HHS Public Access
Author manuscript
Brain Inj. Author manuscript; available in PMC 2016 April 27.

Published in final edited form as:
Brain Inj. 2015 ; 29(0): 848–858. doi:10.3109/02699052.2015.1005135.

Self-awareness and traumatic brain injury outcome

Kayela Robertson and **Maureen Schmitter-Edgecombe**
Washington State University

Kayela Robertson: k.robertson@email.wsu.edu; Maureen Schmitter-Edgecombe: schmitter-e@wsu.edu

Abstract

Primary Objective—Impaired self-awareness following a traumatic brain injury (TBI) can reduce the effectiveness of rehabilitation, resulting in poorer outcomes. However, little is understood about how the multi-dimensional aspects of self-awareness may differentially change with recovery and impact outcome. Thus, we examined four self-awareness variables represented in the Dynamic Comprehensive Model of Awareness: metacognitive awareness, anticipatory awareness, error-monitoring, and self-regulation.

Research Design—We evaluated change of the self-awareness measures with recovery from TBI and whether the self-awareness measures predicted community reintegration at follow-up.

Methods and Procedures—Participants were 90 individuals with moderate to severe TBI who were tested acutely following injury and 90 age-matched controls. Forty-nine of the TBI participants and 49 controls were re-tested after 6 months.

Main Outcome and Results—Results revealed that the TBI group's error-monitoring performance was significantly poorer than controls at both baseline and follow-up. Regression analyses revealed that the self-awareness variables at follow-up were predictive of community reintegration, with error-monitoring being a unique predictor.

Conclusions—Our results highlight the importance of error-monitoring and suggest that interventions targeted at improving error-monitoring may be particularly beneficial. Understanding the multi-dimensional nature of self-awareness will further improve rehabilitation efforts and understanding of the theoretical basis of self-awareness.

Keywords

Awareness; traumatic brain injury; community integration; outcome; self-awareness; rehabilitation

Introduction

Approximately 1.7 million US citizens sustain a traumatic brain injury (TBI) annually, with more than 275,000 requiring intensive rehabilitation [2]. As rehabilitation techniques designed to speed recovery and increase functional independence evolve, it is important to

Correspondence to: Kayela Robertson, Washington State University, Department of Psychology, PO Box 644820, k.robertson@email.wsu.edu, phone number: (509) 335-3587.

Declaration of Interest: The authors report no conflicts of interest.

understand individual characteristics and the rehabilitation process that influence outcome. Some research has shown that lack of self-awareness is associated with poorer outcomes (e.g. employability, community reintegration), suggesting that self-awareness may be important in rehabilitation [3,4,5,6,7]. An often cited general definition of self-awareness is 'the capacity to perceive the 'self' in relatively 'objective' terms while maintaining a sense of subjectivity' [8]. In relation to TBI research, 'lack of self-awareness' pertains to an inability to recognize deficits that have resulted from a neurological injury [9,10].

Research indicates that lack of self-awareness is a common problem in individuals who suffer a moderate to severe TBI [11,12]. Longitudinal studies further suggest that self-awareness is more impaired immediately after injury, when the majority of rehabilitation occurs, but improves over time [13]. Poor self-awareness following TBI can result in decreased motivation [14], compromised safety due to unrealistic goals [15,16], and impaired judgment. Furthermore, it is thought that without the ability to recognize one's deficits an individual is less likely to benefit from therapy [5,17]. Others, however, argue that individuals who lack self-awareness can make gains in rehabilitation due to task-specific learning and habit formation [18].

Empirical studies associating self-awareness to outcome following TBI have resulted in mixed findings. Some studies indicate that self-awareness deficits contribute to more negative outcomes [11,12,19,20]. For example, Sherer et al. [12] found that participants with greater self-awareness, as measured by the Awareness Questionnaire (AQ), had higher employability rates. In a review paper, Ownsworth and Clare [7] concluded that the majority of studies supported or partially supported the idea that self-awareness deficits are associated with poorer outcomes. In contrast, other work suggests little evidence of a relationship between self-awareness and outcome [3,21,22]. For example, Cheng and Man [3] found that greater self-awareness, as measured by the Self-Awareness of Deficits Interview (SADI), did not predict increased difficulties with instrumental activities of daily living (IADL). The lack of consistency in prior studies could partially reflect the differing methodologies and definitions that have been used to assess self-awareness across studies.

Several researchers consider self-awareness to be a complex construct with multiple aspects (e.g. metacognitive knowledge, error-monitoring) [1,23], and it has been suggested that different aspects of self-awareness may impact outcome uniquely. Crosson et al. [23] proposed the first multi-dimensional model of self-awareness called the pyramid model. This model includes three interdependent hierarchical levels of self-awareness: anticipatory awareness, emergent awareness, and intellectual awareness. At the bottom of the pyramid is intellectual awareness, which is the acknowledgment that a particular function is impaired. Emergent awareness, which is the ability to monitor performance and recognize problems as they occur, is in the middle. At the top of the pyramid is anticipatory awareness. Anticipatory awareness is the ability to have the foresight that a problem is likely to occur as a result of the functional deficit [23]. Intellectual and emergent awareness are considered a prerequisite to anticipatory awareness.

Toglia and Kirk [1] later proposed the Dynamic Comprehensive Model of Awareness (DCMA), which does not assume a hierarchical structure. Instead, the DCMA focuses on the relationship between different aspects of metacognition and awareness. The DCMA discriminates between offline awareness, which is awareness that exists prior to a task, and online awareness, which is awareness that exists during and directly after a task. Offline awareness is called metacognitive awareness. Metacognitive awareness encompasses knowledge and beliefs about the person's overall procedural knowledge, knowledge about task characteristics and strategies, as well as the person's perception of his or her own functioning. Online awareness is divided into two primary interacting components. One part of online awareness is the person's conceptualization and appraisal of the task or situation (comparable to anticipatory awareness). After a person experiences a task he or she may alter their beliefs or perceptions about their performance, and this second part of online awareness is called self-monitoring (comparable to emergent awareness). In the DCMA, self-monitoring is further conceptualized as consisting of two parts: error-monitoring and self-regulation. Error-monitoring is the ability to recognize errors, while self-regulation is the ability to adjust performance. The DCMA also recognizes that outside influences may interact with self-awareness, that self-awareness may vary across situations and domains, and that individuals' emotional responses to feedback may vary throughout these components of self-awareness.

The majority of studies that have assessed the relationship between self-awareness and rehabilitation outcome have focused on metacognitive awareness [11,19,24,25]. Metacognitive awareness is often measured using discrepancy scores between the patient and caregiver or staff member on an awareness questionnaire (e.g. the Patient Competency Rating Scale [24,25,26,27]; the Awareness Questionnaire, [11,12,28,29]). The Self-Awareness of Deficits Interview (SADI) [3,15,29] and clinician subjective ratings of self-awareness [11,24] have also been used to assess metacognitive awareness. Of the studies that have assessed metacognitive awareness, the majority of studies have found a positive relationship between self-awareness and outcome [7,11,12]. However, the relationship between metacognitive awareness and outcome is suggested to dissipate in long-term follow-up as metacognitive awareness improves with recovery [19,30].

Few studies have researched the relationship between TBI outcome and measures of online awareness, including error-monitoring, self-regulation, and anticipatory awareness. A study conducted by Heorold et al. [27], which required participants to verbally indicate when they committed an error while performing a computerized digit-monitoring task, revealed that error-monitoring was impaired compared to a control group 2-years post injury. O'Keefe et al [31] used this same computerized task to assess how error-monitoring related to outcome in mild to extremely severe participants with TBI (9 to 84 months post injury). Results suggested that better error-monitoring by participants with TBI was associated with less anxiety, less impairment of frontal behaviours, and better overall competency [31]. In another study with participants with mild to severe TBI injuries (6 to 144 months post injury) [29], error-monitoring was measured by the number of errors (which included rule breaks and repetitions) participants committed on neuropsychological tests (i.e. letter fluency test and five-point test). Findings revealed that poorer error-monitoring at baseline testing was associated with poorer psychosocial reintegration and higher anxiety and depression scores one year after baseline assessment [29].

O'Keefe et al. [31] also evaluated anticipatory awareness by comparing participants with mild to severe TBIs' pre-experience predictions to their actual performance on neuropsychological tests. Results showed that anticipatory awareness was impaired in the TBI group compared to the control group. However, the findings revealed no significant relationship between anticipatory awareness and outcome, as measured by the Hospital Anxiety and Depression Scale (HADS), competency ratings, and disinhibition and executive dysfunction symptoms [31].

Self-regulation has been examined in several studies [32,33] in participants with moderate to severe TBIs by comparing participants' post-experience predictions to their actual test performance. These studies found generally intact self-regulation abilities in individuals with TBI, but did not examine the relationship between self-regulation and TBI outcome. The finding of accurate ability to self regulate immediately following task performance has also been found in individuals with mild cognitive impairment and dementia who exhibited poor anticipatory and metacognitive awareness [34,35]. This suggests that even when individuals can accurately adjust performance immediately following experience with a task, they may not necessarily update beliefs about their task performance thereby reverting back to their original beliefs about how they will perform.

This study will evaluate the relationship between outcome in persons recovering from TBI and the four aspects of self-awareness as proposed by the DCMA: metacognitive awareness, anticipatory awareness, error-monitoring, and self-regulation [1]. The measures of self-awareness used in this study focus specifically on awareness of cognitive performance. Baseline testing of person with TBI occurred in an inpatient rehabilitation facility after emergence from post-traumatic amnesia (PTA). Follow-up testing occurred within 6-months to 1-year post-injury. Control participants were tested at equivalent intervals. Outcome was assessed by level of community reintegration at follow-up. Based on prior research, compared to the control group, we hypothesized that the TBI group will demonstrate impaired metacognitive awareness, anticipatory awareness, and error-monitoring at baseline and impaired anticipatory awareness and error-monitoring at follow-up [19,30,31]. Self-regulation was not hypothesized to be impaired at either baseline or follow-up given the opportunity to immediately benefit from task experience. Furthermore, we hypothesized that metacognitive awareness and anticipatory awareness will predict outcome because these two aspects of self-awareness encompass beliefs about one's performance prior to a task. Past studies suggest that error-monitoring will also predict outcome because it is a process that happens while the participant is engaged in a task. In contrast, self-regulation is not expected to significantly predict outcome because it is an adjustment that happens in a person's belief system after experience with a task, which may not necessarily represent a long-term adjustment.

Methods

Participants

Ninety participants with TBI (28 females and 62 males) and 90 matched control participants were included in this study (40 females and 50 males). Participants with TBI were recruited from a rehabilitation programme in the Pacific Northwest. Participants with TBI received feedback regarding cognitive functioning in return for their involvement in the study. Control participants were recruited from the community through the use of advertisements and received monetary compensation in return for their time.

All participants with TBI suffered a moderate or severe TBI. Forty-seven of the participants with TBI suffered a severe TBI, defined by a Glasgow Coma Scale (GCS) score of 8 or less, documented at the scene of the accident or in the emergency room [36]. The remaining 43 participants with TBI suffered a moderate TBI classified by a GCS between 9 and 12 (*n* =16) or by a GCS of higher than 12 accompanied by positive neuroimaging findings and/or neurosurgery (*n*=27) [36]. Many of the participants with TBI experienced a coma duration longer than two hours as reported in medical records or by careful clinical questioning of the participant and/or knowledgeable informant (*M* = 52.98 hours; *SD*= 114.28 hours; *range*= 0 – 696 hours). All participants exhibited an extended period of post-traumatic amnesia (PTA; *M* = 18.41 days; *SD*= 12.89 days; *range* = 1–55 days). Emergence from PTA was measured by repeated administration of the Galveston Orientation and Amnesia Test (GOAT) [37], or when PTA had resolved prior to arrival at the rehabilitation facility, by asking the individuals with TBI to recall their memories until the evaluator was persuaded that the participant displayed normal continuous memory [38, 39].

For the baseline session, participants were tested an average of 18 days after emergence from PTA (*M*= 18.411 days; *SD*= 12.891 days; *range*= 1–55 days) with time since injury ranging from 7- 198 days (*M*= 45.00 days; *SD*= 35.14 days). Participants also completed a follow-up testing session an average of 8 months after the baseline testing session (*M*= 237.30 days; *SD*= 84.67 days; *range*= 121–445 days), with time since injury ranging from 113–664 days (*M*= 280.11 days; *SD*= 104.11 days).

Fifty-six participants suffered their head injuries as a result of a motor vehicle or motorcycle accident, 3 incurred their injury as a pedestrian in a motor vehicle accident, 29 participant injuries were due to a fall, 2 injuries resulted from an assault, 2 incurred sports related injuries, and 2 participants suffered injuries from none of the aforementioned categories. Participants were excluded from this study if they had a preexisting neurological, psychiatric, or developmental disorder(s) other than a TBI, a history of treatment for substance abuse, or a history of multiple head injuries. Participants were also excluded if they did not have data on at least two or more of the self-awareness measures.

Comparisons between the TBI and control groups revealed that the participants with TBI and control participants did not differ in age (see Table 1) at baseline. However, control participants had a higher level of education (*M*=14.5; *SD*= 2.58) than the participants with TBI (*M*=13.38; *SD*= 2.48); thus, education was controlled for in the analyses. The groups did not differ in gender ratio, X^2 (1, *n*=180) = 3.403. Table 1 also shows that participants with TBI performed more poorly than controls on cognitive measures assessing attention and speeded processing (Symbol Digit Modalities Test [SDMT]; Trail Making Test, Part A), verbal learning and memory (Rey Auditory Verbal Learning Test [RAVLT], and executive functioning (Controlled Oral Word Association test [COWA, PRW]; Letter-Number sequencing sub-test from the Wechsler Adult Intelligence Scale-Third Edition [WAIS-III]; Trail Making Test, Part B).

Forty-nine of the participants with TBI (13 female and 36 male) agreed to be retested approximately 6-months to 1-year after their baseline session. The participants with TBI who were retested did not differ from the nonreturners in age, education, sex, or severity of injury as measured by GCS and duration of PTA (see table 1). Also, performance on tests of attention and speeded processing, verbal learning and memory, and executive functioning skills did not differ between TBI returners and non-returners (see table 1). This suggests that the TBI returners and nonreturners were likely drawn from the same population. Control participants were similarly tested again between 6-months and 1-year (M=191.17; SD= 87.76). Retested control and participants with TBI were matched in age, $t(96)=0.31$ (control: M=36.64; TBI: M=37.78) and gender, X^2 (1, N = 98) = 2.88; however, level of education was higher for the control participants (M=14.45) compared to the participants with TBI (M=13.10), $t(96)= -2.46$, p=0.016.

Procedure

This experiment was completed as part of a larger test battery that included standardized neuropsychological tests and other experimental measures [40]. The neuropsychological measures were administered using standardized instructions across two days of testing. All measures used in this study were administered on the first day of testing.

Self-awareness measures

Metacognitive Awareness—The Problems in Everyday Living Questionnaire (PEDL, [41]) contains 13 questions, which require practical problem solving skills. The questions present an everyday problem (e.g. ‘If you were lost in the forest in the daytime, how would you go about finding your way out?’) and participants must respond with how they would react to the problem. Responses were recorded verbatim and scored on a 3-point scale (0–2). Higher scores indicate higher ability to problem solve in everyday situations. This instrument was used to assess <u>metacognitive awareness</u> because of its ability to evaluate participants’ knowledge and understanding about strategies and task characteristics before task initiation.

Anticipatory Awareness and Self-Regulation—The Rey Auditory Verbal Learning Test (RAVLT, [42]) is a verbal list-learning test that was used to assess anticipatory awareness and self-regulation. Participants were auditorily presented with 15 words, read at a rate of 1 word every 2 seconds, over five learning trials. Following each trial participants recalled as many words as possible. After the 5th learning trial, participants were presented with an interference list, which was followed by short-delay free recall for the original list. Long-delay free recall for the original list occurred after a 20-minute delay filled with other activities. Prior to beginning the list-learning task, participants were provided with a description of the RAVLT and then asked to predict how many of the 15 words they thought they would recall after a 20-minute delay. After the short-delay free recall, participants were asked to make a post-experience prediction about how many of the 15 words they thought they would recall 20 minutes later. Pre-experience prediction accuracy, determined by calculating the absolute difference between the initial prediction and actual performance score, was used to assess anticipatory awareness. Post-experience prediction accuracy, determined by calculating the absolute difference between the prediction made following the short-delay free recall and the actual performance score, was used to assess self-regulation.

Error-Monitoring—Two tasks were used to assess error monitoring: the letter fluency task [43] and five point task (FPT, [44]). For the letter fluency task, participants were given 60 seconds to provide as many words as they could think of that began with a certain letter. Three trials were administered using the letters P, R, and W. Participants were instructed not to provide proper nouns, numbers, or the same word with a different suffix as responses. The FPT required participants to produce as many different designs as they could within three minutes. Participants were told that the designs must be made by using straight lines to connect dots inside of a square. Furthermore, only single lines could be used. The total number of errors and perseverations recorded for both tasks (letter fluency and FPT) were added together and then divided by the total amount of attempts as the measure of error-monitoring. Consistent with prior work by Ownsworth and colleagues [29], an error was counted each time the participant did not follow the instructions (e.g., saying a proper noun on the letter fluency task), and a perseveration was counted when a prior response was repeated on the letter fluency task or reproduced on the FPT. This measure of error-monitoring assessed ability to monitor task performance by recognizing errors in task completion and repetition of task responses [29].

Outcome measure

Community Integration Questionnaire (CIQ) [45]—The CIQ was used to assess general TBI outcome at follow-up. The CIQ includes three subscales that measure overall integration: home competency, social integration, and productivity. There are 15 items, each rated on a scale of 0 to 2, with 2 signifying greater independence. The three subscales were totaled independently and then added together for the total CIQ score that ranges from 0 to 25, with higher scores indicating greater reintegration. The CIQ has high test-retest reliability (r= .91) and high concurrent validity with other disability outcome measures [46].

Results

Analyses

Data were analysed using SPSS statistical software. We began by using Analysis of Covariance (ANCOVA) to compare the full sample of TBI and control participants' performance on the four aspects of self-awareness (i.e. metacognitive awareness, anticipatory awareness, error-monitoring, and self-regulation) at baseline. In these analyses, education served as a covariate. We then conducted t-tests to determine whether our TBI returners and non-returners demonstrated similar performances on the measures of awareness at baseline. To examine whether changes in self-awareness occurred during recovery, we conducted group (TBI and control) by time (baseline and follow-up) mixed model repeated measures ANCOVAs separately for each of the four aspects of self-awareness. Next, multiple regression analyses were used to evaluate whether the four aspects of self-awareness measured at baseline and at follow-up predicted outcome at follow-up (i.e. community reintegration) with the TBI follow-up sub-sample.

Comparing self-awareness measures between TBI and control groups at baseline—Separate ANCOVA's with education as the covariate were conducted at baseline for each of the four awareness variables. The analyses revealed that the TBI group exhibited significantly poorer metacognitive awareness, $F(2,17)=6.40$, $p<0.001$, and poorer error monitoring, $F(2,16)=7.27$, $p<0.001$, at baseline compared to the control group (see table 2). There was no significant difference between the TBI and control groups in anticipatory awareness, $F(2,168)=1.80$. Significant differences between the TBI and control groups were found in self-regulation, $F(2,170)=6.40$, $p<0.001$, although these findings suggested better performance by the TBI group and this will be addressed later (see table 2).

Comparison of TBI returners and non-returners on the self-awareness variables at baseline—Before examining the effects of recovery on the self-awareness variables, comparisons of TBI returners and nonreturners were conducted to determine whether there were significant differences between the two samples. As can be seen in table 2, the TBI returners and nonreturners did not differ significantly in their performances on the self-awareness measures at baseline, suggesting that the returners are likely to be drawn from a similar population as the nonreturners.

Investigating change over time in the self-awareness measures

Metacognitive awareness—Results of a group (TBI vs. control) by time (baseline and follow-up) mixed model repeated measures ANCOVA for metacognitive awareness revealed no significant main effect of group, $F(1,91)=0.14$, $p=0.71$, $\eta^2=0.00$, or time, $F(1,91)= 0.16$, $p= 0.69$, $\eta^2=0.02$. There was, however, a significant interaction, $F(1,91)=7.74$, $p=0.01$, $\eta^2=0.08$. As seen in table 3, the participants with TBI demonstrated significant improvement in their metacognitive awareness scores between baseline (M= 21.55) and follow-up (M= 22.96), $t(41)= -3.91$, $p<0.001$, while there was no significant change in performance for the control group (M= 22.20 vs. M=21.92); $t(48)= 0.70$.

Anticipatory awareness—For anticipatory awareness, a group by time mixed model ANCOVA did not yield significant main effects for group, $F(1,90)=2.80$, $p=0.10$, $\eta^2=0.03$; or time, $F(1,90)=0.50$, $p=0.48$, $\eta^2=0.01$; and no significant interaction was found, $F(1,90)=0.65$, $p=0.42$, $\eta^2=0.01$ (table 3).

Error-monitoring—The ANCOVA for error-monitoring revealed a significant main effect for group, $F(1,84)=10.78$, $p<0.001$, $\eta^2=0.11$ (see table 3). The main effect of time, $F(1,84)=2.02$, $p=0.16$, $\eta^2=0.02$, and interaction, $F(1,84)=0.96$, $p=0.33$, $\eta^2=0.01$, were not significant. As seen in table 3, the TBI group exhibited significantly poorer error-monitoring compared to the control group at both baseline, $F(2,84)= 7.42$, $p < 0.001$, and follow-up, $F(2,87)= 2.98$, $p < 0.05$.

Self-regulation—A group by time mixed model ANCOVA on the self-regulation measure indicated a significant main effect of group; $F(1,90)=8.54$, $p<0.001$, $\eta^2=0.09$. No significant main effect of time was found; $F(1,90)=2.87$, $p=0.09$, $\eta^2=0.03$, and there was no significant interaction; $F(1,90)=0.48$, $p=0.49$, $\eta^2=0.01$. In contrast to our hypothesis of no group difference, the data revealed that the TBI group exhibited significantly better performance than the control group on the self-regulation measure at baseline $F(2,89)= 4.18$, $p < 0.02$, and at follow-up, $F(2,97)= 3.72$, $p < 0.03$ (see table 3).

To further evaluate this unexpected finding, we compared the TBI and control groups' pre- and post-experience predictions on the RAVLT task, actual performance on the RAVLT task, and prediction adjustments (absolute difference between participants' pre-experience and post-experience predictions). As displayed in table 4, both the participants with TBI and control participants' pre-experience predictions were between 6–8 words, which is near the midpoint for the 15-item RAVLT word list. Because the TBI group's actual performances on the RAVLT task fell closer to the midline range (M=7.70, baseline; M=9.48, follow-up) when compared to the control group (M=11.02, baseline; M=11.55, follow-up), if both groups used the midpoint of the 15-item list to anchor their predictions, this would result in better predictions by the participants with TBI. Of note, however, the TBI group's pre-experience and post-experience predictions were either numerically or significantly lower than those of controls at both baseline and follow-up (see table 4), suggesting that the TBI group was accurately adjusting expectation of their performances downward when compared to controls.

Correlations among the self-awareness measures—At both baseline and follow-up, the only significant correlation among the self-awareness measures was that for anticipatory awareness and self-regulation (see Table 5). This is not unexpected because these variables both measured participants' predictions on the same task but at different points in time (i.e. pre-experience versus post-experience). The fact that no other correlations reached significance suggests that these measures were capturing different aspects of awareness.

Regression analyses examining awareness and TBI outcome—To reduce the number of predictors in the regression analyses, we first examined correlations with demographic and injury-related variables that might impact outcome. The correlations were conducted with both the predictor (self-awareness components) and outcome (CIQ) variables. As can be seen in table 6, no significant correlations were found between either the predictor or outcome variables and age, education, gender, TSI, and PTA; therefore, no demographic or injury characteristics were controlled for in our regressions in order to increase power. It is also important to note that our predictor variables were not significantly related to injury severity as measured by PTA, which suggests that they are distinct variables and not measures of injury severity. In addition, all regressions reported were also run as multiple hierarchical regressions with demographic and injury characteristic information entered into the first step and self-awareness predictors into the second step. The regression results did not significantly differ from those reported.

The four awareness measures were entered simultaneously in each regression analysis. There was no significant multicollinearity among the four awareness variables (Variance Inflation Factors < 1.32). Table 6 displays the correlations between the self-awareness components and outcome variable. There was one significant negative correlation between follow-up error-monitoring and CIQ; $r=-0.53$, $p<0.001$.

Self-awareness measures and the CIQ—A regression analysis was performed to test the relative influence of baseline awareness measures on the follow-up CIQ scores (table 7). Results of the regression model were not significant, $F(4,31)=1.63$, $p=0.19$, with 17.3% of the variance in CIQ scores accounted for. However, error-monitoring approached significance as a unique predictor, $t=-1.98$, $p=0.06$.

A similar regression analysis using follow-up awareness measures to predict follow-up CIQ was significant, $F(4,35)= 4.09$, $p=.01$. The model accounted for 31.8% of the variance in the CIQ score. Also, error-monitoring emerged as a significant unique predictor within the model, $t=-3.54$, $p<0.001$, indicating that better error-monitoring predicted higher CIQ scores (see table 7).

Although injury severity, as measured by PTA (see table 6), was not correlated with any of our model measures, we conducted a further follow-up hierarchical regression to rule out severity of injury as a possible driving factor in our analysis. We entered PTA in the first block and the self-awareness measures in the second block. Controlling for injury severity did not significantly change the regression model, $F(5,34)= 3.57$, $p=0.01$ (table 8). This again indicates that our predictor variables are distinct measures, rather than measures of injury severity.

Discussion

The purpose of this study was to investigate components of the DCMA model of cognitive self-awareness (i.e. metacognitive awareness, anticipatory awareness, error-monitoring, and self-regulation) in individuals who had sustained moderate-to-severe TBIs, as well as to evaluate recovery in the self-awareness measures. We also examined whether the measures of self-awareness at both baseline and follow-up predicted community reintegration at follow-up. Participants with TBI completed several neuropsychological tasks that measured metacognitive awareness, anticipatory awareness, error monitoring, and self-regulation in the acute phase of recovery, as well as 6-months to 1-year later.

As expected, participants with TBI demonstrated impaired metacognitive awareness compared to controls in the acute phase of recovery. This suggests that the ability to conceptualize task performance (i.e. knowledge and understanding of task characteristics) is difficult in the early stages following TBI. A lack of metacognitive awareness could make understanding of rehabilitation techniques difficult during the acute phase of recovery [1,7]. For example, subjective beliefs about tasks can limit proper task difficulty appraisal, which can create inaccurate judgments that may interfere with the amount of cognitive effort put forth during rehabilitation. Inaccurate task appraisal can impact type and level of task engagement, selection of strategies, and effort and goal commitment within and outside of the rehabilitation setting [1]. We also found that metacognitive awareness significantly improved over time in the TBI group and was not impaired at follow-up relative to the control group, which is consistent with prior literature [7]. These findings demonstrate that metacognitive awareness can improve with recovery, which may be due to a multitude of factors such as the person's ability to re-learn task strategies, improvement in related cognitive factors, and increased task experience.

Error-monitoring was found to be impaired at both baseline and at follow-up, which is also consistent with prior research [27,29,31]. It appeared that individuals with TBI experienced more difficulty than controls recognizing errors when performing tasks, which can limit ability to recognize flawed task performance and adjust task performance appropriately [1]. Accurate error monitoring depends on the integration of a number of different cognitive abilities (e.g. attention, visual perception), which are necessary for accurate task appraisal and error recognition [1]. Difficulty with error monitoring is particularly concerning because it can limit a person's ability to recognize a potentially dangerous task action. Although we found that error-monitoring did not improve significantly over time, it is possible that there may be an opportunity during rehabilitation to improve error-monitoring with targeted interventions that will be discussed later.

Anticipatory awareness and self-regulation were both measured by pre-experience and post-experience predictions of task performance, respectively. Self-regulation was found to be significantly better in the TBI group compared to the control group, while anticipatory awareness did not show group differences. This suggests that the TBI group was accurately able to appraise the task situation and to predict their task performance both pre-experience and post-experience. Consistent with this interpretation, the TBI group predicted that they would perform more poorly than the control group recalling words from the list learning task, which was consistent with actual delayed memory scores of the TBI group. While we did not expect that self-regulation would be impaired following TBI, the finding that the TBI group performed better on this measure than the control group was unexpected and is recognized as a limitation to our study. Although this may reflect proficiency by the TBI group in using task performance to adjust predictions, another potential contributor to this finding may be the fact that performance anchors (average performance on task for age) were not provided to participants. Some research has shown that without anchors people tend to estimate their performance at the midpoint (i.e. a prediction of 8 on a 16-item word list [33]). Mean group pre- and post-experience predictions suggested that both the participants with TBI and control participants may have been using the midpoint range of the word list to anchor predictions. Thus, because the TBI groups' actual RAVLT performances were closer to the midline, this likely caused their predictions to be more accurate, which is a limitation for our anticipatory awareness and self-regulation measures.

It is also important to point out that neither the TBI or control groups' pre-experience and post-experience predictions were accurate when compared to actual performance scores (i.e. a score of 0 on anticipatory awareness and self-regulation measures). This finding is consistent with previous literature, which has found that cognitively healthy adults do not always accurately predict performances on neurocognitive tests [47,48,49,50]. Thus, it may be that healthy adults are not able to accurately predict performance, but because they have other intact cognitive abilities, this does not significantly impact their daily functioning. However, because individuals with TBI often have other cognitive deficits, a failure to accurately predict task performance could be problematic during rehabilitation. For example, if a healthy adult starts a task that is too complex or challenging, they can use other cognitive abilities, such as problem solving processes, to decide how to safely and reasonably proceed (e.g. ask for help). In contrast, if an individual with a TBI starts a task that is too complex, they may be perseverative, feel overwhelmed, create a dangerous situation, or have compromised judgment regarding their decisions of how to proceed. Of note, these online awareness processes may vary depending on the task and context; thus, these aspects of self-awareness can be relatively unstable [1]. Using prediction scores based on one memory task does not allow us to fully assess how anticipatory awareness and self-regulation may fluctuate throughout different tasks (e.g. executive functioning) and contexts. Therefore, more research on anticipatory awareness and self-regulation and how these components impact rehabilitation is warranted.

We were also interested in how these self-awareness components impacted community reintegration. We found that the follow-up self-awareness variables were predictive of community reintegration at follow-up. Furthermore, error-monitoring approached significance as a unique predictor at baseline and was found to be a unique predictor in the follow-up CIQ regression model. Error monitoring also remained a unique predictor even after controlling for severity of injury, suggesting that it is a unique variable and not just a measure of injury severity. Prior research has consistently demonstrated error-monitoring to be impaired in patients with TBI both acutely and at long-term follow-ups [27,29,31]. Thus, implementing interventions that can target improvement of error-monitoring may be a crucial aspect of rehabilitation. For example, Schmidt, Fleming, Ownsworth, and Lannin [51] developed an intervention using video and verbal feedback during online task performance. They found that participants with TBI who received the intervention demonstrated significantly better error-monitoring compared to participants who did not receive the intervention, as evidenced by the number of errors committed during a post-intervention task. Similarly, Toglia and Kirk [1] suggested that the process of online error-monitoring can lead to a restructuring of task knowledge and beliefs, which can result in effective enhancement of self-awareness. They also emphasized the importance of error-monitoring interventions that utilize tasks that are the ‘just right challenge’. More specifically, they argued that tasks should match the person’s current information processing abilities in order to be stimulating enough to produce errors, but not too challenging, as that may be overwhelming [1]. These types of interventions that target improvement of error-monitoring may facilitate community reintegration following TBI and should be researched further.

This study shows promising results in the area of self-awareness research; however, there were several limitations. We had a limited sample size for the follow-up time point. The smaller sample size, specifically in the regressions, resulted in decreased power and these results should be interpreted with caution. The lack of strong correlations between the awareness measures provides support for the supposition that these components of self-awareness are distinct, but interrelated. However, it could also be argued that the lack of correlations among these measures suggests that they may not be measuring a global concept of self-awareness; thus, further investigation of the relationship between these measures is needed. Also, the self-awareness measures used in this study are not well-researched or validated measures of self-awareness. Specifically, the anticipatory awareness and self-regulation measures involved predictions in performance scores, which have yet to be commonly used in self-awareness research. Some research has critiqued the use of prediction scores and studies have suggested that individuals may need to be provided with anchors [33]. Research has also proposed that the type of task and the context of the situation can impact online self-awareness processes; thus, using prediction scores for one specific task may be a limited assessment of anticipatory awareness and self-regulation [1]. Future research should focus on exploring self-awareness measures further. It is important that we discover how predictions of performance relate to self-awareness and whether anchors should be used or not. Moreover, it should be a goal to increase overall sample size and decrease attrition rates for follow-up time points.

Self-awareness plays an essential role in TBI rehabilitation and can impact motivation, safety, and rehabilitation goals during recovery [14,15,16]. This research provides empirical evidence that self-awareness, as it relates to cognitive performance, is significantly related to community reintegration and suggests that self-awareness interventions focusing on improving error-monitoring may be particularly important. Our results also offer insight into the pattern of recovery for the differing aspects of awareness, which is crucial to understand in rehabilitation. The data were consistent with the underlying theory of the DCMA, which suggests that self-awareness is a complex construct with varying components. However, additional research that addresses the current study limitations is needed to better understand how different aspects of awareness may influence recovery and impact rehabilitation strategies. With a better understanding of self-awareness, we can develop more effective interventions and more comprehensive theories of recovery after TBI, which is of the utmost importance.

Acknowledgments

This work was supported by a grant from NINSD R01-NS047690.

References

1. Toglia J, Kirk U. Understanding awareness deficits following brain injury. Neuro Rehabiliation. 2000; 15:57–70.
2. Faul, Xu; Wald; Coronado. Traumatic Brain Injury in the United States: Emergency Department visits, Hospitalizations, and Deaths [Internet]. Atlanta (GA: Centers for Disease Control and Prevention (US), National Center for Injury Prevention and Control; 2010. [cited 2013 Dec 15]. Available from: http://www.cdc.gov/traumaticbraininjury
3. Cheng SKW, Man DWK. Management of impaired self-awareness in persons with traumatic brain injury. Brain Injury. 2006; 20(6):621–628. [PubMed: 16754287]
4. Fleming JM, Ownsworth T. A review of awareness interventions in brain injury rehabilitation. Neuropsychological Rehabilitation. 2006; 16(4):474–500. [PubMed: 16864483]
5. Goverover Y, Johnston MV, Toglia J, Deluca J. Treatment to improve self-awareness in persons with acquired brain injury. Brain Injury. 2007; 21(9):913–923. [PubMed: 17729044]
6. Leung DPK, Liu KPY. Review of self-awareness and its clinical application in stroke rehabilitation. International Journal of Rehabilitation Research. 2011; 34:187–195. [PubMed: 21694602]
7. Ownsworth T, Clare L. The association between awareness deficits and rehabilitation outcome following acquired brain injury. Clinical Psychology Review. 2006; 26:783–795. [PubMed: 16814436]
8. Pigatano, GP.; Schacter, DL. Awareness of deficit after brain injury: Clinical and theroretical issues. New York NY: 1991.
9. Barco, PP.; Crosson, B.; Bolesta, MM.; Werts, D.; Stout, R. Training awareness and compensation in postacute head injury rehabilitation. Cognitive Rehabilitation for Persons with Traumatic Brain Injury: A Functional Approach. Baltimore, MD, England: 1991.

10. FitzGerald MCC, Carton S, O'Keeffe F, Coen RF, Dockree PM. Impaired self-awareness following acquired brain injury: current theory, models and anatomical understanding. The Irish Journal of Psychology. 2012; 33(2–3):78–85.
11. Sherer M, Bergloff P, Levin E, High W, Oden K, Kathryn E. Impaired awareness and employment outcome after traumatic brain injury. The Journal of Head Trauma Rehabilitation. 1998; 13(5):52–61. [PubMed: 9753535]
12. Sherer M, Hart T, Nick TG, Whyte J, Thompson RN, Yablon SA. Early impaired self-awareness after traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2003; 84:168–176. [PubMed: 12601646]
13. Hart T, Seignourel PJ, Sherer M. A longitudinal study of awareness of deficit after moderate to severe traumatic brain injury. Neuropsychological Rehabilitation. 2009; 19(2):161–176. [PubMed: 18609008]
14. Simmond M, Fleming JM. Occupational therapy assessment of self-awareness following traumatic brain injury. The British Journal of Occupational Therapy. 2003; 66(10):447–453.
15. Fleming JM, Strong J, Ashton R. Self-awareness of deficits in adults with traumatic brain injury: How best to measure? Brain Injury. 1996; 10(1):1–15. [PubMed: 8680388]
16. McPherson KM, Kayes N, Weatherall M. A pilot study of self-regulation informed goal setting in people with traumatic brain injury. Clinical Rehabilitation. 2009; 23(4):296–309. [PubMed: 19293290]
17. Robertson IH, Murre JMJ. Rehabilitation of brain damage: Brain plasticity and principles of guided recovery. Psychological Bulletin. 1999; 125(5):544–575. [PubMed: 10489541]
18. Agnew SK, Morris RG. The heterogeneity of anosognosia for memory impairment in Alzheimer's disease: A review of the literature and a proposed model. Aging and Mental Health. 1998; 2(1):7–19.
19. Malec JF, Moessner AM. Self-awareness, distress, and postacute rehabilitation outcome. Rehabilitation Psychology. 2000; 45:227–241.
20. Ownsworth T, McFarland K. Investigation of psychological and neuropsychological factors associated with clinical outcome following a group rehabilitation programme. Neuropsychological Rehabilitation. 2004; 14(5):535–562.
21. Malec J, Buffington A, Moessner A, Degiorgio L. A medical/vocational case coordination system for persons with brain injury: An evaluation of employment outcomes. Archives of Physical and Medical Rehabilitation. 2000; 81:1007–1015.
22. Noe E, Ferri J, Caballero MC, Villodre R, Sanchez A, Chirivella J. Self-awareness after acquired brain injury: Predictors and rehabilitation. Journal of Neurology. 2005; 252:168–175. [PubMed: 15729522]
23. Crosson C, Barco PP, Velozo C, Bolesta MM, Cooper PV, Werts D, Brobeck TC. Awareness and compensation in postacute head injury rehabilitation. Journal of Head Trauma Rehabilitation. 1989; 4:46–54.
24. Fischer S, Gauggel S, Trexler LE. Awareness of activity limitations, goal setting and rehabilitation outcome in patients with brain injuries. Brain Injury. 2004; 18:547–562. [PubMed: 15204336]
25. Fordyce DJ, Roueche JR. Changes in perspectives of disability among patients, staff, and relatives during rehabilitation of brain injury. Rehabilitation Psychology. 1986; 31:217–229.
26. Anson K, Ponsford J. Who benefits? Outcome following a coping skills group intervention for traumatically brain injured individuals. Brain Injury. 2006; 20:1–13. [PubMed: 16403695]
27. Hoerold D, Pender NP, Robertson IH. Metacognitive and online error awareness deficits after prefrontal cortex. Neuropsychologia. 2013; 51:385–391. [PubMed: 23196146]
28. Carroll E, Coetzer R. Identity, grief, and self awareness after traumatic brain injury. Neuropsychological Rehabilitation. 2011; 21(3):289–305. [PubMed: 21391119]
29. Ownsworth T, Fleming J, Strong J, Radel M, Chan W, Clare L. Awareness typologies, long-term emotional adjustment and psychosocial outcomes following acquired brain injury. Neuropsychological Rehabilitation. 2007; 17(2):129–150. [PubMed: 17454690]
30. Hartman-Maeir A, Soroker N, Ring H, Katz N. Awareness of deficits in stroke rehabilitation. Journal of Rehabilitation Medicine. 2002; 34:158–164. [PubMed: 12201610]

31. O'Keefe F, Dockree P, Moloney P, Carton S, Robertson IH. Awareness of deficits in traumatic brain injury: A multidimensional approach to assessing metacognitive knowledge and online-awareness. Journal of the International Neuropsychological Society. 2007; 13:38–49. [PubMed: 17166302]
32. Anderson JW, Schmitter-Edgecombe M. Prediction of episodic memory following moderate to severe traumatic brain injury during inpatient rehabilitation. Journal of Clinical and Experimental Neuropsychology. 2009; 31(4):425–438. [PubMed: 18686113]
33. Schmitter-Edgecombe M, Woo E. Memory self-awareness and memory self-monitoring following severe closed-head injury. Brain Injury. 2004; 18:997–1016. [PubMed: 15370899]
34. Anderson J, Schmitter-Edgecombe M. Mild cognitive impairment and feeling-of-knowing in episodic memory. Journal of Clinical and Experimental Neuropsychology. 2010; 32(5):505–514. [PubMed: 19821173]
35. Schmitter-Edgecombe M, Seelye AM. Predictions of verbal episodic memory in persons with Alzheimer's disease. Journal of Clinical and Experimental Neuropsychology. 2011; 33:218–225. [PubMed: 20839133]
36. Teasdale G, Jennett B. Assessment of coma and impaired consciousness A practical scale. Lancet. 1974; 2(7872):81–84. [PubMed: 4136544]
37. Levin HS, O'Donnell VM, Grossman RG. The galveston orientation and amnesia test A practical scale to assess cognition after head injury. Journal of Nervous and Mental Disorders. 1979; 167:675–684.
38. King NS, Crawford S, Wenden FJ, Moss NEG, Wade DT, Caldwell FE. Measurement of post traumatic amnesia: How reliable is it? Journal of Neurology, Neurosurgery and Psychiatry. 1997; 62:38–42.
39. McMillan TM, Jongen ELM, Greenwood RJ. Assessment of posttraumatic amnesia after severe closed head injury: Retrospective or prospective? Journal of Neurology, Neurosurgery and Psychiatry. 1996; 60:422–427.
40. Schmitter-Edgecombe M, Rueda A. Estimation of time and episodic memory following traumatic brain injury. Journal of Clinical and Experimental Psychology. 2008; 30:212–223.
41. Beatty WW, Hames KA, Blanco CR, Williamson SI, Wilbanks SL, Olson KA. Correlates of coping style in patients with multiple sclerosis. Multiple Sclerosis. 1998; 4:40–43.
42. Majdan A, Sziklas V, Jones-Gotman M. Performance of healthy subjects and patients with resection from the anterior temporal lobe on matched tests of verbal and visuoperceptual learning. Journal of Clinical and Experimental Neuropsychology. 1996; 18:416–430. [PubMed: 8877625]
43. Regard M, Strauss E, Knapp P. Children's production on verbal and non-verbal fluency tasks. Perceptual and Motor Skills. 1982; 55:839–844. [PubMed: 7162920]
44. Tombaugh TN, Kozak J, Rees L. Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. Archives of Clinical Neuropsychology. 1999; 14(2): 167–177. [PubMed: 14590600]
45. Willer B, Rosenthal M, Kreutzer JS, Gordon WA, Rempel R. Assessment of community integration following rehabilitation for traumatic brain injury. Journal of Head Trauma Rehabilitation. 1993; 8(2):75–87.
46. Kuipers P, Kendall M, Fleming J, Tate R. Comparison of the Sydney Psychosocial Reintegration Scale (SPRS) with the Community Integration Questionnaire (CIQ): Psychometric properties. Brain Injury. 2004; 18:161–177. [PubMed: 14660228]
47. Devolder PA, Brigham MC, Pressley M. Memory performance awareness in younger and older adults. Psychology and Aging. 1990; 5:291–303. [PubMed: 2378695]
48. Hertzog C, Dixon RA, Hultsch DF. Relationships between metamemory, memory predictions, and memory task performance in adults. Psychology and Aging. 1990; 5:215–227. [PubMed: 2378687]
49. Kennedy MRT, Nawrocki MD. Delayed predictive accuracy of narrative recall after traumatic brain injury: Salience and explicitness. Journal of Speech, Language, and Hearing Research. 2003; 46:98–112.
50. Kennedy MRT, Yorkston KM. Accuracy of metamemory after traumatic brain injury: Predictions during verbal learning. Journal of Speech, Language and Hearing Research. 2000; 43:1072–1086.

51. Schmidt J, Fleming J, Ownsworth T, Lannin N. Video feedback on functional task performance improves self-awareness after traumatic brain injury: A randomized controlled trial. Neurorehabilitation and Neural Repair. 2012; 27(4):316–324. [PubMed: 23270921]

Author Manuscript
Author Manuscript
Author Manuscript

Table 1

Demographic Data and Mean Summary Data for TBI and Control groups.

	Baseline Group				TBI Group			
	TBI (*n*=90)		Control (*n*=90)		Returners (*n*=49)		Nonreturners (*n*=41)	
Demographics	M	SD	M	SD	M	SD	M	SD
Age	37.189	17.730	36.633	21.184	37.796	18.294	36.463	17.229
Education	13.456	2.505	14.322*	2.449	13.102	2.616	13.878	2.326
Gender	28F/62M		40F/50M		13F/36M		15F/26M	
Injury Characteristics								
Duration of PTA (days)	18.411	12.891	n/a		18.531	13.945	18.268	11.677
GCS	8.157	4.592	n/a		7.959	4.472	8.400	4.781
General Ability								
Estimated pre-morbid FSIQ	104.933	7.516	105.913	7.869	104.189	7.395	105.798	7.664
Attention and Speeded Processing								
SDMT Total Written Correct	36.000	11.894	54.633**	10.259	53.857	9.878	55.561	10.745
SDMT Total Oral Correct	42.905	12.409	64.933**	13.799	63.102	13.120	67.122	14.424
Trails A (time)	45.615	30.319	26.422**	9.345	27.674	9.510	24.927	9.032
Verbal Learning and Memory								
RAVLT List Learning Score	42.012	10.102	54.287**	8.545	44.417	10.193	40.982	9.614
RAVLT Delayed Recall Score	6.781	3.569	10.878**	3.072	7.659	3.535	6.251	3.333
Executive Functioning Skills								
L-N Sequencing Total Correct	9.060	2.599	11.489**	3.184	10.959	3.149	12.122	3.148
COWA Total Correct	25.500	9.985	41.722**	10.358	41.796	11.164	41.634	9.441
Trails B (time)	115.831	71.791	61.722**	27.660	109.375	44.828	103.233	40.383

Note:

* $p < 0.05$,

** $p < 0.01$,

PTA=Post-Traumatic Amnesia; GCS=Glasgow Coma Score; FSIQ=Full Scale Intelligence Quotient as estimated by the Barona equation; SDMT= Symbol Digit Modalities Test; RAVLT= Rey Auditory Verbal List Learning Task; L-N Sequencing= Letter Number Sequencing subtest of the Weschler Adult Intelligence Scale- Third Edition; COWA= Controlled Oral Word Association test (PRW).

Table 2

TBI and Control Group Performances on Self-Awareness Components at Baseline

	Baseline Group		TBI Group	
	TBI ***n*=90**	**Control** ***n*=90**	**Returners** ***n*=49**	**Nonreturners** ***n*=41**
Metacognitive Awareness‡	21.088 (0.334)	21.876 (0.319)*	21.317 (2.669)	20.667 (3.133)
Anticipatory Awareness†	3.480 (0.320)	4.270 (0.300)	3.425 (2.707)	3.689 (3.103)
Error Monitoring†	0.130 (0.020)	0.040 (0.020)*	4.641 (3.141)	7.273 (8.499)
Self-Regulation†	2.290 (0.264)	3.590 (0.250)*	2.400 (2.4)	2.022 (2.022)

Note:

*$p < 0.01$;

‡higher score indicates better performance;

†lower score indicates better performance

Table 3

Comparisons of TBI and Control Group Performances on Self-Awareness Components at Baseline and Follow-up

	Baseline		Follow-up	
	TBI ***n*=49**	**Control** ***n*=49**	**TBI** ***n*=49**	**Control** ***n*=49**
Metacognitive Awareness‡	21.552 (0.411)	22.200 (0.362)	22.963 (0.413)	21.924 (0.422)
Anticipatory Awareness†	3.402 (0.471)	4.462 (0.411)	3.714 (0.402)	4.192 (0.353)
Error Monitoring†	0.083 (0.012)	0.033 (0.012)	0.072 (0.011)	0.044 (0.011)
Self-Regulation†	2.382 (0.372)	3.884 (0.322)	2.981 (0.412)	4.070 (0.363)

Note:

‡higher score indicates better performance;

b=lower score indicates better performance

Table 4

Comparisons of TBI and Control Group Mean Performances and Predictions

	Baseline		Follow-up	
	TBI ***n*=49**	**Control** ***n*=49**	**TBI** ***n*=49**	**Control** ***n*=49**
RAVLT pre-experience predictions	6.102 (2.899)	7.223 (3.184)	6.766 (3.302)	8.005 (3.212)*
RAVLT delayed recall (actual performance score)	7.659 (3.535)	11.020 (3.010)**	9.479 (4.141)	11.551 (3.565)*
RAVLT post-experience predictions	5.850 (2.842)	7.449 (3.753)*	6.833 (3.392)	7.796 (3.623)
Prediction adjustments	1.025 (2.577)	0.612 (2.842)	0.604 (2.735)	0.122 (2.743)

Note:

* $p < 0.05$,

** $p < 0.01$,

RAVLT= Rey Auditory Verbal List Learning Task

Table 5

Correlations Between TBI Group's Self-Awareness Components at Baseline and Follow-up

	Metacognitive Awareness	Anticipatory Awareness	Error-Monitoring	Self-Regulation
Baseline				
Metacognitive Awareness	1.0	−0.061	−0.131	−0.003
Anticipatory Awareness		1.0	0.104	0.465*
Error-Monitoring			1.0	0.203
Self-Regulation				1.0
Follow-up				
Metacognitive Awareness	1.0	0.183	−0.050	0.067
Anticipatory Awareness		1.0	−0.030	0.350*
Error-Monitoring			1.0	−0.160
Self-Regulation				1.0

Note:

* $p < 0.01$

Table 6

Correlations Between Self-Awareness Measures and Demographics and Injury Characteristics

	Metacognitive Awareness	Anticipatory Awareness	Error-Monitoring	Self-Regulation	CIQ
Age					
Baseline	0.141	−0.213	0.264	0.031	
Follow-up	0.122	0.222	0.021	0.173	0.077
Education					
Baseline	0.244	−0.192	0.014	−0.12	
Follow-up	0.233	0.044	−0.090	0.041	0.101
Gender					
Baseline	−0.042	−0.183	0.060	−0.284	
Follow-up	0.074	−0.011	0.152	0.132	−0.157
Time Since Injury					
Baseline	−0.113	0.081	−0.041	0.071	
Follow-up	−0.110	−0.133	−0.152	−0.092	0.140
PTA					
Baseline	−0.091	0.072	0.283	−0.084	
Follow-up	0.030	−0.061	0.073	−0.092	−0.101
CIQ					
Baseline	0.097	−0.166	−0.310	0.087	
Follow-up	0.076	0.003	−0.532*	0.246	1.000

Note:

* $p < 0.01$;

PTA=Post Traumatic Amnesia

Table 7

Regressions of Baseline and Follow-up Self-Awareness Components Predicting CIQ

	Baseline				Follow-up			
	β	**t**	**R^2**	**F**	**β**	**t**	**R^2**	**F**
Self-Awareness Components								
Metacognitive Awareness	0.039	.236			0.055	0.386		
Anticipatory Awareness	−0.256	−1.387			−0.090	−0.596		
Error-Monitoring	−0.333	−1.981*			−0.501	−3.539**		
Self-Regulation	0.274	1.458			0.194	1.283		
Overall Model			0.173	1.626			.318	4.086*

Note:

* $p < 0.05$,

** $p < 0.01$

Table 8

Regression of follow-up Self-Awareness Component Predicting CIQ, Accounting for Injury Severity

	β	t	R^2	F
Model 1:				
PTA	−0.189	−1.189	0.036	1.413
Model 2:				
PTA	−0.165	−1.162		
Metacognitive Awareness	0.086	0.598		
Anticipatory Awareness	−0.098	−0.654		
Error-Monitoring	−0.490	−3.467*		
Self-Regulation	0.188	1.251		
Overall Model			0.344	3.572*

Note:

* $p<0.01$;

PTA= Post-Traumatic Amnesia