Impact of baseline neurocognitive functioning on outcomes following rehabilitation of executive function training for veterans with history of traumatic brain injury

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ABSTRACT
Traumatic brain injury (TBI) is common among Veterans, and sequelae frequently include deficits in attention and executive function and problems with emotional regulation. Although rehabilitation has been shown to be effective, it is not clear how patient characteristics such as baseline cognitive status may impact response to rehabilitation in this sample. Explore the relationship between baseline neuropsychological status and postintervention functional outcomes in Veterans with chronic TBI. Thirty-three Veterans with chronic mild–severe TBI completed a neuropsychological evaluation, a functional assessment of executive function (EF), and measures of emotional and everyday functioning pre- and post-EF training or control training. Performance on baseline neuropsychological measures was used to cluster participants. Participants’ performance at baseline and postintervention assessment was compared by cluster using multivariate analyses of variance (MANOVAs). Cognitive Difficulty (CD; n = 19) and Cognitively Normal (CN; n = 14) clusters were identified. CD was characterized by z ≤ −0.75 on neuropsychological measures of overall attention/EF, working memory, and memory. CD participants performed worse on functional EF assessment and endorsed more PTSD symptoms and community integration problems, at baseline. CD participants improved post-EF training, but not control training, on neuropsychological and functional measures. CN participants did not show statistically significant improvement. For Veterans with chronic TBI, cognitive assessment can aid in identifying functional impairment and assist treatment planning. Cognitive rehabilitation training appears to be a beneficial treatment option for TBI patients with cognitive, emotional, and daily living difficulties.

KEYWORDS
Executive function; rehabilitation; traumatic brain injury

INTRODUCTION
Traumatic brain injury (TBI) is an acquired injury resulting from the impact of an external force on the brain. TBI is a recognized as a significant health risk in Veterans due to combat- and training-related exposure to blasts and hand-to-hand combat. TBI has been called the “signature injury” of the recent Operation Enduring Freedom and Operation Iraqi Freedom conflicts (Hayward, 2008), although veterans of Vietnam and Gulf War eras are also affected (Reiber et al., 2010; Ommaya, Salazar, Dannenberg, et al., 1996; Ivins, Schwab, Baker, & Warden, 2006). Furthermore, some research suggests that Veterans who have been deployed to a conflict zone are at greater risk for being diagnosed with TBI postdeployment (Regasa, Thomas, Gill, Marion, & Ivins, 2016). TBI may result in deficits in both cognition and emotional functioning.

Because of the biomechanical properties of TBI resulting in both localized contusions and trauma to axonal pathways caused by shearing forces, problems with attention and executive control functions are some of the most common sequelae of TBI (Cicerone & Azulay, 2002; Fork et al., 2005; Mathias et al., 2004; Vanderploeg, Curtiss, & Belanger, 2005). Attention is a complex and nonunitary construct falling under the umbrella of executive control functions and is especially affected by TBI (Wilde, Whiteneck, Bogner,
et al., 2010). Domains falling under the broader construct of attention include working memory, the ability to store and manipulate information in the short term; sustained attention, the ability to maintain focus on a lengthy, repetitive or dull task; and mental flexibility, the ability to shift back and forth smoothly between different mental tasks (Lezak, Howieson, Bigler, & Tranel, 2012). Planning, self-monitoring, initiation, and inhibition are other aspects of complex attention/executive control particularly relevant to daily tasks that may be negatively impacted by TBI (Wilde et al., 2010).

Emotional regulation is also known to be negatively impacted by TBI (Cattran, Oddy, & Wood, 2011; Tate, 1999). PTSD, among other mental disorders, is highly comorbid with TBI, especially in a Veteran population (Simmons & Matthews, 2012; Combs, Berry, Pape, et al., 2015), with estimates as high as 44% among returning soldiers who experienced loss of consciousness due to a head injury (Hoge, McGurk, Thomas, et al., 2008), and 33–39% of Iraq and Afghanistan Veterans who screened positive for mild TBI (Carlson, Nelson, & Orazem et al., 2010). Patients with TBI often struggle to control their emotions and respond appropriately to social situations (Milders, Fuchs, & Crawford, 2003) and can demonstrate irritability and impaired self-awareness (Arciniegas & Wortzel, 2014; Sherer et al., 1998). These difficulties are thought to be related to both neurological damage and adjustment issues.

Theoretical models point to the key role of intact executive skills such as cognitive control in successful emotion regulation (Bush, Luu, & Posner, 2000; Makowski, Sperduti, Blanchet, Nicolas, & Piolino, 2015; Ochsner, Silvers, & Buhle, 2012; Ochsner & Gross, 2005), suggesting one possible explanation for TBI patients’ deficits in this area. Furthermore, problems with planning and response inhibition, cognitive functions vulnerable to TBI, have been shown to contribute to emotional regulation difficulties among TBI patients (Bufkin & Luttrell, 2005). Therefore, it follows logically that treatments targeted at executive control functions may also have a positive impact on emotional regulation for TBI patients.

Rehabilitation for TBI has been shown to be effective (Cicerone, Lagenbahn, Braden, et al., 2011; Storzbach, Twamley, Roost, et al., 2017), but questions remain as to which patients are likely to benefit most. There is evidence that outcomes after cognitive rehabilitation are affected by demographic factors including age, injury severity and education level (e.g., Hammond et al., 2004; Rohling, Faust, Beverly, Demakis, et al., 2009). Some research also suggests that prerehabilitation neuropsychological status impacts rehabilitation outcomes (Sigurdardottir, Andelic, Roe, & Schanke, 2009). For example, there is evidence that poor executive function at baseline negatively impacts ability to engage in rehabilitation (Bajo & Fleminger, 2002). Other studies note that better baseline verbal memory and executive functioning are associated with greater improvement in functioning after rehabilitation (Hanks, Mills, Rickers, Giacino, Nakese-Richardson, et al., 2008; Hanks, Rapport, Millis, & Deshpande, 1999).

In treating the cognitive and emotional deficits associated with TBI, it is important that the areas targeted for improvement be clearly and specifically identified and that improvements in these cognitive skills translate to functional improvements in daily life. Goal Oriented Attentional Self-Regulation (GOALS) is a manualized cognitive intervention that combines mindfulness-based training in attentional control with training in organization, planning and goal management. These skills are applied to participant-selected tasks with individual value and ecological significance. The training protocol is based on problem solving and goal-management interventions that have been applied to patients with brain injury as well as other populations (D’zurilla & Goldfried, 1971; Levine et al., 2000; 2007; Nezu, Nezu, & Perri, 1989; Rath, Simon, Langenbahn, Sherr, & Diller, 2003; Robertson, 1996; Schweizer et al., 2008; von, Cramon, Cramon, & Mai, 1991) and features a prominent mindfulness component. In an initial study, individuals with chronic acquired brain injury significantly improved post-GOALS, but not after brief control intervention, on measures of attention/executive function and memory, functional task performance, and emotional functioning (Chen et al., 2011; Novakovic-Agopian et al., 2011).

GOALS has been shown to result in cognitive improvement in several different populations in previous research, including civilians with remote mild-severe acquired brain injury and healthy older adults (Novakovic-Agopian et al., 2011; Turner et al., under review), and has even been shown to improve goal-directed control over neural processing on fMRI (Arnemann et al., 2015; Chen et al., 2011). A recent study has shown that Veterans with history of chronic TBI post-GOALS training improve on measures of neurocognitive functioning, a functional measure of executive functioning, and self-report measures of emotional regulation and daily functioning (Novakovic-Agopian et al., 2018). However, the
question of if and how demographic factors such as age, education, and gender as well as baseline cognitive status, particularly on measures of attention and executive function, differentially impact outcomes after training in a chronic TBI population remains open.

Current study

The goals of the current study are (a) to describe neuropsychological status and associated functional outcomes in a cohort of Veterans with history of chronic mild-severe TBI and (b) to evaluate the impact of differing baseline neuropsychological status on outcomes after executive skills cognitive rehabilitation. Such information will help guide treatment planning and increase cost-effectiveness of treatment in ensuring that time- and effort-intensive cognitive rehabilitation interventions are offered to patients most likely to benefit.

Methods

This study was approved by IRBs at participating institutions including University of California, San Francisco and the VA Medical Centers in San Francisco and Martinez. All participants provided informed consent prior to any of the study procedures taking place. Behavioral assessments and interventions took place at VA Medical Centers in San Francisco and Martinez.

Participants

A total of 33 veterans with history of chronic TBI (mild-severe as defined by VA/DOD criteria (Veterans Affairs/Department of Defense, 2016)) recruited from VA medical clinics including an interdisciplinary TBI clinic, participated in the study. TBI was diagnosed via medical records (available for all participants) and interview with clinicians trained in brain injury diagnosis and treatment (i.e., neuropsychologist, neurologist). Average age was 43.27 years (SD 11.61). Participants were 85% male, 67% white, and had an average of 14.45 years of education (SD 1.82). Most (55%) participants suffered a mild traumatic brain injury, with the remainder experiencing a greater-than-mild (i.e., moderate [n = 7] or severe [n = 7]) injury. The injuries occurred at least one year prior to study participation (average time since injury: 11 years). The injuries sustained were from mixed causes including blunt injuries, motor vehicle accidents, as well as blasts. Eighteen participants reported experiencing multiple (i.e., greater than one) TBIs. We elected to examine the full spectrum of injury severity because we observed in our work with chronically injured Veterans that outcomes after rehabilitation do not appear to depend solely on injury severity, but instead appear to be moderated by cognitive status at the beginning of training, and we were interested in testing this hypothesis empirically.

All participants were on stable psychoactive medication regimens during the study duration, and had no active illicit drug use, severe depression, aphasia or other conditions that would impede participation in the intervention or measurements. Participants who demonstrated severe or unstable psychiatric status as well as any potential participants with active suicidal ideation (based on interview as well as review of medical records) were excluded.

Please see Novakovic-Agopian et al. (2018) for more detailed information on the recruitment and screening of this sample.

Intervention

Participants were randomized to one of two five-week training protocols: Goal-Oriented Attentional Self-regulation (GOALS) or Brain Health Education (BHE). BHE and GOALS were closely matched for therapist time and training intensity.

Goal-Oriented Attentional Self-regulation (GOALS) Training. The Goal-Oriented Attentional Self-regulation training involves ten two-hour training sessions in small-group format (two to five participants), three individual one-hour training sessions, and approximately 20 h of home practice (approximately 35 homework assignments).

The GOALS intervention emphasizes two key components. First, regulation of distractibility is addressed with attention regulation training. This aspect of the training emphasizes principles of applied mindfulness-based attention regulation to redirect cognitive processes toward task-relevant activities even when distracted. The second major component of GOALS training involves the active application of these goal-oriented attentional self-regulation skills to the identification, selection, and execution of self-generated complex goals. Participants are asked to identify personally relevant and feasible functional goals (e.g., finding an apartment, looking for a job, writing a school term paper, planning a vacation) as individual and group projects. Participants work to achieve two self-generated complex goals, in the form of the
individual and group projects, as well as numerous smaller goals including homework assignments and in-group activities, throughout the training. To ensure consistency of administration, intervention manuals were written for instructors and participants (Instructor and Participant Manuals of Goal-Orientated Attentional Self-Regulation – GOALS; Novakovic-Agopian, Chen, & Rome, 2011). If a session is missed, every effort is made for the participant to complete a make-up session. All participants in the current study completed all aspects of the training. Please see Novakovic-Agopian et al. (2011) for a more detailed description of the GOALS intervention.

**Brain Health Education (BHE) comparison training.** The Brain Health Education (BHE) training is an active comparison matched with GOALS for therapist time, homework load, and participation in a group of two to five participants. It involves ten two-hour sessions of group-based training, three individual one-hour training sessions, and approximately 20 h of home practice. The BHE training is designed to be engaging and provide information about brain functioning and brain health. Group leaders do not assist participants with making connections between the material presented and possible positive effects on their own daily functioning, or how to integrate this information into their daily lives.

To ensure consistency of administration, intervention manuals were written for instructors and participants. If a session is missed, every effort is made for a participant to have a make-up session. Participants are also given up to 30–60 min of daily homework between sessions (approximately 4 h per week). Homework consists of reading articles related to session content and watching DVDs about brain functions and health. Participants are also given an exam during the first and last sessions to gauge their level of knowledge about brain anatomy and health. All participants in the current study completed all aspects of the training.

**Measures**

Participants were evaluated with a multilevel battery consisting of a neuropsychological battery, an ecologically valid functional measure of executive functioning, and self-report measures of daily and emotional functioning before and after GOALS or BHE group intervention. These measures were administered by the same evaluator at both time points, and every attempt was made to administer them at the same time of the day. Evaluators were blinded to participants’ treatment conditions, and evaluators and therapists were separate individuals.

**Neuropsychological assessments.** The current study used a neuropsychological battery specifically designed to assess performance in cognitive domains of complex attention and executive function that are commonly affected by TBI and targeted by GOALS training.

*Working memory* was assessed with (a) Auditory Consonant Trigrams (Stuss, Stethem, & Pelchat, 1988), requiring recall of three consonants after counting backward by threes (e.g., 100, 97, 94, etc.) from a specified number for a variable amount of time, and (b) the Letter Number Sequencing subtest from the Wechsler Adult Intelligence Scale, Third Edition (Wechsler, 1997), requiring mental reordering of scrambled letter-number series of increasing lengths.

*Inhibition* of automatic responding was assessed with a Stroop inhibition task (time and errors) from the Delis-Kaplan Executive Function System Color Word Interference Test (Delis, Kaplan, & Kramer, 2001), in which words are printed in dissonant ink color and participants are instructed to name the color of the ink instead of providing the more automatic response of reading the word.

*Mental flexibility* was assessed with (a) Trail Making Test-Part B (Heaton, Miller, Taylor, & Grant, 2004), requiring rapid alternation between letters and numbers to connect them in order; (b) Design Fluency-Switching (Delis et al., 2001), requiring alternating between empty and filled dots while generating different designs using four lines; (c) Verbal Fluency-Switching (Delis et al., 2001), requiring the generation of words that belong to two specified categories and alternating between them; and (d) DKEFS (Delis et al., 2001) Stroop Inhibition-Switching (time and errors) from the Color Word Interference subtest, during which the participant is presented with words printed in dissonant ink color, some of which are contained in boxes, and the participant is instructed to name the color of the ink unless the word is inside the box, in which case they are to read the word.

*Sustained Attention* was assessed using the Digit Vigilance Test (Kelland & Lewis, 1996) time and error scores.

In order to maintain consistency with our previous work (i.e., Novakovic-Agopian et al., 2011; 2014; Novakovic-Agopian et al., 2018) a composite executive function variable (AVXE) was constructed. This composite represents the mean of Z scores on measures from the Inhibition, Working Memory, Sustained Attention, and Mental Flexibility domains. Please see
Novakovic-Agopian et al., 2018 for more details on the derivation of this variable.

Participants’ performance in cognitive domains commonly affected by TBI, but not targeted by the intervention, was also assessed as a marker of potential nonspecific changes. Changes in attention and executive functioning may indirectly affect memory performance, as well as verbal and visual learning. Total Recall was assessed with Hopkins Verbal Learning Test—Revised (HVLT-R; Brandt & Benedict, 2001) requiring participants to learn 12 words presented over three learning trials, and with Brief Visual Memory Test—Revised (BVMT-R; Benedict, 1997), requiring participants to learn and reproduce six abstract designs over three learning trials. Delayed Recall was assessed with HVLT-R and BVMT-R Delayed Recall trails, requiring participants to recall the word list or figures after a 20–25 min delay. A Total Memory composite score was created using the Total Recall and Delayed Recall scores.

To minimize practice effects, alternative test forms (DKEFS, HVLT-R, BVMT-R) and/or norms for repeated testing (Auditory Consonant Trigrams) were used for repeated administrations whenever feasible.

Functional assessment. Goal Processing Scale. The Goal Processing Scale (GPS; Novakovic-Agopian et al., 2014) involves the observation and rating of a participant completing a challenging task that engages executive control using a scoring system to quantify observations. This measure is administered to one participant at a time. Participants are instructed to plan and execute a task requiring them to gather and compare information about three different activities (or products/services, as designated on alternate forms) of their choice, using the available means while following specified rules in a limited time (30 min). Participants work in an office equipped with a computer with Internet access, a telephone, yellow pages telephone book, blank paper, pen, calculator, and clock. They are given the task instructions page, which contains the key requirements of the task and the task rules. The instructions are read aloud by the evaluator, who is present in the room during the entire evaluation. After the participants’ understanding of the instructions is ensured, they are asked to decide on the actual goals and parameters of the task and to identify the steps needed to complete the task (the “planning stage”). During the 30-min “task execution stage,” participants are evaluated on their ability to effectively execute the task on the basis of their identified plan and adherence to task rules.

The subdomains of executive function evaluated during the Planning stage include the ability to comprehend task instructions and ask for clarifications when needed; to decide on and identify realistic goal(s); and to organize and prioritize steps involved in actual task execution. After the task goals and plan are decided upon, the participants are told to execute the task on the basis of their identified plan and task rules. The domains assessed during the task execution stage include the ability to initiate task-directed activities; Maintain Attention on a task both in a nondisturbing environment and during the built-in task distractions; Self-monitor Performance (including inhibiting task activities to stop at specified times, review performance, notice, and correct errors); Sequence and Switch Attention between and among the identified task subcomponents; demonstrate Flexibility in approaching alternate solutions when the situation changes (e.g., the ability to continue with specified task goals when the preferred means of obtaining information such as the Internet or phone become unavailable). Memory, including both the ability to recall strategies when needed and the ability to correct previously noted errors, is also assessed. The Execution score reflects the accuracy of completion of identified task goals and effectiveness of time management while executing steps relevant to the identified plan and goals. Finally, a GPS Overall Performance score is also calculated.

Functional performance in these domains is rated on a scale ranging from 0 (not able) to 10 (absolutely not a problem). The GPS Overall Performance score is the average of the seven subdomain scores.

To assist in rating of performance on the subdomains and to ensure rating consistency, the domains were operationally defined in the GPS Rating Instruction Manual. Furthermore, this manual operationally defines and calibrates the following: (a) the cognitive domains evaluated; (b) the task-based context; (c) the rating scale; and (d) the objective criterion-based scoring used for evaluation. For further information regarding the development and validation of this measure, see Novakovic-Agopian et al. (2014).

Measures of daily and emotional functioning. Participants also completed self-report measures of daily and emotional functioning. Participants completed the Mayo-Portland Adaptability Inventory, Version 4 (MPAI-4; Malec, 2005) a measure of common sequelae of TBI including impact on activities of daily living, emotional adjustment, and community integration. Depressive symptoms were assessed using the Beck Depression Inventory-II (BDI-II; Beck, Steer,
Symptoms of posttraumatic stress disorder (PTSD) were evaluated with the PTSD Checklist, Military Version for DSM-IV (PCL-M; Weathers, Litz, Herman, Huska, & Keane, 1994). Level of psychological distress was assessed using the Profile of Mood States (POMS; McNair, Lorr, & Droppelman, 1981).

**Study design**

At baseline, veterans underwent a comprehensive multilevel evaluation of neuropsychological, emotional, and functional status. Consecutively recruited participants were placed in small groups (average group size: three participants), and the entire group was then randomized to receive either GOALS (n = 20) or BHE (n = 13). Intervention groups did not differ based on age (t = 1.59, p = .12), education (t = 1.20, p = .24), gender (χ² = .93, p = .34), ethnicity (χ² = 1.59, p = .21), or TBI severity (mild vs. moderate-severe; χ² = .25, p = .62). The multilevel evaluation was repeated after treatment completion.

Scores on neuropsychological measures completed at baseline were used to place Veterans into clusters based on cognitive functioning. Next, Veterans’ post-treatment cognitive, functional, and emotional regulation status was examined to determine whether baseline neurocognitive status group (i.e., cluster) impacted treatment gains. Separate multivariate analyses of variance (MANOVAs) were used to compare pre- vs. post-treatment scores on neurocognitive, functional, and emotional regulation for each cluster.

Baseline neuropsychological data were missing for one veteran. GPS data were missing for three veterans, and questionnaire data were missing for four veterans. Veterans with missing data for a measure were removed from that analysis, resulting in slightly different sample sizes (see Tables 1–4). Veterans with missing data did not differ from the rest of the sample on age or time since injury. They were slightly but significantly better educated (p = .047), and female patients were overrepresented among participants with missing data as compared to those without (p = .01). There was no difference in study group (GOALS vs. BHE) or injury severity (mild vs. moderate-severe).

**Statistical analyses**

All scores on neuropsychological and functional variables were converted to standardized scores using age and education-based norms where available and then transformed to Z-scores before analysis. Scores on GPS functional assessment, BDI-II, and PCL-M were analyzed in their original scales; POMS raw scores were converted to Z scores, and MPAI raw scores were converted to T scores. All analyses were conducted using SPSS Version 23 (IBM Corp, 2015). Descriptive statistics were calculated for the neuropsychological (individual tests and domain scores), functional, and self-report variables for the whole sample and both intervention groups separately (GOALS vs. BHE).

Baseline neuropsychological composite domain scores of Overall Attention/Executive Function (OA/EF), Auditory Working Memory (AWM), Sustained Attention (SA), Mental Flexibility (MF), Inhibition (I), Composite Memory (TM), Total Recall (TR), and Delayed Recall (DR) were used to place participants into homogenous clusters using two-step cluster analysis. Scores on GPS and measures of emotional functioning were not used to determine cluster membership. Cluster analysis was used instead of median split due to the exploratory nature of the research question, which sought to characterize existing patterns of cognitive function within the sample based on preintervention neuropsychological test performance.

Separate Repeated Measures MANOVAs were conducted with SPSS v. 23 for each cluster, comparing neuropsychological, functional EF, and emotional functioning performance at baseline and post-GOALS or BHE training.

**Results**

**Cluster analysis**

Two distinct clusters were identified: “Cognitive Difficulty” (CD) and “Cognitively Normal” (CN). Clusters did not differ on demographic variables or injury severity (Table 5). Bayes Information Criterion (BIC) was 141.56, BIC change was −8.109, ratio of BIC changes was 1.00, and ratio of distance measures was 1.24. Cluster quality measures of cohesion and separation fell in the Good range. The largest identified group (CD) contained 60% of the sample and was characterized by weak scores (mean Z scores=.75 or below) on Overall Attention/Executive Function, Auditory Working Memory, Total Memory, Total Recall, and Delayed Recall. The second-largest group (CN) contained 40% of the sample and consisted of average scores (all mean Z scores greater than −2) on the neuropsychological variables.

Clusters differed significantly on all neuropsychological domain scores (Figure 1). The CN cluster
Table 1. Interaction effects of GOALS vs. BHE training on neurocognitive outcomes, CD group.

<table>
<thead>
<tr>
<th></th>
<th>GOALS Pretraining</th>
<th>GoALS Post-training</th>
<th>BHE Pretraining</th>
<th>BHE Post-training</th>
<th>F (1,17)</th>
<th>p</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory Working Memory</td>
<td>−1.02 0.39</td>
<td>−0.55 0.56</td>
<td>−0.89 0.51</td>
<td>−1.25 0.78</td>
<td>10.97</td>
<td>.00₁</td>
<td>.39</td>
</tr>
<tr>
<td>Attention</td>
<td>−0.81 0.79</td>
<td>−0.57 0.64</td>
<td>−0.66 0.90</td>
<td>−0.56 0.88</td>
<td>0.35</td>
<td>.56</td>
<td>.02</td>
</tr>
<tr>
<td>Mental Flexibility</td>
<td>−0.49 0.52</td>
<td>−0.14 0.41</td>
<td>−0.83 0.52</td>
<td>−0.61 0.53</td>
<td>0.65</td>
<td>.43</td>
<td>.04</td>
</tr>
<tr>
<td>Inhibition</td>
<td>−0.62 1.01</td>
<td>−0.30 0.74</td>
<td>−0.65 0.80</td>
<td>−0.77 0.70</td>
<td>0.40</td>
<td>.10</td>
<td>.19</td>
</tr>
<tr>
<td>Overall Attention/Executive Function</td>
<td>−0.72 0.44</td>
<td>−0.36 0.40</td>
<td>−0.79 0.42</td>
<td>−0.83 0.43</td>
<td>13.37</td>
<td>.00₁</td>
<td>.44</td>
</tr>
<tr>
<td>Total Recall</td>
<td>−0.93 0.82</td>
<td>−0.74 1.00</td>
<td>−1.64 0.70</td>
<td>−1.54 0.97</td>
<td>0.04</td>
<td>.84</td>
<td>.00</td>
</tr>
<tr>
<td>Delayed Recall</td>
<td>−1.24 0.80</td>
<td>−0.59 1.02</td>
<td>−1.50 0.82</td>
<td>−1.32 0.95</td>
<td>2.48</td>
<td>.13</td>
<td>.13</td>
</tr>
<tr>
<td>Total Memory</td>
<td>−1.08 0.70</td>
<td>−0.66 0.91</td>
<td>−1.56 0.72</td>
<td>−1.43 0.90</td>
<td>0.91</td>
<td>.35</td>
<td>.05</td>
</tr>
</tbody>
</table>

Note. GOALS = Goal Oriented Attentional Self-Regulation; BHE = brain health education; CD = cognitive difficulty.
*Significant at the p < .01 level.

Table 2. Interaction effects of GOALS vs. BHE training on GPS performance, CD group.

<table>
<thead>
<tr>
<th></th>
<th>GOALS Pretraining</th>
<th>GoALS Post-training</th>
<th>BHE Pretraining</th>
<th>BHE Post-training</th>
<th>F (1,15)</th>
<th>p</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>7.14 1.46</td>
<td>7.99 1.23</td>
<td>6.58 1.34</td>
<td>6.00 1.18</td>
<td>7.78</td>
<td>.01₁</td>
<td>.34</td>
</tr>
<tr>
<td>Initiation</td>
<td>9.75 0.42</td>
<td>10.00 0.00</td>
<td>10.00 0.00</td>
<td>10.00 0.00</td>
<td>2.38</td>
<td>.14</td>
<td>.14</td>
</tr>
<tr>
<td>Self-Monitoring</td>
<td>5.58 2.01</td>
<td>7.91 1.24</td>
<td>5.34 1.46</td>
<td>6.22 1.76</td>
<td>2.20</td>
<td>.18₄</td>
<td>.12</td>
</tr>
<tr>
<td>Maintenance of Attention</td>
<td>7.63 1.34</td>
<td>8.46 1.68</td>
<td>7.14 1.48</td>
<td>7.66 1.03</td>
<td>0.28</td>
<td>.61₄</td>
<td>.02</td>
</tr>
<tr>
<td>Sequencing/Switching</td>
<td>5.95 2.06</td>
<td>7.70 1.97</td>
<td>6.17 2.37</td>
<td>6.57 1.67</td>
<td>2.46</td>
<td>.14</td>
<td>.14</td>
</tr>
<tr>
<td>Divergent Thinking</td>
<td>7.6 2.22</td>
<td>8.00 2.54</td>
<td>7.39 1.77</td>
<td>6.64 2.29</td>
<td>0.71</td>
<td>.41</td>
<td>.19</td>
</tr>
<tr>
<td>Execution</td>
<td>4.98 1.82</td>
<td>7.38 2.09</td>
<td>5.98 1.75</td>
<td>6.60 2.25</td>
<td>3.12</td>
<td>.10₄</td>
<td>.17</td>
</tr>
<tr>
<td>Learning and Memory</td>
<td>5.11 2.23</td>
<td>8.22 1.52</td>
<td>4.70 1.33</td>
<td>5.28 1.75</td>
<td>3.92</td>
<td>.07₄</td>
<td>.21</td>
</tr>
<tr>
<td>Overall</td>
<td>6.72 1.18</td>
<td>8.21 1.20</td>
<td>6.66 0.96</td>
<td>6.87 1.06</td>
<td>5.95</td>
<td>.03⁴</td>
<td>.28</td>
</tr>
</tbody>
</table>

Note. GOALS = Goal Oriented Attentional Self-Regulation; BHE = brain health education; GPS = Goal Processing Scale; CD = cognitive difficulty.
*Significant effect of time (pre- vs. post-training), p < .05.
*Significant effect of time (pre- vs. post-training), p < .01.
*Significant interaction effect of time (pre- vs. post-training) and group (GOALS vs. BHE), p < .05.

Table 3. Interaction effects of GOALS vs. BHE training on self-reported emotional functioning outcomes, CD group.

<table>
<thead>
<tr>
<th></th>
<th>GOALS Pretraining</th>
<th>GoALS Post-training</th>
<th>BHE Pretraining</th>
<th>BHE Post-training</th>
<th>F (1,12)</th>
<th>p</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCL-M Raw Total</td>
<td>44.75 22.67</td>
<td>38.00 10.88</td>
<td>60.83 11.68</td>
<td>59.83 11.27</td>
<td>0.98</td>
<td>.34</td>
<td>.08</td>
</tr>
<tr>
<td>Re-experiencing</td>
<td>13.13 8.27</td>
<td>10.00 4.69</td>
<td>18.17 4.49</td>
<td>16.83 4.96</td>
<td>5.24</td>
<td>.04⁴</td>
<td>.30</td>
</tr>
<tr>
<td>Avoidance</td>
<td>20.00 9.09</td>
<td>16.00 5.53</td>
<td>24.17 5.23</td>
<td>24.83 4.36</td>
<td>1.31</td>
<td>.28</td>
<td>.10</td>
</tr>
<tr>
<td>Arousal</td>
<td>14.75 6.52</td>
<td>13.25 4.92</td>
<td>18.00 2.97</td>
<td>18.17 2.93</td>
<td>0.18</td>
<td>.68</td>
<td>.02</td>
</tr>
<tr>
<td>POMS Z-score Tension</td>
<td>−0.96 1.20</td>
<td>−0.23 1.07</td>
<td>−0.84 1.03</td>
<td>−1.08 1.16</td>
<td>2.39</td>
<td>.15</td>
<td>.17</td>
</tr>
<tr>
<td>Depression</td>
<td>−3.06 0.87</td>
<td>−1.05 2.07</td>
<td>−1.56 1.64</td>
<td>−1.47 1.92</td>
<td>2.15</td>
<td>.17₄</td>
<td>.15</td>
</tr>
<tr>
<td>Anger</td>
<td>−2.17 1.35</td>
<td>−0.96 1.12</td>
<td>−0.49 1.05</td>
<td>−1.31 1.70</td>
<td>5.37</td>
<td>.04₄</td>
<td>.31</td>
</tr>
<tr>
<td>Confusion</td>
<td>−2.17 0.73</td>
<td>−0.90 0.91</td>
<td>−1.78 1.12</td>
<td>−2.17 1.15</td>
<td>7.08</td>
<td>.02₄</td>
<td>.37</td>
</tr>
<tr>
<td>Vigor</td>
<td>−0.31 0.87</td>
<td>−0.14 1.03</td>
<td>−1.63 0.60</td>
<td>−1.54 0.64</td>
<td>0.04</td>
<td>.85</td>
<td>.00</td>
</tr>
<tr>
<td>Fatigue</td>
<td>−1.24 0.68</td>
<td>−0.78 1.23</td>
<td>−1.63 1.12</td>
<td>−2.23 0.71</td>
<td>2.85</td>
<td>.12</td>
<td>.19</td>
</tr>
<tr>
<td>Total Mood Disturbance</td>
<td>−2.29 0.86</td>
<td>−1.07 1.15</td>
<td>−1.61 1.33</td>
<td>−2.01 1.38</td>
<td>3.91</td>
<td>.07</td>
<td>.25</td>
</tr>
</tbody>
</table>

Note. GOALS = Goal Oriented Attentional Self-Regulation; BHE = brain health education; CD = cognitive difficulty; BDI-II Raw = Beck Depression Inventory; PCL-M Raw = PTSD Checklist, Military; POMS = Profile of Mood States.
*Significant omnibus effect of time (pre- vs. post-treatment), p < .05.
*Significant interaction effect of time (pre- vs. post-training) and group (GOALS vs. BHE), p < .05.
*Significant interaction effect of time (pre- vs. post-training) and group (GOALS vs. BHE), p < .01.

exhibited stronger performance on the GPS functional assessment of executive function in domains of Overall Score, Self-monitoring, Sustained Attention, Execution, and Learning and Memory (Figure 2). The
clusters differed on re-experiencing PTSD symptoms ($t = 2.16$, $p = .04$) and post-TBI community integration ($t = -.24$, $p = .03$), with the CD cluster endorsing more problems in these domains. Clusters did not differ on PCL-M Avoidance or Hypervigilance, other scales from the MPAI, BDI score, or scales from the POMS (data not shown). Intervention group membership (GOALS vs. BHE) was evenly distributed across clusters ($\chi^2 = .04$, $df = 1$, $p = .84$), such that 11 members of the CN cluster and eight members of the CD cluster completed GOALS training, and eight members of the CD cluster and five members of the CN cluster completed BHE.

**Planned comparisons/follow-up analyses**

Separate multivariate repeated measures analyses of variance were conducted for each group (CD and CN)
Comparing performance at baseline and after either GOALS or BHE on neurocognitive, functional executive, and emotional functioning outcomes.

Analyses examining neurocognitive outcomes revealed that in the CD group, there was a multivariate omnibus effect of time \(F(7,11) = 3.90, p = .02\), partial eta squared = .71, such that participants improved on neurocognitive variables after participating in either training. In addition, interaction effects were observed such that neuropsychological domain scores in Overall Attention/Executive Function and Auditory Working Memory improved significantly more for participants who completed GOALS when compared to those who completed a control BHE training (Table 1). In the CN group, there was no significant change regardless of intervention type. There were no other significant omnibus, within-subjects, or between-subjects effects for either the CD or the CN group.

For the functional assessment of executive function, tests of within-subjects effects showed that the CD group improved after either treatment on Overall score \(F(1,15) = 10.43; p = .006\); partial eta squared = .41, Self-monitoring \(F(1,15) = 9.87; p = .007\); partial eta squared = .40, Maintenance of Attention \(F(1,15) = 5.00; p = .041\); partial eta squared = .25, Sequencing/Switching of Attention \(F(1,15) = 6.25; p = .025\); partial eta squared = .29, Execution \(F(1,15) = 8.98; p = .009\); partial eta squared = .37, and Learning and Memory \(F(1,15) = 8.33; p = .011\); partial eta squared = .36. There was a significant interaction effect for the CD group between time (pre- vs. post-treatment) and group (GOALS vs. BHE) such that GOALS participants improved more on Overall Performance and Planning score, compared to BHE participants (Table 2). Participants in the CN group improved in Planning after participating in either treatment \(F(1,15) = 4.60; p = .049\); partial eta squared = .24]. There were no other significant effects.

Regarding self-report measures of emotional and daily functioning, tests of within-subjects effects showed that CD participants improved on POMS Depression \(F(1,23) = 5.34; p = .028\); partial eta squared = .19, BDI Total Score \(F(1,23) = 5.49; p = .028\); partial eta squared = .19, and PCL-M Re-experiencing \(F(1,23) = 5.50; p = .028\); partial eta squared = .193 after treatment, regardless of intervention group. Tests of between-subjects effects showed that the CD group had higher average scores on POMS Vigor \(F(1,23) = 9.78; p = .005\); partial eta squared = .030 and PCL-M Total Score \(F(1,23) = 6.23; p = .020\); partial eta squared = .213 both pre- and post-treatment; CN participants improved on POMS Tension \(F(1,12) = 7.22; p = .03\); partial eta squared = .48 and POMS Depression \(F(1,12) = 5.91; p = .041\); partial eta squared = .43 and PCL-M Arousal \(F(1,12) = 9.24; p = .02\); partial eta squared = .54 after treatment regardless of intervention group.

There was a significant interaction effect such that CD participants improved more after GOALS treatment on POMS Anger and Confusion and PCL-M Re-experiencing compared to BHE (Table 3). For the CN group, there were significant interaction effects such that PCL-M Arousal improved significantly more after GOALS compared to BHE (Table 4).

Neither group improved following treatment on any MPAI scales. There were no significant omnibus effects for this measure.

**Discussion**

This study sought to identify neuropsychological profiles among Veterans with history of TBI and to examine the differing impact of a cognitive rehabilitation intervention targeting attentional control and executive function based on participants’ baseline cognitive status. Results show two distinct profiles of neuropsychological functioning in a sample of veterans with history of chronic mild to severe TBI: a cognitively normal group, and a second group with cognitive dysfunction (particularly in attention,
executive function, and learning and memory), that also experienced more difficulty with emotional regulation and daily functioning. Of interest, and contrary to expectations, these groups did not differ based on age, education, gender, or injury severity. This suggests that for these chronic injuries, there may be other latent factors impacting cognitive and daily functioning outcomes. Because the two groups differed on some measures of emotional distress, the presence of psychiatric comorbidity is a likely candidate for a possible factor driving the differing outcomes. The two distinct profiles also highlight the diversity in outcomes for Veterans with history of TBI over time, particularly for patients with injuries occurring on average over a decade prior to neuropsychological evaluation.

The characteristics of the CD subsample are consistent with previous findings showing the predominance of executive dysfunction in some TBI patients (Cicerone & Azulay, 2002; Fork et al., 2005; Mathias et al., 2004; Vanderploeg et al., 2005). The GOALS intervention is designed to target these deficits using training in mindfulness-based attention regulation and planning and problem-solving strategies. Our results indicate that, for Veterans struggling with cognitive function in these domains pretraining, gains occur specifically in these targeted areas: on neuropsychological measures, the CD group improved significantly more after GOALS, compared to BHE control training, on attention and executive function. Members of the CD group also improved on a functional measure of executive planning and execution skills after GOALS. Members of the CN group showed no significant changes on neuropsychological variables after either training. However, they demonstrated improvement in the Planning domain of the functional measure of executive planning and execution skills after GOALS or BHE training. Our findings suggest GOALS training may be a promising intervention for Veterans with chronic TBI, especially those who have neurocognitive difficulty in attention/executive functioning. These results also suggest that cognitive improvement after GOALS training occurs predominantly for those participants who struggle the most at baseline and that participants who are already performing within normal limits do not improve to statistically significant levels on measures of cognitive functioning.

In contrast to previous research (Bajo & Fleminger, 2002), it appears that in our sample, executive dysfunction does not interfere with ability to participate in rehabilitation, at least at the mild to moderate levels of dysfunction present here. Our findings also differ from previous work conducted with more acutely injured participants (Hanks et al., 2008; Hanks et al., 1999) in the implication that baseline deficits in executive function are actually predictive of greater rehabilitation gains. The chronic nature of the injuries in our sample, occurring on average 11 years prior to baseline evaluation, may partially explain this discrepancy, perhaps because participants with chronic injury have had the opportunity to become aware of their deficits and develop more effective coping strategies. Indeed, self-report of problems with attention/executive function was an inclusion criterion for our participants. Furthermore, for our chronic Veteran TBI sample, participants who perform well on neurocognitive testing at an average of 10 years postinjury may not have as much “room for improvement” as those who struggle with measures of attention/executive function at prerehabilitation evaluation.

Overall, TBI-exposed Veteran participants in this study derived benefit from the GOALS training in self-reported emotional regulation. Some previous research suggests that baseline deficits in emotional regulation may interfere with rehabilitation participation (Rochat, Ammann, Mayer, Annoni, & Linden, 2009); that effect was not seen here. Both the CD and the CN groups had relatively high levels of PTSD and depressive symptoms at baseline, and both groups showed measurable post-training improvement in their perception of their own emotional symptoms. Although the CN group did not demonstrate improvement on neuropsychological measures after GOALS training as the CD group did, results suggest they did benefit from the training, as shown by lower levels of perceived emotional distress. Thus, it appears that improvement in emotional regulation may be distinct from improvement in cognitive control for this sample of veterans with chronic TBI. It is also important to note that this study does not rule out possible improvement by participants in both groups on other outcomes not directly measured by this study (e.g., quality of life, functional status).

**Conclusions**

The results of the present study suggest that neuropsychological measures, especially of complex attention and executive function, may aid in identifying chronic TBI patients with functional impairment and assist with treatment planning. Furthermore, consistent with results from previous studies, executive function training may improve elements of cognitive...
functioning for Veterans with TBI who are demonstrating residual cognitive impairment. These results also suggest there is a benefit to training of executive function skills for emotional regulation outcomes, even for participants who are functioning well cognitively, and indicate that most Veterans with chronic TBI can derive benefit from cognitive rehabilitation training with a focus on executive control. Moreover, preliminary results from a recently completed study reveal that the majority of participants retain the cognitive benefits they receive from GOALS training for as long as two years postintervention.

Strengths of this study include the randomized design, blinded evaluators, multilevel assessment, and the use of a control intervention matched for time and intensity.

One important limitation of this study is small sample size, and replication of this research with larger samples is required. The use of self-report data for some of the outcome measures is an additional limitation. Finally, more extensive evaluation, including neuroimaging, may be helpful in specifying injury-specific details and the potential neuroplastic effects of training.

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Declaration of Interest

The authors report no conflict of interest exists.

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