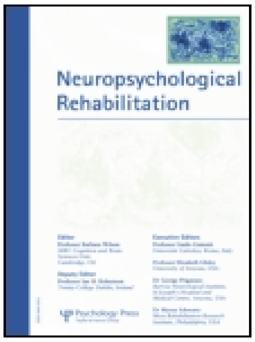

Routledge
Taylor & Francis Group

Neuropsychological Rehabilitation
An International Journal

ISSN: 0960-2011 (Print) 1464-0694 (Online) Journal homepage: www.tandfonline.com/journals/pnrh20

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To cite this article: Anne W. Hunt, Gary R. Turner, Helene Polatajko, Carolina Bottari & Deirdre R. Dawson (2013) Executive function, self-regulation and attribution in acquired brain injury: A scoping review, Neuropsychological Rehabilitation, 23:6, 914-932, DOI: 10.1080/09602011.2013.835739

To link to this article: https://doi.org/10.1080/09602011.2013.835739

Published online: 16 Sep 2013.

Neuropsychological Rehabilitation, 2013
Vol. 23, No. 6, 914–932, http://dx.doi.org/10.1080/09602011.2013.835739

Executive function, self-regulation and attribution in acquired brain injury: A scoping review

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(*Received 13 December 2012; accepted 13 August 2013*)

Impairments in executive function, self-regulation and attribution individually have been implicated in impairment in goal-directed behaviour, resulting in reduced participation in daily activities by individuals with brain injury. There is minimal literature that explicitly addresses the relationships among these constructs, how these may be affected by brain injury and the implications for rehabilitation. The objectives of this study were to determine what is known about the relationship between executive function, self-regulation and attribution, and to understand how these inter-relationships affect goal-directed behaviour in adults with acquired brain injury. A scoping review of the cognitive neuroscience, neuropsychology, rehabilitation, educational and social psychology literature from 1985 to 2011 was performed. The identified literature provided definitions of the constructs and insight into the relationships between them according to their neural underpinnings

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The first author gratefully acknowledges financial support from the Canadian Institutes of Health Research, the Canadian Federation of University Women, and the Ontario Ministry of Health and Long Term Care through the Ontario Research Coalition of Research Institutes/Centres on Health and Aging.

and theoretical models. These data also provided for the development of a new model illustrating the hypothesised relationships between constructs. This review and the model developed, suggest that attribution may play an important role in executive function and self-regulation. Rehabilitation interventions that address formulation of appropriate attributions should be considered in conjunction with those targeting self-regulation and executive function for individuals with brain injury.

Keywords: Executive function; Self-regulation; Attribution; Rehabilitation; Brain injury.

INTRODUCTION

Independence in daily life relies on complex cognitive functions that promote adaptive goal-directed behaviour. Goal direction, the process through which we identify, pursue and evaluate progress towards desired outcomes, is frequently disrupted by acquired brain injury (Duncan, Emslie, & Williams, 1996) and this can negatively impact independence. One potential mechanism underlying poor goal-directed behaviour after acquired brain injury is disruption of its constituent processes, including executive function, self-regulation and attributions (cognitive beliefs) (Anderson, 2009; Hart & Evans, 2006; Kennedy & Coelho, 2005; Moore & Stambrook, 1995; Stuss, 2009). While the impact of discrete deficits in each of these constructs is becoming better understood, little is known about how impairment in these areas interact, and the potential impact on goal-directed behaviour following brain injury.

Moore and Stambrook (1995) took an initial step towards acknowledging this relationship in their conceptual model that described an association between cognitive deficits (executive function, self-regulation) and cognitive beliefs (attribution). They proposed a relationship that was detrimentally affected by acquired brain injury and resulted in poor psychosocial outcomes. The nature of the relationship between executive function, self-regulation and attribution was not explicitly stated, nor were direct links made with performance of goal-directed behaviours. Theories of self-regulation (Kennedy & Coelho, 2005; Zimmerman, 2005) and self-regulated learning (Boekaerts, 1996; Butler & Winne, 1995; Garner, 2009) have more specifically linked the use of metacognitive strategies (executive function) and one's beliefs (attribution) to goal-directed behaviours.

Research about these constructs has been undertaken in many disciplines including neuroscience, social psychology, education, and rehabilitation, yet, there is little work that combines findings across fields resulting in variability in how constructs are defined and studied. Previous conceptual models have not been reviewed in light of emerging neuroscience research. For example, Moore and Stambrook's model could be updated to include what we now know about executive function and attribution. Neuroscience literature appears to have paid little attention to the education literature that addresses self-regulated learning and goal-oriented performance. To date, there is no specific model that explicitly addresses the relationship between executive function, self-regulation and attribution and the implications for acquired brain injury.

PURPOSE AND OBJECTIVES

The purpose of this review was to undertake an investigation into the relationship between executive function, self-regulation and attribution with respect to goal-directed behaviour in adults with acquired brain injury across diverse research literatures. The specific objectives were: (1) To define the constructs of executive function, self-regulation and attribution; (2) To describe what is known about the relationship between these constructs in goal-directed behaviour; (3) To develop a conceptual model that illustrates this relationship; and (4) To describe the effects of impairment on this relationship.

METHOD

A scoping review methodology was used as its purpose is to identify, extract and summarise relevant literature concerning a particular topic when expansive literature exists (Arksey & O'Malley, 2005). Scoping reviews offer a broad perspective regarding the topic of interest and aid in identifying questions for more specific review and future study (Arksey & O'Malley, 2005). While systematic and scoping reviews both use methods that are transparent and reproducible, scoping reviews are focused more on summarising results across multiple sources. We anticipated scoping review methodology would enable us to provide a general overview of multiple areas of literature through the inclusion of a variety of publications, including reviews, qualitative and quantitative studies, theoretical papers, and book chapters.

Data sources

The following databases were searched for relevant literature published from 1985 to 2011: Education Abstracts, ERIC, Medline, PsycArticles, PsycCritques, and PsycInfo. These databases were selected as they provide broad coverage of published research in the fields of rehabilitation, social psychology, educational psychology, cognitive neuroscience and neuropsychology.

Data search

Initial search terms were purposefully broad (executive function, self-regulation, attribution). The terms "locus of control", "causality",

TABLE 1
Search terms

Search	*Keywords used*	*Relevant sources identified*
1.	executive function* OR executive control AND self-regula* AND attribution* OR attribution theor* OR locus of control OR causality	3 sources
2.	executive function* OR executive control AND self-regul* OR self-regulated learning	590 sources
3.	self-regul* OR self-regulated learning AND attribution* OR locus of control OR causality	
4.	executive function* OR executive control AND attribution* OR locus of control OR causality	

"executive control", and "self-regulated learning", were added following preliminary searches as these terms appeared to be used interchangeably in the various literatures with our chosen search terms. We opted not to use specific cognitive skills (e.g., problem solving, awareness, metacognition) as search terms as we were interested in finding out which cognitive skills were associated with each construct and felt that this approach may bias our results. Since only three papers were identified using search terms that addressed all three areas (see Table 1), additional searches were conducted using combinations of search terms including two of the three constructs. These identified an additional 590 abstracts. Forward and backward searches of reference lists, and manual searches of related conference proceedings were also conducted. Additional literature was identified as it was previously known to the first author and/or by the senior author.

Study selection

A total of 593 abstracts were reviewed using the following criteria. Papers were included if they:

1. Addressed one or more of the constructs of self-regulation, attribution or executive function; and/or
2. Provided a definition of the particular construct(s) addressed; and/or
3. Addressed the construct in healthy adults or adults with acquired brain injury (stroke, traumatic brain injury, brain tumour); and/or
4. Addressed the neural correlates of these constructs within the populations noted in (3).

Papers were excluded if they:

1. Addressed clinical paediatric, or developmental diagnoses (e.g., attention deficit disorders, learning disabilities, autism spectrum disorders).
2. Addressed non-acquired brain injury impairments (e.g., mild cognitive impairment related to the aging process or neurodegenerative diseases).
3. Addressed cognitive impairment due to mental health diseases (substance abuse, depression, schizophrenia).
4. Were written in languages other than English.

Fifty-three papers were chosen for more in-depth review.

Data extraction, collation and summation

Each paper meeting criteria was reviewed using a common analytical framework. Quantitative papers examined hypotheses, study population, methodology, outcome measures and results. A descriptive framework was used for qualitative papers and book chapters, and included construct definition, evidence and/or models described. Data were extracted and organised according to each objective and then according to similar themes identified within those groupings. Data were then examined for inter-relationships between constructs according to objectives.

RESULTS

Defining executive function, self-regulation and attribution

Since considerable variability was found regarding definitions of executive function, self-regulation and attribution, the first objective of the review became defining each construct to establish a foundation from which we could explore similarities and differences. Definitions were developed by examining how each construct functions within the context of goal-directed behaviour from neuroscience and behavioural perspectives.

Executive function. Executive function is defined as an overarching cognitive process, mediated by attention, that coordinates and integrates multiple subordinate cognitive skills to enable goal-directed behaviour (Cicerone, Levin, Malec, Stuss, & White, 2006; Stuss, 2009). This definition was developed based on three commonalities that emerged from the literature.

The first commonality, the overarching nature of executive function, was described in earlier seminal conceptualisations as a "central executive" (Baddeley, 1996) and a "supervisory attentional system" (Norman & Shallice, 1986) that direct behaviour. More recently, Cicerone and colleagues (2006) explained executive cognitive functions, using neuroanatomical features, as one of four frontal lobe domains.

The second common theme is that executive function is comprised of subordinate cognitive skills. There is great variability reported as to what those skills are. However, there is a trend toward those associated with task setting and task monitoring (Stuss, 2009) such as goal selection, cognitive flexibility, impulse control, planning and organsation, problem solving and decision making (Anderson, 2009; Declerck, Boone, & De Brabander, 2006; Garner, 2009). There is overlap reported between executive function and self-regulation definitions with respect to monitoring functions (Cicerone et al., 2006) which may be explained, in part, by frontal activation networks in which common neural structures are activated according to differing cognitive demands and task settings (Duncan & Owen, 2000). Stuss (2009) includes self-monitoring, defined as the process of checking the task over time for quality and subsequent adaptation of behaviour, within executive cognitive function, and associates it with right frontal ventro-lateral regions of the brain.

The third major commonality is the general consensus that the frontal lobe and, in particular, prefrontal cortex is central to executive function (Stuss, 2009). The dorsal lateral prefrontal cortex (dlPFC) has been implicated in integrative activity (Chikazoe, 2010; Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004; VanOverwalle, 2009) while the dorsal medial prefrontal cortex (dmPFC) has been implicated in impulse and inhibitory control (Declerck et al., 2006; Tops, Boksem, Luu, & Tucker, 2010). Increased communication between these areas has been demonstrated during conscious goal-directed behaviour supporting the integrative and regulative nature of executive cognitive functions (Cavanagh, Cohen, & Allen, 2009). Schmahmann (2004) implicates the cerebellum in executive function, and extends our understanding of executive function beyond the frontal lobe, supporting Stuss's (2006) contention that executive function is comprised of specific processes that are integrated and expanded beyond the frontal lobes as required by specific tasks.

Self-regulation. Self-regulation is the process used to adjust performance as an individual works toward identified behavioural goals within a specific context. This process occurs on two levels: complex or unfamiliar tasks use consciously directed self-regulation involving executive processing, while more automatic, familiar tasks forgo this additional dispensation. Reflected in this definition are themes identified in the various literatures that self-regulation is an active, overarching process involving engagement in planning, self-observation, self-reflection and performance adaptations that occur automatically or at a conscious level (Crocker, Brook, Niiya, & Villacorta, 2006; Garner, 2009; Hart & Evans, 2006; Ownsworth, Fleming, & Hardwick, 2005;

Ownsworth, Quinn, Fleming, Kendall, & Shum, 2009; Rasmussen, Wrosch, Schier, & Carver, 2006). Social cognitive psychologists depict effective self-regulation as the ability to exert control over one's own behaviour while recognising the importance of context in this process (Zimmerman, 2005). This view is shared with cognitive neuroscientists who distinguish self-regulation from executive cognitive functions with evidence from lesion studies, and contend that self-regulation involves emotional and reward processing and recognition of the consequences of one's behaviour, and is required in situations where determining an adaptive response is unique to a particular context (Cicerone et al., 2006; Stuss, 2009). In other words, self-regulation is required when a behavioural response cannot be determined based on habit, environmental cues or cognitive scrutiny (Stuss, 2009). Viewed in this way, self-regulation appears to be an overarching construct that utilises executive functions.

Like executive function, self-regulation is largely associated with activity in the prefrontal cortex. While overlap is evident, medial prefrontal structures tend to be associated with self-regulation. For example, ventral medial (vmPFC) and dmPFC have been found to be active in evaluative and monitoring activity (D'Argembeau et al., 2005). The anterior cingulate cortex (ACC) has also been shown to be active during monitoring behaviour and to initiate recruitment of prefrontal areas when further executive processing is required, demonstrating a possible neural link between executive function and self-regulation (Krug & Carter, 2010).

Attribution. Attribution is the process used by individuals to explain the cause of their behaviour and that of others (Weiner, 1985). It involves formulating judgements about observed behaviours, making comparisons to previously stored experiences, and recruiting other cognitive processes to enable an immediate or future behavioural response that is contextually appropriate. Like executive function and self-regulation, it is understood as a dynamic construct that is continually updated with experience (Weiner, 1985).

Attribution has been widely studied in social psychology since the 1960s (Liebermann, Gaunt, Gilber, & Trope, 2002; Rotter, 1966; Weiner, 1985) and more recently in cognitive neuroscience (Harris, Todorov, & Fiske, 2005; Schroeter, Ettrich, Menz, & Zysset, 2010). Modern theoretical descriptions of attribution are largely based on the work of Weiner who explains attribution in terms of three dimensions: locus of causality/control (who, what, where is the cause?); stability (is cause constant or changing?); and controllability (amount of control the individual has over the cause). Each dimension is potentially influenced by an individual's performance, namely, task success and failure. For example, positive life experiences enhance the development of internal locus of control through optimistic attributions ("I was successful because I am good at that") leading to increased confidence, initiative, motivation and positive self-efficacy (Bandura, 1991; Furnham, 2009). In contrast, negative life experiences lead to the development of external locus of control and consequently decreased confidence, control, motivation and negative self-efficacy (Bandura, 1991; Furnham, 2009). Throughout this paper, attribution is referred to in the broader, general sense or according to the particular dimension studied in a particular work.

The use of functional imaging has enabled study of attribution from a cognitive neuroscience perspective (Blackwood et al., 2003; Harris et al., 2005; Henry, Phillips, Crawford, Letswaart, & Summers, 2006; Schroeter et al., 2010; Terbeck, Chesterman, Fischmeister, Leodolter, & Bauer, 2008). Attribution processing largely occurs in the superior temporal sulcus (STS) and ACC (Henry et al., 2006; Schroeter et al., 2010) with some activity found in dorsal medial prefrontal areas (Harris et al., 2005; Mason & Morris, 2010) suggesting overlap with executive function and self-regulation.

Characterising interactions among executive function, self-regulation and attribution

The second objective of this review was to describe what is known about the relationship between executive function, self-regulation and attribution. Empirical evidence was found to support relationships between two of the three constructs (Garner, 2009; Ide & Li, 2011; Nickel & Spink, 2010; Schmeichel, 2007; Shell & Hussman, 2008; Soric & Palekcic, 2009; VanOverwalle, 2009) but only two papers were found that addressed all three constructs (Declerck et al., 2006; Henry et al., 2006). Four themes emerged: self-regulation as a super-ordinate construct; the influence of attribution; the role of conscious, explicit processing; and the impact of impairment resulting from acquired brain injury.

Self-regulation: A super-ordinate process. Self-regulation emerged as the super-ordinate construct to which executive cognitive functions and attribution contribute. This tacit relationship is evident in theories and research about self-regulation (Bandura, 1991; Hart & Evans, 2006; Zimmerman, 2005), self-regulated learning (Boekaerts, 1996), attribution ascription (Lieberman et al. 2002; Weiner, 1985) and neural underpinnings (Stuss, 2006).

Empirical studies of goal-directed performance in self-regulated learning support the notion of self-regulation as a super-ordinate construct (Cleary, Zimmerman, & Keating, 2006; LeFoll, Rascle, & Higgins, 2006; Peterson, Lavell, & Guarino, 2006). These studies examined an individual's abilities to learn new performance-based tasks (e.g., golf putting or basketball throws) and found that individuals learned to self-regulate behaviour based on internal and external cues. This adaptive process contributed to the positive development and maintenance of one's executive function and ability to make appropriate attributions regarding performance (Cleary et al., 2006). These behaviours and choices influence future planning and performance (Hagger, Chatzisarantis, Griffin, & Thatcher, 2005; Liu, Chan, Lee, Li, & Hui-Chan, 2002; Nickel & Spink, 2010). In sum, effective self-regulation involves choosing appropriate strategies in preparing for, and carrying out performance, combined with using self-reflection to make appropriate attributions about performance outcome.

Self-regulation is represented as a central construct influenced by executive functions and attributions in rehabilitation literature (Toglia, Johnston, Goverover, & Dain, 2010). Empirically, Liu and colleagues (2002) trained self-regulation to improve performance in daily activities with adults with brain injury. Following training, these individuals were able to identify and implement potential solutions, and to evaluate progress until their solution was effective. Training executive functions (attention, working memory, planning) has also been shown to positively influence self-regulation (Novakovic-Agopian et al., 2010; Ownsworth et al., 2009).

The super-ordinate nature of self-regulation is also depicted in several theoretical models. Boekaerts (1996) explicitly linked executive processes and attribution within a cognitive-motivational model. Self-regulation is clearly put forth as the central construct mediated by executive and attribution components. Similarly, other theoretical models depict self-regulation as the overarching process and describe a relationship between constructs that is cyclical (Barkley, 2001; Hart & Evans, 2006; Kennedy & Coelho, 2005; Zimmerman, 2005), illustrating that feedback from previous performance is needed to adjust current behaviour and future planning (Zimmerman, 2005).

The initial phase of these models described an individual's preparation for action, typically consisting of executive activities including goal setting, planning and strategising (Boekaerts, 1996; Kennedy & Coelho, 2005; Zimmerman, 2005). The choice and nature of preparatory actions is influenced by individuals' beliefs about their control and capability to perform a task (i.e., their attributions) (Bandura, 1991; Barkley, 2001; Zimmerman, 2005). For example, if individuals believe they are not capable of performing a task, their planning will be different than if they believe they have the capability and control necessary to be successful.

The second phase involves the performance or execution of the planned behaviour with ongoing self-monitoring, using self-observation, and task-specific strategies to adjust performance as required. This phase may be influenced by attributions about the success/failure of previous performance, use of specific strategies, and self-observations.

The third phase is self-reflection during which individuals self-evaluate and make causal attributions to explain the outcome of their performance (Zimmerman, 2005). Attribution influences all three phases of these models of self-regulation whereas executive function appears to be largely involved in the initial or preparatory phase.

The influence of attribution. Attributions are important in self-regulation of goal-directed behaviour and can enhance or disrupt this process and alter the use of executive function. (Cleary et al., 2006; Hagger et al., 2005; LeFoll, Rascle, & Higgins, 2006; Nickel & Spink, 2010; Shell & Husman, 2008; Soric & Palekcic, 2009; Turban, Brown, Tan, & Sheldon, 2007). Declerck and colleagues (2006) reported that individuals with internal locus of control are more motivated in rewarding situations, and use evaluative feedback and metacognitive skills to gain control more than those with external locus of control. This finding is consistent with educational literature (e.g., Boekaerts, 1996; Garner, 2009), and implies that individuals with internal locus of control may be more effective self-regulators, and the ability to make appropriate attributions is based, in part, on the engagement of executive cognitive function. In other words, the individual must actively engage in executive cognitive tasks (e.g., strategising, problem solving) and self-regulation (self-evaluation and self-observation) to form accurate attribution ascriptions that will enable them to adjust performance appropriately. Previously reported neural underpinnings, in which attribution processing appeared to trigger the involvement of executive function to enable contextually appropriate behavioural performance support this contention (Blackwood et al., 2003; Cleary et al., 2006; Hagger et al., 2005; LeFoll, Rascle, & Higgins, 2006; Rasmussen et al., 2006; Weiner, 1985).

Attributions are clearly important in self-regulation, and a certain level of cognitive skill is necessary to make accurate attributions (Logan, 2000). The ability to make appropriate attributions appears to have considerable influence on self-regulatory behaviour by affecting executive function in the preparatory phases and in self-reflection post-activity. While this hypothesis is supported by the reviewed literature, there is very little literature that addresses attribution in rehabilitation or brain injury recovery.

Conscious, explicit processing. The relationship between executive function, self-regulation and attribution is most evident in consciously directed behaviour. With familiar day-to-day tasks, goal-directed behaviour occurs subconsciously and engagement of executive functions or attribution ascription is not necessary. However, when confronted with unfamiliar or complex tasks, individuals must engage executive function to consciously focus planning and performance (Stuss & Alexander, 2007).

Descriptions of neural processing demonstrate how the constructs work together in conscious goal-directed behaviour (D'Argembeau et al., 2005). Information enters sensory cortices and travels in ventral or dorsal pathways to the superior temporal sulcus (STS) (Blackwood et al., 2003; Mason &

Morris, 2010). Here, it is processed automatically by accessing, comparing and then responding to previously stored behavioural "scripts" or contingencies stored in this area. When encountering new or unfamiliar situations that do not match these scripts, additional processing is required beyond the STS. This cues the need for more effortful, conscious processing involving the anterior cingulate cortex (ACC) which is thought to integrate information from multiple areas. When the ACC is activated, it, in turn, recruits prefrontal areas subsequently engaging higher level processing (e.g., executive function and self-regulation). This enables planning, strategising, decision-making, and attributions that will in turn lead to a contextually appropriate behavioural response (Declerck et al., 2006; Domenech & Dreher, 2010; Krug & Carter, 2010; Mason & Morris, 2010; Rudebeck et al., 2008).

Cognitive neuroscience literature associates all three constructs with neural activity and structures within the prefrontal cortex during conscious goal-directed behaviour. The dorsal lateral prefrontal cortex (dlPFC) and ventral medial prefrontal cortex (vmPFC), both important in executive function (Stuss & Alexander, 2007), are also needed for the monitoring of behaviour (self-regulation) (Declerck et al., 2006; Tops et al., 2010). Dorsal medial prefrontal cortex (dmPFC) has been associated with evaluative judgements in attribution processing (Harris et al., 2005; Mason & Morris, 2010).

Models of self-regulation in education and rehabilitation research explicitly recognise two levels of self-regulation (Garner, 2009; Hart & Evans, 2006; Kennedy & Coelho, 2005). Likewise, models of attribution ascription also posit dual levels of processing involving conscious self-reflective or automatic behaviours (Liebermann et al., 2002). Corno (1986) implicitly raised the notion of dual processing in her description of how students become effective self-regulated learners. Students' initial attempts to engage in self-regulated learning are often impulsive and lacking in executive control. With experience, metacognitive control (executive function) and control and capability beliefs (attribution) develop, and self-monitoring abilities (self-regulation) become more efficient. Through consistent practice of adaptive self-regulation, behaviours may eventually become automatic (Corno, 1986).

In brief, individuals are motivated to use executive functions to consciously manage behaviour to reach goals (self-regulation), and that behaviour is contingent upon previous and anticipated capability, and cause and control beliefs (attribution).

The impact of brain injury. Abundant evidence shows that injury to the brain affects the neural structures and processes that enable efficient executive function, self-regulation and attribution (Eslinger, Grattan, & Geder, 1995; Hart & Evans, 2006; Stuss & Alexander, 2007). These impairments are significantly associated with problems in managing day-to-day activities, and participating in work or educational pursuits, leisure and other activities within their communities (Barkley, 2001; Kennedy & Coelho, 2005).

Misattributions (e.g., incorrectly identifying one's perceived cause or control of an outcome/behaviour) are thought to result from the long-lasting behavioural, cognitive, emotional, psychiatric and interpersonal after-effects of brain injury (Moore & Stambrook, 1995). Misattributions may contribute to repeated task failure resulting in poor coping and self-efficacy, and emotional distress, (Kennedy & Coelho, 2005; Logan, 2000; Moore & Stambrook, 1995; Ownsworth et al., 2005). For example, distorted beliefs about one's skills and abilities may lead to repeated task failure which may then create situations of "learned helplessness" whereby brain injured individuals inaccurately believe they are not capable of performing a particular task and therefore do not even attempt to do so (Hornich-Agnieszka, 2008; Kennedy & Coelho, 2005; Medley, Powell, Worthington, Chohan, & Jones, 2010; Moore & Stambrook, 1995). In contrast, changes towards a more positive locus of control (internal, controllable causes) were a significant predictor of community reintegration in chronic brain injury survivors (Hornich-Agnieszka, 2008).

According to Weiner's (1985) attribution theory, in healthy adults, failure situations require the individual to engage in more attribution processing than do successful ones, as they attempt to understand what happened to better predict future performance. However, healthy adults have also been shown to be impaired in making appropriate attributions in failure situations (Cleary et al., 2006; LeFoll, Rascle, & Higgins, 2006). Cognitively impaired individuals presumably would be at even greater disadvantage.

Summary. Although executive function, self-regulation and attribution appear to be separate behavioural constructs, their neural structures, particularly those active in executive function and self-regulation, are interconnected. In conscious goal-directed behaviour the STS appears to be a gate keeper that, when triggered by novel or complex situations, cues the ACC which in turn recruits prefrontal cortical areas involved with executive function and self-regulation to enable contextually appropriate behaviour. These findings suggest a cyclical relationship between self-regulation, executive function and attribution that is influenced by previously formed attributions.

Integrating executive function, self-regulation and attribution: The Performance Model of Self-Regulation

Given the interactions among executive function, self-regulation and attribution that emerged from the review, we propose a new model, the Performance Model of Self-Regulation. This model explicitly recognises these interactions and proposes that performance is the key outcome of conscious goal-directed behaviour. Self-regulation is the super-ordinate construct, executive function is key to preparing for performance and, along with attribution, is an influential component throughout the process. These inter-relationships are most salient at a conscious, explicit level of behaviour in complex or unfamiliar tasks.

Our model is informed by previous models of self-regulation, found in the educational psychology (Boekaerts, 1996), rehabilitation (Kennedy & Coelho, 2005; Hart & Evans, 2006), and social psychology literature (Zimmerman, 2005) and elaborates on the cognitive influences proposed by Moore and Stambrook (1995). Our model is unique as it highlights the key role that attributions have on goal-directed behaviour.

Operationally, there are three phases: preparation and planning, performance, and adaptation. (See Figure 1) First, to engage in conscious, goal-directed behaviour, executive functions are engaged to prepare and plan a course of intended action (Cicerone et al., 2006; Duncan et al., 1996). Development of this action plan is influenced by individuals' past experiences, problem solving abilities and beliefs about their capability and control (attribution) (Cleary et al., 2006; Logan, 2000; Weiner, 1985). Next, during the performance phase, self-regulatory abilities are recruited to self-observe and adapt behaviour according to performance demands (Kennedy & Coehlo, 2005; Zimmerman, 2005). During adaptation, the individual

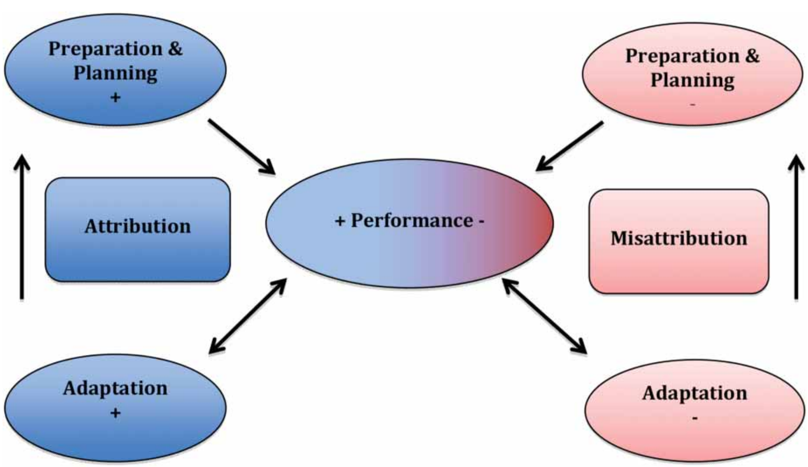

Figure 1. The Performance Model of Self-Regulation. Executive function is represented by behavioural designate "Preparation & Planning"; self-regulation is represented as the overarching process. Single and bidirectional arrows signify interaction between constructs that occurs at different times throughout the performance process. The left side of the model diagram represents effective self-regulation and is denoted by " + ". The right side depicts ineffective self-regulation, which may occur as a result of brain injury, and is represented by "–".

engages in self-reflection about performance outcomes, and formulates evaluative judgements and attributions about that performance (Hart & Evans, 2006; Logan, 2000; Weiner, 1985; Zimmerman, 2005). This information is then relayed back, and influences preparation for future performance.

Preparation and planning. This phase represents the engagement of executive function in goal-directed behaviour. Here, individuals consciously engage in preparatory activities to organise and plan an intended course of action, and to choose relevant strategies, relying on executive functions to do so. Their choices are influenced motivation, beliefs about capability regarding success, and failure expectations, and are shaped by previously formed judgements about past performance (Corno, 1986; Garner, 2009; Moore & Stambrook, 1995).

Performance. Once a course of action is decided upon, the plan is executed during the "Performance" phase. Here, the individual is actively engaged in task performance and self-monitoring using self-observation skills. Performance adaptations are made as necessary to bring performance in line with the intended goal given presenting contextual factors. Bidirectional arrows leading to and from the Adaptation and Performance phases represent this two-way interaction.

Adaptation. Adaptation is the third phase in the model. Performance adjustments can be made while engaged in a task (Performance phase), through adaptive self-monitoring, and may also occur after performance through self-reflection. This is represented by bidirectional arrows between Adaptation and Performance (see Figure 1).

Ineffective self-regulation. Our model is distinctive as it depicts how the self-regulatory process may be affected by impairments following brain injury. Impairments in executive function and misattributions will affect preparation for action and subsequent task performance, leading to a negative feedback cycle. A distorted perception of performance may lead to negative self-judgements and incorrect attributions about performance (Moore & Stambrook, 1995; Weiner, 1985). For example, individuals with impaired executive function may decide that their poor task performance is based on lack of ability rather than impaired cognition resulting from brain injury.

If behaviour is adapted appropriately, task performance is adjusted, and this information is stored for future use in the preparation phase (left side of model). If performance is unsuccessful, attribution ascriptions for the failure are made and this information is also stored for future use (Bandura, 1991; Weiner, 1985). However, if misattributions for performance are made, the individual runs the future risk of ineffective or inappropriate preparation and adaptation based on the misattribution, leading to engagement of the negative self-regulatory cycle in the right side of the model. Other common impairments following brain injury, such as in awareness, memory and task initiation, may also contribute to the development of misattributions.

FUTURE DIRECTIONS AND LIMITATIONS

This review provides a novel view of the relationships between executive function, self-regulation and attribution. Developing a more precise understanding of these inter-relationships will further elucidate the proposed model. Examining the cognitive neuroscience literature, with attention to neural network processing, may illuminate aspects of directionality in the model and further delineate self-regulation and executive function. Determining if, and how, these two constructs are distinct may inform the development of target rehabilitation interventions. Exploring literature from developmental psychology for commonalities and differences in how constructs evolve may also contribute toward establishing these distinctions.

We found that attribution appears to have considerable influence on goal-directed performance and yet little is known about how rehabilitation clinicians understand this construct or how attribution is addressed in brain injury rehabilitation. Determining the role of awareness in the proposed model may be of particular importance for brain injury rehabilitation in view of the propensity for misattributions and impairment in executive function contributing to poor functional outcomes. Further study is warranted to determine how to address attribution in recovery and rehabilitation. Considering connections between attribution and the literature on awareness deficits in brain injury may be one place to start.

The scoping review methodology allows for a summative review rather than offering a critique of methodological issues or strength of the evidence. While broad in scope, there were nonetheless boundaries to this review and other factors that may contribute to the model, such as awareness and memory, were not addressed. To date, the proposed model and relationships depicted have not been tested. Its utility is yet to be determined and requires further study. Wood and Rutterford (2006) offer one possible mechanism using regression analysis to evaluate relationships between neuropsychological constructs depicted in the model of interest and outcome measures. This may be one way to begin testing the model.

CONCLUSION

The Performance Model of Self-Regulation was conceptualised based on current evidence regarding the inter-relationships between the constructs of self-regulation, executive function and attribution. Scoping review methodology was crucial to the model's development, as it enabled integration of research from diverse literatures notably linking neuroscience, education, rehabilitation and social cognitive psychology. Underlying neural correlates, empirical studies and theory support this model, which recognises the importance of attribution in goal-directed performance, as well as its inter-relationship with executive function and self-regulation.

REFERENCES

Anderson, P. (2009). Toward a developmental model of executive function. In V. Anderson, R. Jacobs, & P. Anderson (Eds.), *Executive function and the frontal lobes a lifespan perspective* (pp. 3–21). New York, NY: Taylor & Francis.

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19–32.

Baddeley, A. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology*, *49A*, 5–28.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behaviour and Human Decision Processes*, *50*, 248–287.

Barkley, R. (2001). The executive functions and self-regulation: An evolutionary neuropsychology perspective. *Neuropsychology Review*, *11*(1), 1–29.

Boekaerts, M. (1996). Self-regulated learning at the junction of cognition and motivation. *European Psychologist*, *1*(2), 100–112.

Blackwood, N., Bental, R., Ffytche, D., Simmons, A., Murray, R., & Howard, R. (2003). Self-responsibility and the self-serving biases: An fMRI investigation of causal attributions. *NeuroImage*, *20*, 1076–1085.

Butler, D., & Winne, P. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, *65*(3), 245–281.

Cavanagh, J., Cohen, M., & Allen, J. (2009). Prelude to and resolution of an error: EEG phase synchrony reveals cognitive control dynamics during action monitoring. *Journal of Neuroscience*, *29*(1), 98–105.

Chikazoe, J. (2010). Localizing performance of go/no-go tasks to prefrontal cortical sub regions. *Current Opinion in Psychiatry*, *23*, 267–272.

Cicerone, K., Levin, H., Malec, J., Stuss, D., & Whyte, J. (2006). Cognitive rehabilitation interventions for executive function: Moving from bench to bedside in patients with traumatic brain injury *Journal of Cognitive Neuroscience*, *18*(7), 112–122.

Cleary, T., Zimmerman, B., & Keating, T. (2006). Training physical education students to self-regulate during basketball free throw practice. *Research Quarterly for Exercise and Sport*, *77*(2), 251–262.

Corno, L. (1986). The metacognitive control components of self-regulated learning. *Contemporary Educational Psychology*, *11*, 333–346.

Crocker, J., Brook, A., Niiya, Y., & Villacorta, M. (2006). The pursuit of self-esteem: Contingencies of self-worth and self-regulation. *Journal of Personality*, *74*(6), 1749–1772.

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., DelFiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2005). Self-referential reflective activity and its relationship with rest: A PET study. *NeuroImage*, *25*, 616–624.

Declerck, C., Boone, C., & De Brabander, B. (2006). On feeling in control: A biological theory for individual differences in control perception. *Brain and Cognition*, *62*, 143–176.

Domenech, P., & Dreher, J-C. (2010). Decision threshold modulation in the human brain. *Journal of Neuroscience*, *30*(3), 14305–14317.

Duncan, J., Emslie, H., & Williams, P. (1996). Intelligence and the frontal lobe: The organization of goal-directed behaviour. *Cognitive Psychology*, *30*, 257–303.

Duncan, J., & Owen, A. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences*, *23*(10), 475–483.

Eslinger, P., Grattan, L., & Geder, L. (1995). Impact of frontal lobe lesions on rehabilitation and recovery from acute brain injury. *Neurorehabilitation*, *5*, 161–182.

Furnham, A. (2009). Locus of control and attribution style. In M. Leary & R. Hoyle (Eds.), *Handbook of individual differences in social behaviour* (pp. 274–287). New York, NY: Guilford Press.

Garner, J. (2009). Conceptualizing the relations between executive functions and self-regulated learning. *Journal of Psychology*, *143*(4), 405–426.

Hagger, M., Chatzisarantis, N., Griffin, M., & Thatcher, J. (2005). Injury representations, coping, emotions and functional outcomes in athletes with sports-related injuries: A test of self-regulation theory. *Journal of Applied Social Psychology*, *35*(11), 2345–2374.

Harris, L. Todorov, A., & Fiske, S. (2005). Attributions on the brain: Neuro-imaging dispositional interferences, beyond theory of mind. *NeuroImage*, *28*, 763–769.

Hart, T., & Evans, J. (2006). Self-regulation and goal theories in brain injury. *Journal of Head Trauma Rehabilitation*, *21*(2), 142–155.

Henry, J., Phillips, L., Crawford, J., Letswaart, M., & Summers, F. (2006). Theory of mind following traumatic brain injury: The role of emotion recognition and executive dysfunction. *Neuropsychologia*, *44*, 1623–1628.

Hornich-Agnieszka, A. (2008). Examination of self-efficacy and locus of control protecting community integration following moderate to severe traumatic brain injury. (Unpublished doctoral thesis). Marshall University. Huntington, West Virginia, USA.

Ide, J., & Li, C. (2011). A cerebellar thalamic cortical circuit for error related cognitive control. *NeuroImage*, *54*, 455–464.

Kennedy, M., & Coelho, C. (2005). Self-regulation after traumatic brain injury: A framework for intervention of memory and problem solving. *Seminars in Speech and Language*, *26*(4), 242–255.

Krug, M., & Carter, C. (2010). Anterior cingulate cortex contributions to cognitive and emotional processing: A general purpose mechanism for cognitive control and self-control. In R. Hassin, K. Ochsner, & Y. Trope (Eds.), *Self-control in society, mind, and brain* (pp. 3–37). New York, NY: Oxford University Press.

LeFoll, D., Rascle, O., & Higgins, N. (2006) Persistence in a putting task during perceived failure: Influence of state attributions and attributional style. *Applied psychology: An international review*, *55*(4), 586–605.

Liebermann, M., Gaunt, R., Gilber, D., & Trope, Y. (2002). Reflection and reflexion: A social cognitive neuroscience approach to attributional inference. *Advances in Experimental Social Psychology*, *34*, 199–249.

Liu, K., Chan, C., Lee, T., Li, L., & Hui-Chan, C. (2002). Self-regulatory learning and generalization for people with brain injury. *Brain Injury*, *16*(9), 817–824.

Logan, M. (2000). A comparative analysis of causal attribution. (Doctoral dissertation, University of Calgary, 2000). *Dissertation Abstracts International*, *61*, 881.

Mason, M., & Morris, M. (2010). Culture, attribution and automaticity: A social cognitive neuroscience view. *SCAN*, *5*, 292–306.

Medley, A., Powell, T., Worthington, A., Chohan, G., & Jones, C. (2010). Brain injury beliefs, self-awareness and coping: A preliminary cluster analytic study based within the self-regulatory model. *Neuropsychological Rehabilitation*, *20*(6), 899–921.

Moore, A., & Stambrook, M. (1995). Cognitive moderators of outcome following traumatic brain injury: A conceptual model and implications for rehabilitation. *Brain Injury*, *9*(2), 109–130.

Nickel, D., & Spink, K. (2010). Attributions and self-regulatory efficacy for health-related physical activity. *Journal of Health Psychology*, *15*(1), 53–63.

Norman, D., & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R. J. Davidson, G. E. Schwartz, & D. E. Shapiro (Eds.), *Consciousness and self-regulation* (Vol. 4, pp. 1–14). New York, NY: Plenum Press.

Novakovic-Agopian, T., Chen, A., Rome, S., Abrams, G., Castelli, H., Rossi, A., McKim, R., Hills, N., & D'Esposito, M. (2010). Rehabilitation of executive functioning with training in attention regulation applied to individually defined goals: A pilot study bridging theory, assessment and treatment. *Journal of Head Trauma Rehabilitation*, *26*(5), 325–338.

Ownsworth, T., Fleming, J., & Hardwick, S. (2005). Symptom reporting and associations with compensation status, self-awareness, causal attributions, and emotional wellbeing following traumatic brain injury. *Brain Impairment*, *7*(2), 95–106.

Ownsworth, T., Quinn, H., Fleming, J., Kendall, M., & Shum, D. (2009). Error self-regulation following traumatic brain injury: A single case study evaluation of metacognitive skills training and behavioural practice interventions. *Neuropsychological Rehabilitation*, *20*(1), 59–80.

Peterson, R., Lavelle, E., & Guarino, A. (2006). The relationship between college students' executive functioning and study strategies. *Journal of College Reading and Learning*, *36*(2), 59–67.

Rasmussen, H., Wrosch, C., Schier, M., & Carver, C. (2006). Self-regulation processes and health: The importance of optimism and health. *Journal of Personality*, *74*(6), 1721–1748.

Ridderinkhof, K. R., van den Wildenberg, W. P. M., Segalowitz, S., & Carter, C. (2004). Neurocognitive mechanisms of cognitive control: The role of prefrontal cortex in action selection, response inhibition, performance monitoring, and reward-based learning. *Brain and Cognition*, *56*, 129–140.

Rotter, J. (1966). Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs*, *80*(1), 609.

Rudebeck, P., Behrens. T., Kennerley, S., Baxter, M., Buckley, M., Walton, M., & Rushworth, M. (2008). Frontal cortex subregions play distinct roles in choices between actions and stimuli. *Journal of Neuroscience*, *28*(51), 13775–13785.

Schmahmann, J. (2004). Disorders of the cerebellum. Ataxia, dysmetria of thought, and the cerebellar cognitive affective syndrome. *Journal of Neuropsychiatry and Clinical Neurosciences*, *16*(3), 367–378.

Schmeichel, B. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology*, *136*(2), 241–255.

Schroeter, M., Ettrich, B., Menz, M., & Zysset, S. (2010). Traumatic brain injury paffects the frontomedian cortex – an event related fMRI study on evaluative judgments. *Neuropsychologia*, *48*, 185–193.

Shell, D., & Husman, J. (2008). Control, motivation, affect and strategic self-regulation in the college classroom: A multidimensional phenomenon. *Journal of Educational Psychology*, *100*(2), 443–459.

Soric, I., & Palekcic, M. (2009). The role of students' interest in self-regulated learning: The relationship between students' interests, learning strategies and causal attributions. *European Journal of Psychology of Education*, *24*(4), 545–565.

Stuss, D. (2006). Frontal lobes and attention: Processes and networks, fractionation and integration. *Journal of the International Neuropsychological Society*, *12*, 261–271.

Stuss, D. (2009). Rehabilitation of frontal lobe dysfunction: A working framework. In M. Oddy, & A. Worthington (Eds.), *The rehabilitation of executive disorders: A guide to theory and practice* (pp. 3–17). Oxford: Oxford University Press.

Stuss, D., & Alexander, M. (2007). Is there a dysexecutive syndrome? *Philosophical Transactions of the Royal Society of Biological Sciences*, *362*, 901–915.

Terbeck, S., Chesterman, P., Fischmeister, F., Leodolter, U., & Bauer, H. (2008). Attribution and social cognitive neuroscience: A new approach for the online assessment of causality ascriptions and their emotional consequences. *Journal of Neuroscience Methods*, *173*, 13–19.

Toglia, J., Johnston, M., Goverover, Y., & Dain, B. (2010). A multicontext approach to promoting transfer of strategy use and self-regulation after brain injury: An exploratory study. *Brain Injury*, *24*(4), 664–677.

Tops, M., Boksem, M., Luu, P., & Tucker, D. (2010). Brain substrates of behavioural programs associated with self-regulation. *Frontiers in Psychology Cognition*, *1*, 1–14.

Turban, D., Brown, K., Tan, H., & Sheldon, K. (2007). Antecedents and outcomes of perceived locus of causality: An application of self-determination theory. *Journal of Applied Social Psychology*, *37*(10), 2376–2404.

VanOverwalle, F. (2009). Social cognition and the brain: A meta-analysis. *Human Brain Mapping*, *30*, 829–858.

Weiner, B. (1985). An attributional theory of achievement and motivation and emotion. *Psychological Review*, *92*, 548–573.

Wood, R., & Rutterford, N. (2006). Demographic and cognitive predictors of long term psychosocial outcome after brain injury. *Journal of the International Neuropsychological Society*, *12*(3), 350–358.

Zimmerman, B. (2005). Attaining self-regulation. A social cognitive perspective. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self regulation* (pp. 13–39). New York, NY: Academic Press.