBI as well. The inclusion of multiple neuropsychological measures that emphasize various components of executive functioning afforded the opportunity to examine the nature of this relationship. Given the established association between positive affect and cognitive elaboration and flexibility in non-clinical populations, it was hypothesized that PA would be positively correlated with performance on measures of problem solving (WCST), word generation (COWAT), and set-shifting (TMT-B). Conversely, PA was expected to be inversely related to performance on working memory tasks (LNS). NA was also expected to show significant, albeit weaker, univariate associations with performance on measures of executive functioning; however, the literature provided little basis for specific hypotheses pertaining to specific components of executive functioning.

Based on previous findings from prognostic studies in TBI, measures of executive functioning were expected to be associated with outcome following TBI, as assessed by measures of perceived community integration and employability.

The influence of PA and NA on psychosocial outcome after TBI had not been directly investigated in previous research. Although these analyses were largely exploratory, the results of studies of post-TBI depression suggest that negative affectivity is associated with worse outcome. It was therefore hypothesized that lower levels of NA would be predictive of competitive employability and a greater sense of community integration. The nature of the relationship between PA and outcome may be more complex than previously considered in light of evidence that PA can influence executive functioning, which, in turn, may influence outcome. However, there was insufficient evidence to make specific predictions as to the nature of this relationship.

Finally, it was expected that accounting for positive and negative affect in addition to executive functioning would enhance the statistical prediction of employability and community integration after TBI.

Method

Participants

Participants were selected from persons enrolled in the Southeastern Michigan Traumatic Brain Injury System (SEMTBIS), which is part of the National Institute for Disability and Rehabilitation Research TBI Model Systems (TBIMS) project that examines the course of recovery and outcome after TBI. The TBIMS project defines TBI as “damage to brain tissue caused by an external mechanical force as evidenced by medically documented loss of consciousness or post traumatic amnesia (PTA) due to brain trauma or by objective neurological findings that can be reasonably attributed to TBI on physical examination or mental status examination” (Dijkers, Harrison-Felix, & Marwitz, 2010, p. 84). To be enrolled in the project, participants must be at least 16 years of age, receive acute care at a designated TBIMS site within 72 hours of injury, be directly transferred to an inpatient brain injury rehabilitation program within the Model System, and provide informed consent directly or by legal proxy. Individuals who sustain mild injuries that do not warrant acute inpatient hospitalization and rehabilitation and those with very severe injuries requiring subacute rehabilitation are excluded from the project.

For the present study, data from 236 participants with complicated mild to severe TBI were extracted from the SEMTBIS database. Injury severity was classified using admission Glasgow Coma Scale scores (GCS; Teasdale & Jennett, 1974). Uncomplicated mild brain injuries (GCS scores 13-15 *without* documented intracranial hemorrhage) were excluded, as the vast majority of individuals who sustain such an injury demonstrate a full recovery within 3 months postinjury (Carroll et al., 2004). In contrast, recent evidence suggests that the neuropsychological and functional outcome of individuals with complicated mild injuries (GCS scores 13-15 *with* documented intracranial hemorrhage) is comparable to that of moderate TBI (Kashluba, Hanks, Casey, & Millis, 2008).

Of 236 eligible participants, 9 were excluded because they had not completed the PANAS or any of the executive functioning measures during their follow-up evaluations. Those participants excluded as a result of missing data did not differ from the remaining sample in terms of age, gender, ethnicity, educational attainment, time since injury, cause of injury, or injury severity ($p>.05$ for all comparisons).

Demographic, premorbid, and injury related characteristics of the 227 participants comprising the study sample are presented in Table 1. As can be seen, participants were predominantly Black men with a high school education or less who were injured in motor vehicle collisions or blunt assaults. With respect to injury severity, median GCS score at admission was 8 ($SD = 4$). Over half the participants (54%) had sustained severe TBI (GCS scores below 9), 23% had sustained moderate injuries (GCS scores between 9 and 12), and 23% had sustained complicated mild injuries (GCS scores between 13 and 15 with evidence of intracranial abnormality).

Table 1

Demographic, Premorbid, and Injury Related Characteristics of Sample

	Mean	SD	Min-Max	n	%
Gender					
Male				180	79
Female				47	21
Race					
Black				168	74
White				53	23
Hispanic				3	1
Native American				2	1
Asian/Pacific Islander				1	<1
Age (years)					
At injury	38.98	14.11	16-87		
At follow-up evaluation	45.04	13.89	17-89		
Years of education	11.86	2.11	6-18		
Pre-injury employment status					
Competitively employed				133	59
Unemployed				63	28
Retired				14	6
Student				6	3
Homemaker				5	2
Other				5	2
GCS score at admission	8.67	3.89	3-15		
Length of PTC (days)[†]	26.95	19.62	<1-84		
Cause of injury					
Blunt assault				77	34
Vehicle collisions				70	31
Pedestrian				29	13
Gunshot				25	11
Fall				21	9
Other				5	2
Time since injury (years)	6.06	5.15	1-15		
1				65	29
2				37	16
5				36	16
10				49	21
15				40	18

Note. GCS, Glasgow Coma Scale; PTC, posttraumatic confusion.

[†]Data were available for 165 participants.

Procedure

Data were collected between 2003 and 2007 during follow-up evaluations that occurred 1 to 15 years postinjury. In accordance with SEMTBIS protocol, participants were administered a battery of neuropsychological tests that included the executive functioning measures described below. A series of self-report questionnaires and outcome measures, including the DRS, were also collected over the course of the evaluation. The neuropsychological tests and outcome measures were administered and scored according to standardized instructions by trained research staff and supervised technicians. Demographic-adjusted *T*-scores were calculated on the basis of comprehensive norms provided by Heaton et al. (Heaton, Grant, & Matthews, 1991) or norms found in the test manuals. In the event that a participant underwent multiple evaluations during the study time period, data from the first available time point was used in the analyses in order to minimize practice effects on the neuropsychological tests[1].

Measures

Wisconsin Card Sorting Test (WCST-64 card version). The WCST-64 (Kongs, Thompson, Iverson, & Heaton, 2000) is an abbreviated version of a widely used measure of problem solving and cognitive flexibility. WCST performance has been shown to be sensitive to brain injury severity (Ord, Greve, Bianchini, & Aguerrevere, 2010) and predictive of functional outcome following TBI (Hanks et al., 1999). The test requires participants to match cards to one of four stimulus cards on the basis of colour, form, or

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[1] If PANAS scores, outcome data, or executive test scores were missing at the first time point, but subsequently available, data from the next time point (i.e., more complete data) was used in the analyses.

number, with the sorting principle changing at intervals throughout the test. The participant receives feedback regarding the accuracy of each choice to determine the next appropriate match. When a participant persists in responding to a stimulus characteristic that is incorrect, the response is scored as perseverative (e.g., continuing to sort on the basis of colour when the set has shifted to number or form). As such, lower scores reflect better performance on this task. The total number of perseverative responses was used in the analyses.

Color Word Interference Test (CWIT). The CWIT is a subtest of the Delis-Kaplan Executive Function System (Delis, Kaplin, & Kramer, 2001) that is based on the classic Stroop procedure for examining inhibitory control. Participants must inhibit a more automatic response (i.e., reading colour names) in order to produce a conflicting response of naming dissonant ink colours in which the words are printed. CWIT performance has been shown to distinguish persons with focal frontal lesions from controls (Homack, Lee, & Riccio, 2005). Time to complete the interference trial was used in the current study, with lower scores reflecting better performance on the task.

Trail Making Test – Part B (TMT-B). The TMT (Reitan & Wolfson, 1993) assesses visuomotor tracking, information processing speed, cognitive flexibility, and set shifting ability. This measure is used extensively in the cognitive assessment of persons with TBI and distinguishes TBI participants from controls (Perianez et al., 2007; Ruffolo, Guilmette, & Willis, 2000). Part A requires participants to draw lines in order to connect circled numbers on a page as quickly as possible. Part B presents encircled numbers and letters and requires participants to connect the circles in sequence, alternating between numbers and letters. Time to complete TMT-B was included in the analyses, with better performance reflected in lower scores.

Letter Number-Sequencing (LNS). LNS is a measure of working memory from the Wechsler Adult Intelligence Scale – Third Edition (Wechsler, 1997) in which participants are orally presented with a mixed series of letters and numbers. After each presentation, the participant is asked to repeat the numbers in ascending order and then to repeat the letters in alphabetical order. Studies have demonstrated a meaningful relationship between LNS performance and brain injury severity (Donders, Tulsky, & Zhu, 2001). The number of correct trials was used in the current analyses, with higher scores reflecting better performance.

Controlled Oral Word Association (COWAT). The COWAT (Spreen & Benton, 1977; also referred to as verbal fluency) is a popular measure of word initiation, strategic retrieval, set maintenance, and inhibitory control. The task requires participants to orally generate as many words as possible that begin with a specified letter (F, A, and S) within an allotted time period, without providing proper names or variations of the same word. COWAT performance has been shown to distinguish TBI participants from controls (Henry & Crawford, 2004). The total number of correct words across three 1-minute trials was included in the analyses, with higher scores reflecting better performance on the task.

Positive and Negative Affect Schedule (PANAS). The PANAS (Watson et al., 1988) consists of two 10-item scales developed to provide brief measures of PA and NA (see Appendix D). Participants were asked to rate the extent to which they are currently experiencing each affective state on a 1 (*very slightly, not at all*) to 5 (*extremely*) scale.

Items were summed within subscales to derive PA and NA state scores, with higher scores reflecting greater degrees of positive and negative affect, respectively. The PANAS has demonstrated good reliability and validity in clinical and non-clinical populations (Crawford & Henry, 2004; Watson, Clark, & Tellegen, 1988). In the present sample, internal consistency estimates were high for the PA (Cronbach's $\alpha = .88$) and NA (Cronbach's $\alpha = .87$) subscales.

Neurobehavioral Functioning Inventory – Depression Subscale (NFI Depression). The NFI (Kreutzer, Seel, & Marwitz, 1999) is a 76-item self-report inventory in which participants rate the presence and frequency of problems that are commonly encountered by persons with neurological disabilities across six domains: depression, somatization, memory/attention, communication, aggression, and motor. The reliability and validity of the NFI has been established in persons with TBI (Kreutzer, Marwitz, Seel, & Serio, 1996). The depression subscale, comprised of 13 items rated on a 1 (*never*) to 5 (*always*) scale, was included in the regression analyses to examine whether PANAS scores contributed to psychosocial outcome above and beyond depressive symptoms. Consistent with the findings of Kreutzer and colleagues (1996), internal consistency of the NFI Depression subscale was .93 in the present sample.

Brief Symptom Inventory – 18 (BSI-18). The BSI-18 (Derogatis, 2001) is a self-report measure of psychological distress that requires participants to rate their level of distress over the past seven days on a 0 (*not at all*) to 4 (*extremely often*) scale. A recent validation study demonstrated the reliability, validity, and utility of the BSI-18 among persons with TBI (Meachen, Hanks, Millis, & Rapport, 2008). The Global Severity Index (GSI), based on the total of all 18 items was included in the regression analyses to examine whether PANAS scores contributed to psychosocial outcome above and beyond generalized distress. Internal consistency of the BSI-18 GSI in the present sample was .92.

Community Integration Measure (CIM). The CIM (McColl, Davies, Carlson, Johnston, & Minnes, 2001) is a 10-item scale that evaluates participants' perceived connections and participation within their community. Items take the form of declarative statements based on definitions of community integration provided by individuals with brain injury (McColl et al., 2001). CIM items relate to how comfortable individuals feel in their community, their sense of belonging, their perception of relationship to others in the community, and whether they feel useful and productive. Each statement is rated on a 1 (*always disagree)* to 5 (*always agree*) scale (see Appendix F). The authors assert that the CIM measures an independent aspect of integration by virtue of its emphasis on subjective experience (McColl et al., 2001). For instance, the CIM asks respondents whether they believe that there are things that they can do in their community for fun in their free time rather than quantifying time spent in recreational activities.

A recent validation study in an overlapping sample of TBI survivors demonstrated construct validity of the CIM through significant correlations with other subjective measures of well-being and quality of life, social support, and community integration (Griffen, Hanks, & Meachen, 2010). CIM item ratings were summed to provide a total score, with higher scores reflecting increasing levels of perceived community integration and participation. Internal consistency was .86 in the present sample.

Disability Rating Scale (DRS). The DRS (Rappaport et al., 1982) was specifically designed to assess disability among persons with moderate to severe TBI from time of coma to reintegration into the community. In its entirety, this instrument is comprised of eight items in four categories: arousal and awareness, cognitive ability to handle self-care, physical dependence on others, and psychosocial adaptability. DRS scores have demonstrable validity in predicting discharge disposition, supervision requirements, and return to work following injury (Eliason & Topp, 1984; Gouvier, Blanton, LaPorte, & Nepomuceno, 1987; Ponsford, Olver, Curran, & Ng, 1995). Moreover, the DRS has been shown to be more sensitive to clinical changes following rehabilitation discharge relative to other established outcome measures (Hall, Cope, & Rappaport, 1985; Hall et al., 1996).

The DRS was administered via interview with participants during follow-up evaluations. Examiners received training and certification through the TBIMS; satisfactory interrater reliability has been documented in numerous studies (e.g., Gouvier et al., 1987; Rappaport et al., 1982). Scores on the Employability item, which assesses overall cognitive and physical ability to be an employee, homemaker, or student, were included in the analyses. Traditionally, the Employability item is rated from 0 (*Not Restricted*) to 3 (*Not Employable*). In an effort to increase the sensitivity of the DRS, the TBIMS project adopted the option of scoring half points when subjects did not fit the whole point definitions. For the purposes of this study, scores were collapsed into two clinically meaningful categories: competitively employable and noncompetitive (see Appendix G) in order to ensure adequate sample sizes and facilitate statistical modeling.

Statistical Analyses

Prior to analyses, all variables were screened for violations of assumptions associated with parametric multivariate tests. Inspection of standardized and studentized residuals, leverage statistics, and Mahalanobis distance failed to identify outliers ($p < .001$). Similarly, examination of residual plots did not reveal departures from linearity, homoscedasticity, or normality. Analyses were undertaken with listwise deletion of missing data.

Descriptive statistics were calculated for covariate and outcome variables utilized in the analyses. As recommended by Silverberg and Millis (2009), raw scores on neuropsychological tests were used in the statistical prediction of outcome. For descriptive purposes, raw scores were also compared to demographically corrected normative data and classified according to the system of Heaton et al. (1991).

Following these preliminary analyses, bivariate correlations among demographic variables, injury characteristics, executive test performance, affect, and concurrently measured outcome were calculated. Spearman's rho correlations were used for dichotomous variables (DRS Employability) and highly skewed variables (PANAS NA). Although injury severity and time since injury were not significantly correlated with outcome, these variables were retained in the regression models because of their association with long-term functional and psychosocial outcome in previous studies.

To assess the contribution of executive functioning measures and affect to psychosocial outcome following TBI, two separate multiple regression models were constructed. Specifically, a series of hierarchical multiple linear regression analyses were used to predict perceived community integration and hierarchical binary logistic regression analyses were used to predict employability on the DRS. In each of these models, the covariates were entered in blocks to determine the extent to which the variables added significantly to the model. Demographic and injury related variables (age, education, GCS score at admission, time since injury) were entered into the model in one block, followed by the executive functioning measures (WCST, TMT-B, CWIT, LNS, COWAT) in the second block, and PA and NA scores in the final block. Thus, the unique and combined effects of executive test performance and affect in predicting community integration and employability was determined after accounting for the influence of demographic and injury characteristics on outcome.

Results

Descriptive Statistics

Scores on the executive functioning tests, PANAS, measures of psychological distress, and outcome variables are summarized in Table 2. Examination of adjusted *T* scores shows that, on average, performance on the executive functioning tests fell within the Mildly Impaired range, with the exception of mean WCST and COWAT performances, which corresponded to the Average range (Heaton et al., 1991). Caution must be exercised in making comparisons across tests as the normative data were derived from different samples and the norms do not necessarily correct for the same demographic variables. Nonetheless, a substantial proportion of participants scored below a1 *SD* cutoff for impairment on the WCST, TMT-B, CWIT, LNS, and COWAT tests (40, 54, 48, 44, and 44%, respectively).

Participants endorsed a broad range of positive affect (median PA = 36), whereas scores on the negative affect scale were positively skewed (median NA = 14). Clinically significant levels of psychological distress, as determined by Global Severity Index *T* scores of 63 or above, were present for 26% of the sample. According to the NFI Depression categories delineated by Seel and Kreutzer (2003), 40% of participants were "minimally depressed," 45% were "borderline depressed," and 15% were "clinically depressed."

With regard to psychosocial outcome, participants in the current study reported fairly high levels of perceived community integration and slightly less than half (48%) were deemed competitively employable.

Table 2
Descriptive Data for Covariates

Variable	N	Mean (SD)	Min-Max	*T* Score Mean (SD)
WCST				
Perseverative responses	197	16.82(13.11)	2-62	42.20(9.67)
TMT-B				
Time to complete (s)	211	157.12(90.06)	41-301	37.11(13.32)
CWIT				
Time to complete inhibition trial (s)	193	78.74(29.74)	39-180	37.77(13.01)
LNS				
Number of correct trials	205	6.97(3.22)	0-17	39.01(10.46)
COWAT				
Number of correct words	214	26.62(10.90)	0-56	40.68(10.67)
PANAS				
Positive Affect	227	33.37(9.06)	12-50	
Negative Affect	227	16.05(6.99)	10-45	
BSI-18				
Total score	221	13.19(12.78)	0-64	54.94(11.81)
NFI				
Depression subscale score	196	31.17(11.07)	13-62	
CIM				
Total score	224	39.42(7.94)	15-50	
DRS Employability				
Competitively employable	108			
Noncompetitive/Unemployable	119			

Note. WCST, Wisconsin Card Sorting Test; TMT-B, Trail Making Test – Part B; CWIT, Color Word Interference Test; LNS, Letter Number-Sequencing; PANAS, Positive and Negative Affect Schedule; BSI-18, Brief Symptom Inventory-18; NFI, Neurobehavioral Functioning Inventory; CIM, Community Integration Measure; DRS, Disability Rating Scale.
T scores based on comparison to normative data.

Bivariate Correlations

As shown in Table 3, there were generally moderate zero-order correlations among the executive functioning variables (*r* range, .20 - .67, $p<.01$). The negative correlations between LNS, COWAT and other executive tests merely reflects that lower scores indicate better performance on all but these tasks. As expected, age and educational attainment were modestly correlated with executive task performance (*r* range, .18 - .36, $p<.05$). Each of the executive measures was significantly related to concurrent employability ratings (ρ range, .16 -.33 p<.05), such that better executive test performance was associated with being deemed competitively employable. In contrast, executive test performance was not closely associated with perceived community integration. Three of the five executive measures were significantly related to the PANAS; however, only correlations with LNS were significant at the more conservative .01 level. LNS and TMT-B performance showed modest correlations with the PA subscale (r =.27, p<.01 and r = -.18, p<.05, respectively) and the NA subscale (ρ =-.26, p<.01 and ρ =.15, p<.05, respectively). Thus, better performance on these working memory and cognitive flexibility tasks was associated with higher levels of positive affect and lower levels of negative affect. Higher levels of negative affect were associated with worse performance on the word initiation task (ρ =-.20, p<.05).

A weak negative correlation between PA and NA scores was demonstrated (ρ = -.29, p<.01), consistent with prior empirical studies indicating that the scales measure two distinct, albeit related, constructs (Crawford & Henry, 2004). Both PA and NA were significantly related to perceived community integration (r =.31 and ρ =-.33, p<.01, respectively), but not to employability. Notably, the psychosocial outcome measures (CIM and DRS Employability) were not significantly correlated.

Table 3

Bivariate Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age													
2. Education	0.13												
3. GCS Score	0.19*	0.05											
4. Time Since Injury	0.13	0.01	-0.11										
5. WCST	0.14	-0.24**	0.04	-0.05									
6. TMT-B	0.25**	-0.27**	0.05	0.12	0.39**								
7. CWIT	0.18*	-0.20*	-0.15*	0.18*	0.28**	0.59**							
8. LNS	-0.26**	0.36**	-0.04	-0.05	-0.43**	-0.67**	-0.55**						
9. COWAT	-0.08	0.21**	0.07	0.08	-0.20*	-0.28**	-0.34**	0.43**					
10. PANAS PA	0.02	0.12	-0.01	0.18*	-0.01	-0.18*	-0.06	0.27**	0.07				
11. PANAS NA†	-0.03	-0.17*	0.02	-0.04	0.03	0.15*	0.15	-0.26**	-0.20*	-0.29**			
12. CIM	0.10	0.05	0.03	0.02	0.05	0.00	0.01	0.09	0.00	0.31**	-0.33**		
13. DRS Employability†	-0.06	0.17*	0.10	0.16*	-0.23**	-0.33**	-0.30**	0.29**	0.16*	0.10	-0.02	0.09	

Note. *$p<.05$;**$p<.01$; † Spearman’s rho correlations were calculated for dichotomous and highly skewed variables

Relationship Between Executive Functioning and Affect

To further examine the relationship between executive functioning and affect, the sample was divided into two groups based first on a cut off score corresponding to the 75th percentile for PA, and again based on a cut off score corresponding to the 25th PA percentile. Not surprisingly, the "high PA" group (PA scores ≥ 40; n = 62) reported lower negative affect than did the remaining participants ($t = -4.94$, $p < .05$). The high PA group outperformed the remaining participants on the executive tests ($p < .05$), with the exception of the WCST and COWAT. Conversely, those participants reporting low levels of positive affect (PA scores ≤ 28; n = 62) generally exhibited poorer performances relative to those reporting higher PA levels, with differences on TMT-B and LNS reaching statistical significance ($p < .05$).

Conversely, when the sample was divided on the basis of NA scores, the "high NA" group (NA scores ≥ 20 corresponding to the 75th percentile; n=60) reported slightly lower positive affect ($t = 2.06$, $p < .05$) and exhibited poorer performances on the executive tests than did the remaining participants. Statistically significant differences were found for the CWIT, LNS, and COWAT tests. Participants endorsing low levels of negative affect (NA scores ≤ 10; n = 69) scored significantly better on the LNS task ($t = 2.34$, $p< .05$).

Of note, when the sample was divided in this manner the groups did not differ in terms of injury characteristics, with the exception of lower GCS scores (i.e., more severe injuries) among those participants reporting low levels of positive affect ($t = 2.25$, $p < .05$).

Relationship of Executive Functioning and Affect to Perceived Community Integration

Demographic and injury related variables did not account for a significant proportion of the variance in CIM scores. As a group, the executive functioning measures did not add significant predictive value to the model ($F_{change}(5, 155) = 0.93$, p = .463; see Table 4). However, the model became statistically significant with the addition of the PANAS scores ($R^2_{change} = .15$, $F_{change}(2, 153) = 13.66$, p < .001). Affect accounted for 13% of the variance in perceived community integration (*adjusted* $R^2 = .13$, p< .001). Both positive affect and negative affect were identified as significant predictors, accounting for approximately 4% (*semipartial* $r^2 = .038$) and 7% (*semipartial* $r^2 = .068$) of the unique variance in CIM scores, respectively. Higher levels of positive affect and lower levels of negative affect were associated with improved community integration and participation.

Table 4
Hierarchical Regression of Community Integration on Executive Functioning and Affect Measures

Variables	adjusted R^2	F_{change}	df	β	*t*	p
Block 1	-.01	.49	4, 160			.742
Age						ns
Education						ns
Injury Severity						ns
Time Since Injury						ns
Block 2	-.02	.93	5, 155			.463
WCST						ns
TMT-B						ns
CWIT						ns
LNS						ns
COWAT						ns
Block 3	.13	13.66	2, 153			.000
PANAS PA				.22	2.69	.008
PANAS NA				-.28	-3.57	.000

Note. ns, nonsignificant.

In order to explore the possibility that positive affect was moderated by negative affect, an interaction term was created by multiplying the mean-centered values of PA and NA[2]. Adding this product term to the regression model following PA and NA yielded no evidence of an interaction effect, indicating that the relationship between positive affect and CIM scores was independent of negative affect, and vice versa.

The possibility that affect moderated the relationship between executive functioning and outcome was also considered. To facilitate this post-hoc analysis[3], an executive functioning composite was created by averaging participants' standardized z-scores on the executive measures. Individuals with missing data on more than two of the executive variables were excluded from this analysis (n=16). Because lower scores on the WCST, TMT-B, and CWIT imply better performance, z-scores on these measures were multiplied by –1 before inclusion in the composite. Interaction terms were then created by multiplying the mean-centered values of PA/NA and the executive functioning composite. As shown in Table 5, both the interaction terms were nonsignificant, suggesting that the relationship between executive functioning and community integration did not vary significantly as a function of positive or negative affect.

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[2] Centering the predictors prior to forming the interaction term is recommended as it reduces their correlation with the interaction term.

[3] Because the direction of the relationship between PA/NA and executive functioning was consistent across measures, a composite EF score could be created, thereby reducing the number of potential interaction effects.

Table 5
Final Step of Hierarchical Regression Demonstrating that Affect Does Not Moderate the Relationship Between Executive Functioning and Community Integration

Variables	adjusted R^2	F_{change}	df	β	t	p
Block 4	.15	1.11	2, 197			.332
Age						ns
Education						ns
Injury Severity						ns
Time Since Injury						ns
EF						ns
PANAS PA				.22	3.16	.002
PANAS NA				-.31	-4.48	.000
PANAS PA x EF						ns
PANAS NA x EF						ns

Note. EF, executive functioning composite; ns, nonsignificant.

Relationship of Executive Functioning and Affect to Employability

As noted, employability on the DRS was recoded into a dichotomous variable (noncompetitive = 0, competitively employable = 1) and a series of hierarchical logistic regression analyses were conducted to assess the unique and combined effects of executive functioning and affect in predicting employability status. A test of the full model that included the demographic and injury variables, executive tests, and PANAS variables against a constant-only model was statistically reliable (likelihood ratio = 199.11, χ^2_{11} = 29.47, p = .002), indicating that the set of predictors reliably distinguished between participants who were or were not deemed competitively employable. As shown in Table 6, the executive tests, as a group, added significantly to predicting employability status after accounting for demographic and injury characteristics (χ^2_5 = 16.028, p = .007), consistent with expectations. Conversely, the PANAS variables did not add significant predictive value to the model. The proportional reduction in the absolute value of the log-likelihood measure of the model including the executive functioning tests was significant and moderate in magnitude, Nagelkerke's R^2 = .22. Nagelkerke's R^2 is analogous to the conventional R^2 statistic used in ordinary least squares regression to calculate the proportion of the variance in the dependent variable which is explained by the covariates. Thus, executive test performance accounted for an additional 22% of the overall "variance" in employability. Inspection of the odds ratios (ORs) for the predictor variables indicated that only time since injury was a significant individual contributor, controlling for other covariates in the final model (OR = 1.12; 95% CI, 1.04-1.19). Specifically, each additional year postinjury increased the odds of being deemed competitively employable by 12%.

Table 6
Hierarchical Binary Logistic Regression of Employability on Executive Functioning and Affect Measures

Variables	χ^2	p	-2 log likelihood	Nagelkerke R^2	OR	95% CI
Block 1	13.366	.010	215.21	.10		
Age					0.98	0.95-1.00
Education					1.20	1.02-1.39
Injury Severity					1.07	0.98-1.17
Time Since Injury					1.09	1.02-1.16
Block 2	16.028	.007	199.19	.22		
WCST					1.00	0.97-1.03
TMT-B					1.00	0.99-1.00
CWIT					0.99	0.97-1.00
LNS					1.06	0.89-1.27
COWAT					1.00	0.96-1.03
Block 3	0.074	.964	199.11	.22		
PANAS PA					0.99	0.95-1.03
PANAS NA					1.00	0.94-1.05

Note. OR, odds ratio; CI, confidence interval.

The relationship between executive functioning and employability was not moderated by positive or negative affect, as there was no evidence of interaction effects (see Table 7).

Table 7
Final Step of Hierarchical Binary Logistic Regression Demonstrating that Affect Does Not Moderate the Relationship Between Executive Functioning and Employability

Variables	χ^2	p	-2 log likelihood	Nagelkerke R^2	OR	95% CI
Block 4	1.10	.574	248.56	.25		
Age					0.99	0.97-1.02
Education					1.00	0.86-1.17
Injury Severity					1.07	0.99-1.17
Time Since Injury					1.10	1.03-1.17
EF					3.41	1.96-5.93
PANAS PA					0.99	0.96-1.03
PANAS NA					0.97	0.92-1.02
PANAS PA x EF					1.02	0.97-1.08
PANAS NA x EF					1.03	0.96-1.11

Note. EF, executive functioning; OR, odds ratio; CI, confidence interval.

Positive and Negative Affect in Relation to Measures of Psychological Distress

Lastly, PA and NA scores were compared to self-report measures of psychological distress to assess the unique role played by affect following TBI. NA was significantly correlated with concurrently measured depressive symptoms (NFI Depression, $\rho = .48$, $p < .001$) and generalized distress (BSI-18 GSI, $\rho = .52$, $p < .001$). To a lesser extent, PA scores were correlated with NFI Depression ($r = -.29$ $p < .001$) and BSI-18 GSI ($r = -0.22$, $p < .05$) measurements.

Hierarchical multiple regression was used to determine whether affect predicted community integration above and beyond generalized measures of distress and depression. Demographic and injury related variables were not included in this model as they had no predictive value in previous analyses. After accounting for generalized distress and depression, PANAS scores added significant value to the prediction of community integration (see Table 8). Together, BSI-18 GSI and NFI Depression subscale scores accounted for 13% of the overall variance in CIM scores. PA and NA accounted for an additional 12% of the explained variance (R^2_{change} = .12, $F_{change}(2, 184) = 14.73$, p < .001). Examination of individual predictor coefficients showed that PA and NA each contributed significantly to the prediction of perceived community integration in the final model (*t* = 4.33 and *t* = -3.18, p <.05, respectively) whereas the generalized distress and depression ratings did not. Again, higher levels of positive affect and lower levels of negative affect were associated with a greater sense of community integration.

Table 8
Regression of Community Integration on Distress, Depression, and Affect

Variables	adjusted R^2	F_{change}	df	β	*t*	p	zero-order r	semipartial r^2
Block 1	.13	15.34	2, 186			<.001		
NFI Depression				-.02	-0.23	ns	-.343	.000
BSI-18 GSI				-.18	-1.84	ns	-.359	.013
Block 2	.24	14.73	2, 184			<.001		
PANAS PA				.28	4.33	<.001	.343	.073
PANAS NA				-.24	-3.18	.002	-.378	.041

Note. ns, nonsignificant.

Discussion

The current study revealed little association between affect and executive functioning following complicated mild to severe TBI. Affect and performance on neuropsychological tests of executive functioning were independent predictors of community integration and employability, respectively. However, hypotheses regarding the joint contribution of these variables to psychosocial outcome were not supported.

Unexpectedly, executive functioning was only weakly related to positive and negative affect ratings. Three of the five executive measures employed in this study were significantly correlated with affect, but the magnitude of association was small. Better performance on tasks requiring individuals to hold alphanumeric sequences ‘in their heads’ and organize this information (LNS) or shift cognitive set (TMT-B) was associated with higher levels of positive affect and lower levels of negative affect. Better performance on the word generation task (COWAT) was also associated with lower levels of negative affect.

The observed trend for individuals endorsing the highest levels of positive affect to perform better across the executive tasks is inconsistent with documented effects of experimentally induced positive mood on executive functions. In these studies, very subtle fluctuations in positive mood have been shown to significantly impair or facilitate performance, depending on the nature of the task. There are a number of possible explanations for the discrepancy in findings. Firstly, the executive tasks employed in the current study differ from those typically used by cognitive researchers which may contribute to variability in results. For example, Spies et al. (1996) used a reading span task to examine the effect of mood induction on working memory whereas the current study used a letter number-sequencing task. Although these tasks are both putative working memory measures, they may assess different cognitive processes to varying degrees. Furthermore, the measures selected for the current study tapped a range of executive functions, but none emphasized the aspects of executive functioning that are consistently enhanced by positive mood inductions in non-clinical populations, namely, cognitive elaboration, creativity, and innovative problem-solving (Isen, 1999).

Another important methodological difference relates to the operational definition of positive and negative affect within the mood manipulation literature. In most studies procedures were designed to temporarily induce happy or sad mood states with an emphasis on the valence dimension of affect (i.e., the degree of pleasantness or unpleasantness). By contrast, the current study adopted the view that PA and NA are predominantly defined by the *activation* of positively and negatively valenced affects (Watson et al., 1999). As such, PA in the current study was represented by emotions such as enthusiasm and alertness rather than happiness. It is unclear whether the relative emphasis on activation contributed to the inconsistency in results. Future studies should systematically investigate the role of valence and arousal when trying to understand the influence of mood on higher-order cognition.

Failure to find a strong association between negative affect and executive functioning may be related to a restriction in the range of NA scores observed in this study. However, the distribution of NA was similar to that reported in the general population (Crawford & Henry, 2004) and several other TBI samples (Arenth, Corrigan, & Schmidt, 2006; Burton Hultsch, Strauss, & Hunter, 2002). Furthermore, these results are consistent with null findings from negative mood induction experiments as well as several studies that failed to demonstrate an appreciable link between post-TBI depression and neuropsychological test performance (Burton & Volpe, 1992; Chaytor et al., 2007; Rohling, Green, Allen & Iverson 2002; Satz et al., 1998).

In addition to the abovementioned methodological considerations, it is plausible that the nature of the relationship between affect and executive functioning may differ in TBI such that the results from studies in healthy individuals cannot be generalized to this population. For example, if the beneficial effects of positive affect on executive functioning are mediated by increased dopamine projections to the anterior cingulate and prefrontal cortex, as suggested by Ashby et al. (1999), then disruption of these pathways as a result of diffuse axonal injury may obviate any such effects. Of course, neuroimaging studies that characterize the nature and extent of damage to prefrontal cortical pathways are needed to test this hypothesis directly. Experimental mood induction studies in TBI would also help to address whether differences in populations account for the discrepancy in findings.

The second aim of this study was to examine the contributions of affect and executive functioning to psychosocial outcome following TBI. The results are consistent with Chaytor et al.'s (2007) research showing that neuropsychological measures are significant predictors of functional status after TBI, regardless of the presence of depressive symptoms. However, the current results extend these findings by focusing on "purer" indices of affect and measures of executive functioning in particular. Taken together, and contrary to expectation, the findings suggest that information regarding mood states does not add to the prediction of TBI outcome above and beyond neuropsychological tests. Rather, affect and executive functioning appear to be uniquely related to distinct aspects of psychosocial functioning.

It is not surprising that a greater sense of belonging, perception of closeness to others, and satisfaction with one's participation within the community, as reflected in total CIM scores, was associated with high levels of positive affect and low levels of negative affect. Previous research has linked mood to long-term psychosocial outcome after TBI (Draper, Ponsford, Schönberger, 2007; Hibbard et al., 2004; Hoofien, Gilboa, Vakil, & Donovick, 2001), although the current study was the first to investigate this relationship using the CIM. The finding that both positive and negative affect were uniquely related to community integration supports the potential importance of evaluating positive affectivity in the TBI population. Moreover, the modest correlations between PA and measures of depression and affective distress suggest that positive affectivity is not well captured in typical clinical assessment procedures.

Because affect and community integration were measured concurrently in this study, the direction of the relationship cannot be ascertained. Arguably, the experience of being disconnected from others, unproductive, and dissatisfied with one's living situation may lead to subjective distress and a broad range of negative emotions. Alternatively, negative affectivity may disrupt social relationships and limit participation, contributing to poor reintegration. To the extent that state PA and NA scores reflect a general predisposition to experience positive or aversive emotional states (Watson et al., 1999), it is possible that these traits contribute to resiliency or vulnerability to poor outcomes following injury. Trait PA has been shown to influence a number of clinical health outcomes (Pressman & Cohen, 2005) and an enduring tendency to experience positive emotions may buffer the detrimental consequences of brain injury as well. Exploring positive and negative affectivity as premorbid personality factors that may contribute to individual differences in outcome and adjustment after TBI is a meaningful avenue for future work.

Affect was not related to employability in the current study, even though prior studies indicate a relationship between emotional status and employment outcomes after TBI (Ownsworth & McKenna, 2004). Methodological differences such as the reliance on measures of depressive symptomatology and a limited period of follow-up in previous studies may explain the difference in findings. It is also important to note that a standardized measure of employment *potential* was used as the measure of outcome in this study rather than actual work status in order to minimize potential confounds. As Mateer and Sira (2006) point out, cognitive and emotional factors interact with a host of other variables to determine individuals' ability to return to competitive employment following TBI. For example, environmental factors such as access to vocational rehabilitation services and a supportive workplace are likely to influence post-injury work attainment but these factors are not considered when assessing employability.

Considering the complexity of TBI outcome, the proportion of variance in employability accounted for by performance on executive functioning measures (23%) was impressive and generally consistent with prior research demonstrating the ecological validity of tests of executive functioning (Hanks et al., 1999; Ownsworth & McKenna, 2004; Struchen et al., 2008). It seems reasonable that tests tapping the capacity to formulate strategies, flexibly adapt to changes in the environment, hold information 'in mind' while simultaneously performing other mental tasks, and suppress actions that are inappropriate in a given context are associated with employability in the competitive job market. That no measure was a significant predictor of employability on its own underscores the importance of a broad-based approach to the assessment of executive functioning in clinical practice.

Previous research has demonstrated that the prediction of psychosocial outcome after TBI depends on the assessment measures used. Because outcome is a multifaceted construct, the present study sought to capture various facets of outcome and to incorporate both objective and subjective perspectives. Unlike commonly used measures of community integration such as the CIQ, the CIM is based on words and ideas of TBI survivors regarding full participation in community life and makes no assumptions about the relative importance of particular activities or relationships (McColl et al., 2001). Furthermore, it does not place greater value on independent participation relative to supported or mutual participation. As such, this approach allows for individual differences in priorities with respect to outcome (Sander et al., 2010). Despite these advantages, there are few published studies using the CIM with which the current findings can be compared. Notably, the present TBI sample is much larger than reported in published studies to date (see Linden, Crothers, O'Neill, & McCann, 2005; McColl et al., 2001; Reistetter, Spencer, Trujillo, & Abreu, 2005).

The negligible correlation between objective and subjective measures of outcome may reflect differing priorities vis-à-vis societal norms. As Sander and colleagues (2010) aptly remarked, employment may be the most valuable outcome to society, but it may not be the most important outcome for every person with TBI. Within the current sample, overall satisfaction with community participation did not differ between participants who were deemed competitively employable and those who were not[4]. A closer inspection of responses on the final CIM item, "*I have something to do in this community during the main part of my day that is useful and productive*" also revealed comparable scores for participants considered competitively employable and those who were not. Only 21% of survivors whose limitations precluded competitive employment disagreed with the statement while 56% agreed that they felt useful and productive.

The relative importance assigned to different aspects of community integration outcome may also vary among different racial/ethnic groups (Sander et al., 2010; Sherer et al., 2010), which is particularly relevant given that the current sample was predominantly comprised of African Americans. Previous TBIMS studies using objective measures have reported that minority groups experience poorer community integration and employment outcomes relative to Whites after accounting for sociodemographic and injury characteristics (Arango-Lasprilla et al., 2008; Hart, Whyte, Polansky, Kersey-Matusiak, & Fidler-Sheppard, 2005; Sherer et al., 2003). Few outcome studies involving diverse participants have incorporated subjective measures of community integration. Mascialino and colleagues (2009) recently found little difference in objective participation between racial/ethnic minorities and whites at two or more years post-TBI, whereas subjective ratings of outcome consistently differed between these groups. The authors argue this finding may be the result of cultural differences in the experience and expression of disability.

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[4] Mean CIM score = 40.5, *SD* = 7.43 versus 38.44, *SD* = 8.29, respectively. Recall that employability ratings take into account the ability to be an employee, homemaker, or student.

It is also possible that the lack of association between objective and subjective appraisals of outcome in the current study may be partly due to impaired self-awareness associated with TBI. It is widely acknowledged that survivors may be less aware of deficits resulting from their brain injury relative to those around them. Studies have shown that individuals with moderate to severe TBI tend to underestimate the extent of their cognitive and behavioural difficulties when compared to evaluations made by significant others and clinicians (Prigitano, Altman, & O'Brien, 1990; Sherer et al., 1998) in both the acute and postactute stages of recovery (Hart, Sherer, Whyte, Polansky, & Novack, 2004; Hart, Whyte, et al., 2003). Furthermore, impaired self-awareness has been linked to worse performance on some measures of executive functioning (Bogod, Mateer, & MacDonald, 2003; Hart, Whyte, Kim, & Vaccaro, 2005; Ownsworth & Fleming, 2005) and mood/emotional adjustment after injury in some studies (Godfrey, Partridge, Knight, & Bishara, 1993). This is consistent with the notion that greater insight into one's residual cognitive and functional limitations is associated with emotional distress. Including significant other ratings of outcome would provide further information on the potential impact of self-awareness on the findings.

Even though the main hypotheses of this study were not supported, the findings have important implications for neuropsychological practice and TBI rehabilitation. Indeed, the results suggest that neuropsychologists should be cautious in attributing poor performance on tests of executive functioning to survivors' affective state at the time of the evaluation. Knowledge of executive functioning can help answer referral questions concerning individuals' capacity for gainful employment. However, it is equally important to consider subjective aspects of outcome and to address each individual's priorities for community participation.

The findings also support the potential importance of addressing mood in a broader sense in the assessment of persons with TBI. The PANAS is a brief measure that may be useful in this regard, as it provides information about positive affectivity that is often omitted in commonly used measures of emotional functioning. Psychological intervention in conventional neurorehabilitation often focuses on reducing negative affect (i.e., depression, anxiety) and maladaptive coping after injury rather than fostering positive affect directly. Positive affect represents a potential target that could ultimately improve community reintegration of survivors. A range of interventions designed specifically to enhance positive emotions have been identified and subjected to empirical validation within the growing field of positive psychology (Seligman, Steen, Park, & Peterson, 2005). However, a review of the research literature revealed few studies examining these techniques in the TBI population. Recent pilot investigations by Smart (Azulay, Smart, Mott, & Cicerone, 2010) and Bédard (Bédard et al., 2003) represent encouraging progress, but there is a need for well-controlled and sufficiently powered studies to determine the future role of such interventions.

Limitations and Future Directions

Several characteristics of the current sample may limit the generalizability of the findings. Firstly, participants had received interdisciplinary inpatient rehabilitation and may not be representative of other TBI survivors (e.g., those with very severe injuries who required subacute hospitalization). The overrepresentation of men of ethnic minority background living in an urban area may also limit generalizability, particularly with respect to community integration outcomes. The findings require replication in samples with different demographic compositions and other contexts. Furthermore, time since injury ranged from 1 to 15 years in this sample, with an average of six years. While univariate analyses failed to find significant differences among executive test scores, affect, community integration, or employability ratings at the five follow-up time points, larger samples are needed to facilitate multivariate analyses at different stages of recovery.

Because affect, executive functioning, and psychosocial outcome were measured at the same time point, any assumptions regarding causality are speculative. Prospective longitudinal studies are needed to determine whether survivors who experience relatively high levels of positive affect and low levels negative affect during early recovery report greater satisfaction with community life and participation years later. Likewise, the value of neuropsychological tests of executive function in predicting future employability needs to be confirmed.

As noted, the DRS Employability item was used as an outcome measure in this study rather than actual work status in order to minimize potential confounds, including the high rate of unemployment in this region. Indeed, 28% of the sample was unemployed prior to injury. Of those deemed competitively employable, 38% reported being an employee or student and 26% reported being retired at the time of the follow-up evaluation. It should be noted that while the DRS employability item is rated by trained assessors, this method relies on information provided by survivors, thereby limiting its objectivity. Future studies should include objective measures such as employment status when possible.

The current study included a relatively broad assessment of executive functioning using measures commonly used in clinical practice. Nonetheless, other aspects of executive functioning that may interact with mood and impact outcome (e.g., judgment, planning, divided attention) were not assessed. Given the complex nature of these types of tasks, it is difficult to interpret the results in terms of specific executive processes. At the same time, it is unlikely that affect is strongly related to all the cognitive processes underlying executive functioning. Therefore, future studies should attempt to parcel out the component processes and identify the prefrontal regions that mediate them. This may entail the use of experimental tasks or procedures designed to fractionate standard tests (e.g., Stuss et al., 2000). Indeed, neuropsychologists should take advantage of research advances in the fields of cognitive and affective neuroscience to inform studies in clinical populations.

Finally, future research should identify additional factors, such as coping style and metacognitive skills, which may influence the complex interrelationships between affect, executive functioning, and outcome following TBI.

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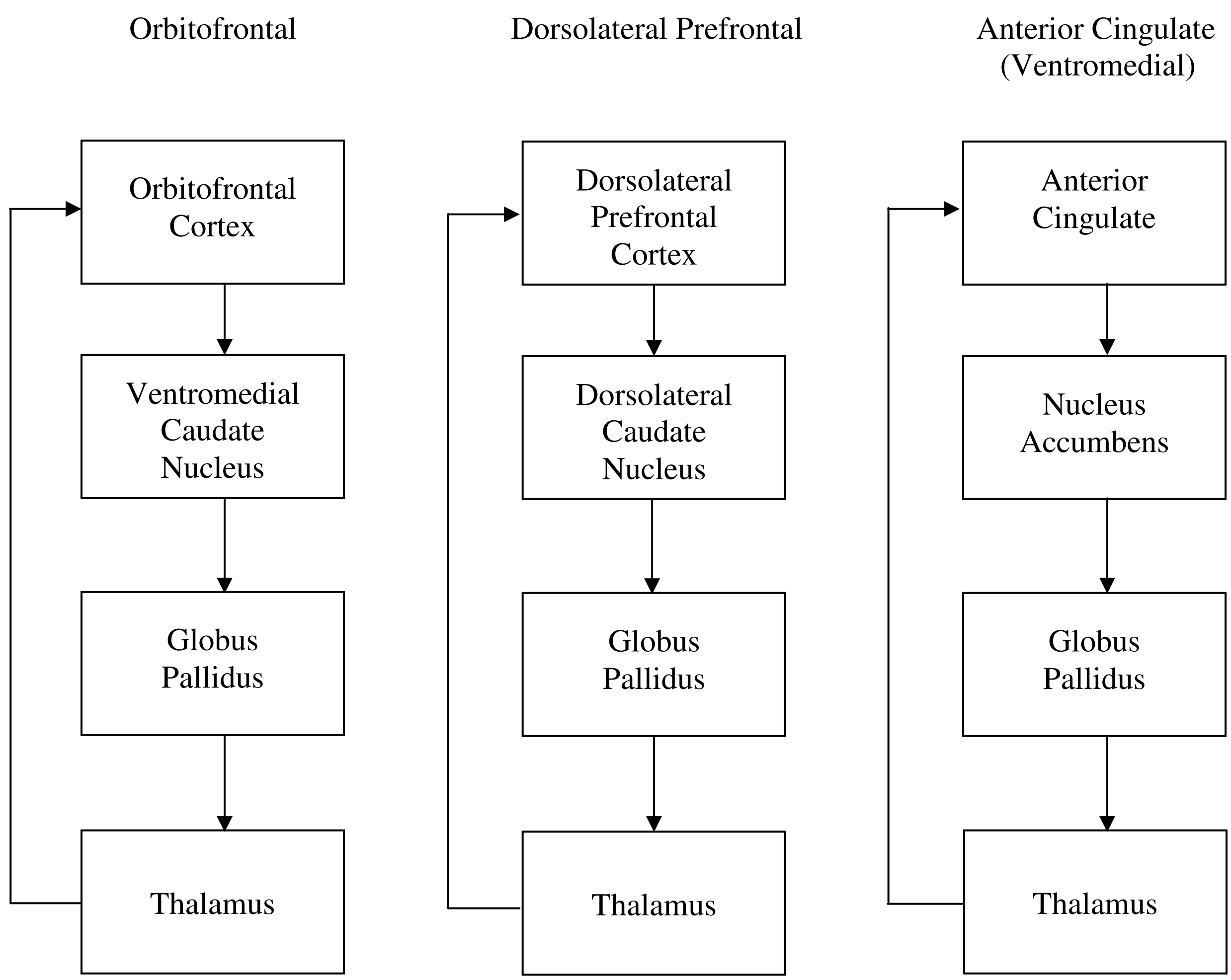
Appendix A

Frontal-subcortical circuits



Adapted from Cummings & Miller, 2007.

Appendix B

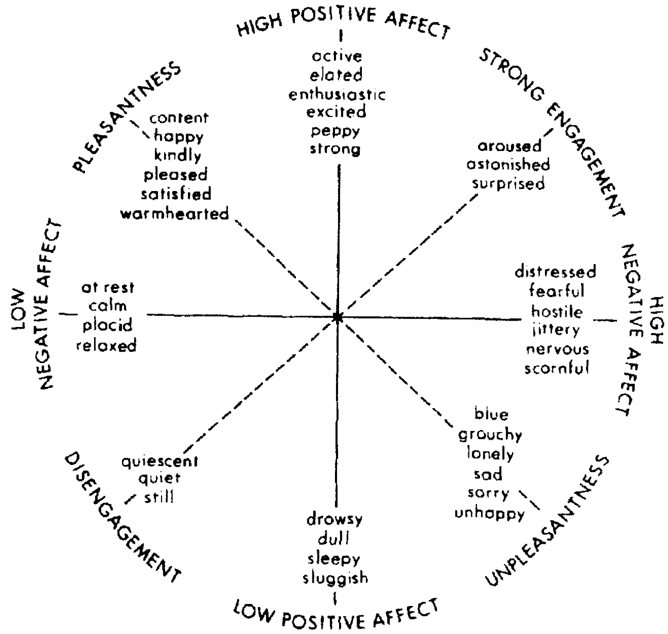
Commonly Used Tests of Executive Functioning

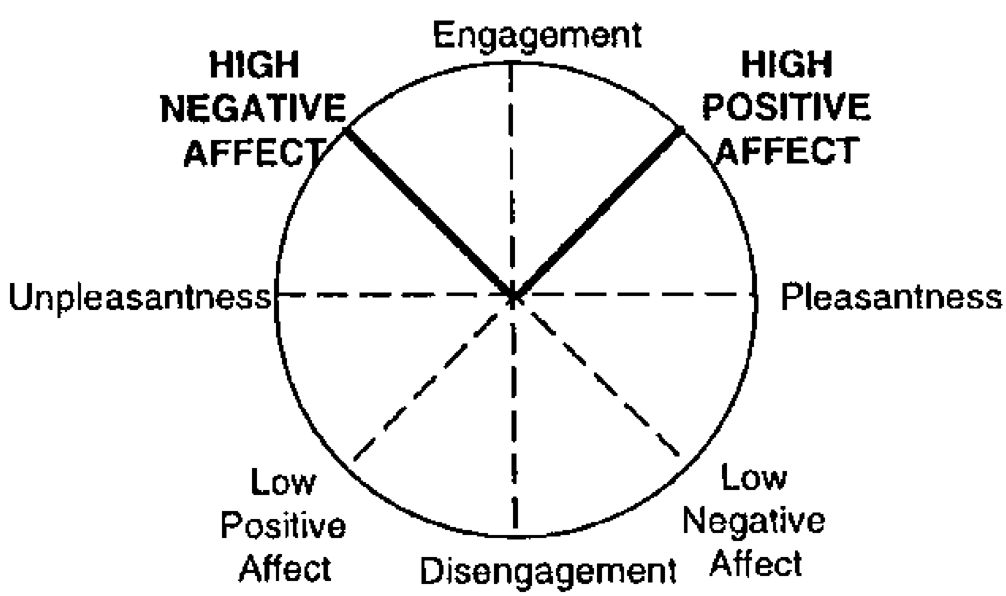
Test/Battery	Executive Function
Brixton Spatial Anticipation Test	Concept formation, Rule detection
California Sorting Test (CST)	Concept formation
Category Test	Concept formation, Set maintenance, Set shifting, Rule detection
Continuous Performance Tests	Response inhibition
Controlled Oral Word Association Test (COWAT)	Response generation/Initiation, Inhibition
Letter Number Sequencing[a]	Working memory
Paced Auditory Serial Addition Test (PASAT)	Divided attention, Working memory
Stroop Color Word Test	Set shifting, Response inhibition
Tower of London (TOL)	Planning, Response inhibition
Trail Making Test (TMT)	Set shifting
Wisconsin Card Sorting Test (WCST)	Concept formation, Set maintenance, Set shifting, Response inhibition, Rule detection
Behavioral Assessment of the Dysexecutive System (BADS)	Set shifting, Planning, Cognitive Estimation, Response inhibition
Delis-Kaplin Executive Function System (D-KEFS)	Response inhibition, Concept formation, Set shifting, Word and design generation, Planning, Rule deduction, Abstraction

Adapted from Jurado & Rosselli (2007) and McDonald, Flashman, & Saykin (2002). See Spreen & Strauss (1998) for detailed test descriptions.
[a]Subtest of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III).

Appendix C

The two-dimensional structure of affect proposed by Watson & Tellegen





Adapted from Watson & Tellegen (1985) and Feldman Barrett & Russell (1999).

Appendix D

Positive and Negative Affect Schedule (PANAS)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you are feeling this way right now (that is, at the present moment). Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

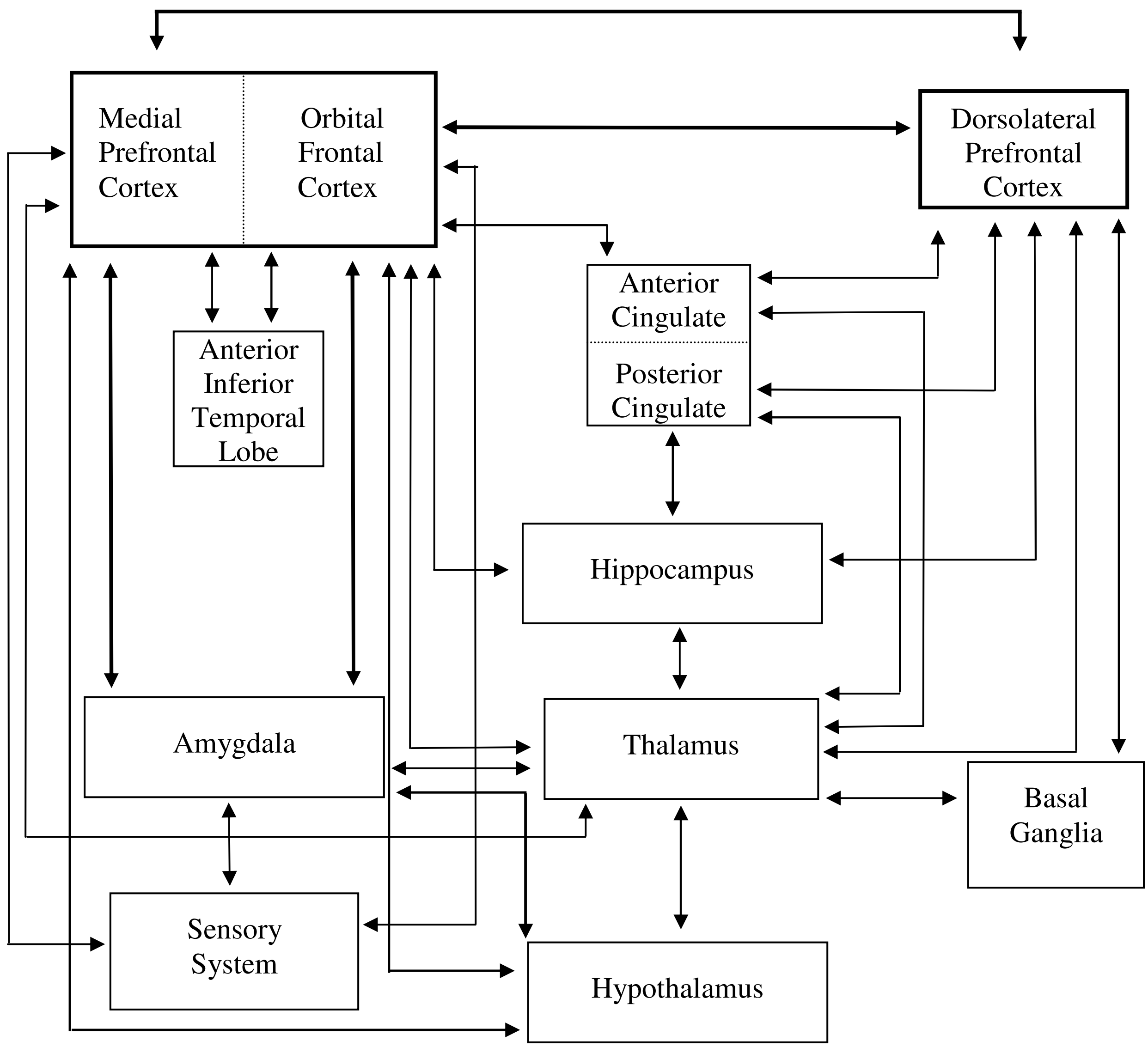
____	interested*	____	irritable
____	distressed	____	alert*
____	excited*	____	ashamed
____	upset	____	inspired*
____	strong*	____	nervous
____	guilty	____	determined*
____	scared	____	attentive*
____	hostile	____	jittery
____	enthusiastic*	____	active*
____	proud*	____	afraid

Note. * denotes PA items

Adapted from Watson, Clark, & Tellegen (1988).

Appendix E

Affective Circuitry



Adapted from Pavuluri, Herbener, & Sweeney, 2005.

Appendix F

Community Integration Measure (CIM)

1 always disagree	2 sometimes disagree	3 neutral	4 sometimes agree	5 always agree

I feel like part of this community, like I belong here	_____
I know my way around this community	_____
I know the rules in this community and I can fit in with them	_____
I feel that I am accepted in this community	_____
I can be independent in this community	_____
I like where I’m living now	_____
There are people I feel close to in this community	_____
I know a number of people in this community well enough to say hello and have them say hello back	_____
There are things that I can do in this community for fun in my free time	_____
I have something to do in this community during the main part of my day that is useful and productive	_____

Adapted from McColl et al. 2001.

Appendix G

Disability Rating Scale Employability Scoring

Original Rating	Description	Dichotomy
0.0 = *Not Restricted* 0.5 = *Not Restricted/ Selected Jobs, Competitive*	Can compete in the open market for a relatively wide range of jobs commensurate with existing skills; or can initiate, plan, execute, and assume responsibilities associated with homemaking; or can understand and carry out most age relevant school assignments.	**Competitively Employable (≤1.0)**
1.0 = *Selected Jobs, Competitive* 1.5 = *Selected Jobs/ Sheltered Workshop*	Can compete in a limited job market for a relatively narrow range of jobs because of limitations of the type described above and/or because of some physical limitations; or can initiate, plan, execute, and assume many, but not all responsibilities associated with homemaking; or can understand and carry out many but not all school assignments.	**Noncompetitive/ Unemployable (≥1.5)**
2.0 = *Sheltered Workshop*, *NonCompetitive* 2.5 = *Sheltered Workshop/ Not Employable*	Cannot compete successfully in a job market because of limitations described above and/or because of moderate or severe physical limitations; or cannot without major assistance initiate, plan, execute and assume responsibilities for homemaking; or cannot understand and carry out even relatively simple school assignments without assistance.	
3 = *Not Employable*	Completely unemployable because of extreme psychosocial limitations of the type described above, or completely unable to initiate, plan, execute and assume any responsibilities associated with homemaking; or cannot understand or carry out any school assignments.	

The Employability item takes into account overall cognitive and physical ability to be an employee, homemaker or student. This determination should take into account considerations such as: 1) ability to understand, remember and follow instructions; 2) ability to plan and carry out tasks at least at the level of an office clerk or in simple routine, repetitive industrial situation or can do school assignments; 3) ability to remain oriented, relevant and appropriate in work and other psychosocial situations; 4) ability to get to and from work or shopping centers using private or public transportation effectively; 5) ability to deal with number concepts; 6) ability to make purchases and handle simple money exchange problems; and 7) ability to keep track of time and appointments.

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