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Long-term effects of executive function training among veterans with chronic TBI

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ABSTRACT
Objective: To investigate long-term effects of GOALS executive function training in Veterans with chronic TBI. In a recently completed study Veterans with chronic TBI showed improvement immediately post-GOALS but not control training on measures of executive function, functional task performance, and emotion regulation. We now examine the long-term maintenance of post-GOALS training changes in the same sample.

Setting: San Francisco VA Health Care System (SFVAHCS), and VA Northern California Health-Care System (VANCHS) in Martinez.

Participants and Design: 24 Veterans with chronic TBI were assessed at baseline, post-GOALS training, and long-term follow-up 6+ months following completion of training with a structured telephone interview, neuropsychological and complex functional performance measures, and self-report measures of daily and emotional functioning.

Results: Participants reported an increased likelihood of involvement in competitive employment/volunteering at follow-up (61%) compared to baseline (26%; \( \chi^2 = 5.66, p < .01, \psi = .35 \)). Repeated measures MANOVAs indicated improvement on attention/executive function (\( F = 13.85, p < .01, \text{ partial } \eta^2 = .42 \)), complex functional task performance (GPS Total: \( F = 9.12, p < .01, \text{ partial } \eta^2 = .38 \)) and daily functioning (MPAI Total: \( F = 3.23, p < .05, \text{ partial } \eta^2 = .21 \)), and reduction in overall mood disturbance (POMS Total: \( F = 3.42, p < .05, \text{ partial } \eta^2 = .22 \)) at follow-up relative to baseline.

Discussion: Training in attention regulation applied to participant-defined goals is associated with meaningful long-term improvement in cognitive skills, emotion regulation, and daily functioning in Veterans with chronic TBI.

Introduction

Traumatic brain injury (TBI) is a major health problem among both civilians and military Veterans with significant public health costs (1–6). Long-term sequelae of TBI can be highly debilitating due to deficits in the executive control functions (7,8). Executive functioning encompasses many complex cognitive processes (such as planning, prioritizing, organizing, decision-making, error correction, overriding habits and inhibition, and mental flexibility) needed to accomplish a particular goal in a flexible manner. Deficits in these cognitive control functions have been linked with difficulties in community reintegration, educational and occupational functioning, and are some of the leading causes of long-term disability among Veterans (1–6,9).

A recent study reported that one-year post deployment 65% of returning Veterans with a history of mild TBI sought treatment for concerns related to reintegration (10).

Cognitive rehabilitation interventions focusing on training to improve metacognition (11,12), problem-solving (13), and goal management (14) have been found to be helpful in improving goal-directed functioning following brain injury, and are part of current professional guidelines and recommendations (15,16) for brain injury rehabilitation. In a review of 360 studies of cognitive rehabilitation interventions, Cicerone et al. (16) concluded that these interventions can improve executive function in patients with a history of TBI. However, most studies did not include follow-up data, and the long-term impact of training and the maintenance of any training gains was less clear. In addition, there was not adequate information available regarding either social participation or quality of life, two areas of functioning that are of high importance for meaningful recovery. The authors (16) concluded that one possible reason many studies do not address changes in these variables is that these outcomes may take some time to fully manifest in participants’ lives, and therefore are not able to be detected without long-term follow-up. Cicerone et al. (16) noted that long-term follow-up in the future research would strengthen the evidence base for these types of interventions.

In addition to questions about social participation and quality of life, it is unclear whether immediate training gains in executive functioning can be maintained over time and whether they are associated with improvements in everyday life pursuits and goals. Limited information is available on the long-term functional impact of interventions designed to...
improve goal-directed functioning for individuals with brain injury. Recent comprehensive reviews of interventions targeting goal-directed functioning (17–20) included only a few studies with follow-up data. Some studies that have examined the long-term impact of training have reported positive outcomes, primarily evidenced via task-specific improvements on laboratory-based simulations (21,22) neuropsychological tests (23,24) or independent activities of daily living and self-reported quality of life (25–27). More recently, Caplan and colleagues (28) reported that Veterans with history of mild TBI who received compensatory cognitive training continued to use a range of trained strategies to help with planning, organization, and time management up to 5 weeks post-training.

The current study examines Goal-Oriented Attentional Self-Regulation (GOALS), a cognitive rehabilitation training program that targets executive control functions by teaching participants in applied mindfulness-based attention regulation and goal management strategies and applying them to real-life goals determined by the participant (29,30). The GOALS training protocol was based on metacognitive problem solving and goal-management interventions that have been applied to patients with brain injury as well as other populations (12,13,30–33) and features a prominent mindfulness component. In contrast to training via practice on isolated tasks, this training protocol involves application of attention regulation skills and strategies to participant-defined goals in real-life, ecologically valid settings. One of the main training aims is to improve self-regulatory control mechanisms as they contribute to goal attainment.

GOALS have been shown to result in post-treatment gains for both civilian and Veteran participants with history of brain injury (29,31). In an initial study, 16 individuals with chronic brain injury significantly improved after GOALS, but not after undergoing brief control intervention, on measures of attention/executive function and memory, functional task performance, and goal-directed control over neural processing on fMRI (29,32). In structured telephone interviews conducted on average 20 months following completion of GOALS training, nearly all participants (94%) spontaneously reported continued use of at least one trained strategy in their daily lives, and 75% reported improved functioning that they directly attributed to their training (33). One major limitation of this long-term follow-up study (33) is that it did not include any objective indicators of treatment efficacy (e.g., performance on ecologically valid measures, neuropsychological measures, functional task performance). Using both objective and subjective indicators of the long-term impact of training can improve understanding of the long-term impact of training on multiple domains of participants’ functioning.

The objective of the current study was to conduct a multi-level assessment of the long-term effects of GOALS training in Veterans with a history of mild-severe TBI. In a recently completed randomized-control study with 33 Veterans with a history of chronic mild-severe TBI, participants who completed GOALS showed post training improvement on measures of complex attention/executive function, functional task performance, and emotion regulation, whereas participants who completed intensity-matched Brain Health Education (BHE) psychoeducational control training did not improve (31). The current study examines Veterans from this same sample who completed GOALS training. Measures of multiple functional domains assessed were compared at baseline, end of treatment and at 6 months (minimum) posttreatment.

Methods

Design and participants

This study was approved by IRBs at participating institutions including University of California, San Francisco VA Health Care System (SFVAHCS), and VA Northern California Health Care System (VANCHCS) in Martinez. All participants provided informed consent prior to any of the study procedures taking place. Behavioral assessments and interventions took place at SFVAHCS and VANCHCS in Martinez.

The majority of participants were referred by their healthcare providers and TBI Clinics at SFVA HCS and VANCHCS in Martinez. Inclusion criteria included: history of chronic TBI (>6 months post-injury); stable psychoactive medication regimen; self-reported cognitive difficulties in areas of concentration, planning, multitasking and memory that interfere with daily function; and interest/availability to participate in cognitive training. Exclusion criteria included: unstable medical, neurologic, or psychiatric conditions; psychosis, severe depression, anxiety or PTSD precluding participation in research activities; ongoing illicit drug or alcohol abuse; or poor English comprehension. TBI diagnosis and severity were established using VA/DOD TBI classification criteria, via review of participant medical records as well as a detailed interview conducted by a clinician (neurologist or neuropsychologist) experienced in the diagnosis of brain injury. All participants were independent in basic activities of daily living but reported continuing to experience mild to moderate difficulties on tasks involving organization, problem-solving, multitasking and concentration.

In the original study, the results of which were recently reported (31), 33 Veterans with history of chronic TBI were randomized to one of two 5 week interventions: Goal-Oriented Attentional Self-regulation (GOALS) (30) training (n = 20) or Brain Health Education (BHE) (34) control training (n = 13). Ten out of 13 participants who completed BHE control training completed GOALS training immediately after completing BHE. Participants who completed control BHE training prior to completing GOALS training did not differ from participants who completed GOALS only on any demographic characteristics (age, p = .23; time since injury, p = .67; years of education, p = .14, TBI severity, p = .57; ethnicity, p = .29; or gender, p = .43).

Out of the 30 participants who completed GOALS training, 24 completed at least one aspect of both post-GOALS training evaluation and the follow-up evaluation at 6+ months (mean 13.25 months, SD 8.94 months; range 6–34 months) after training completion: 23 participants completed a structured telephone interview; 20 participants completed the neuropsychological assessment; 18 completed the functional evaluation; and 14 completed the self-report questionnaires. Among the 24 participants completing the follow-up evaluation, the
average age was 41.13 years (range 25–66; SD 11.39); they were 96% male, 68% white, and had an average of 14.21 years of education (range 12–18; SD 1.72). A majority of participants (N = 13) sustained a mild traumatic brain injury, with the remainder experienced moderate (N = 5) or severe (N = 6) brain injury. The injuries occurred at least 2 years prior to study participation (average time since injury: 11.5 years). At the time of baseline assessment, a majority of participants were not working (18) or going to school (17). Six participants were gainfully employed and six were students but indicated having difficulties completing work and/or school tasks. Please see Novakovic-Agopian et al., 2018 (31), for description of the original study sample.

Veterans who completed follow-up did not differ from those who did not complete follow-up (N = 6) on ethnicity, years of education, injury severity, or time since injury. There was also no difference between completers and non-completers on whether participants completed just GOALS training or BHE control training first. Female Veterans were overrepresented among the group that did not complete follow-up (n = 3; χ^2 = 5.23, p = .02). Out of the six Veterans who did not complete follow-up, three had moved out of area, one indicated that his/her schedule did not allow time for assessments, and we were unable to reach two.

At baseline (BL), post-GOALS (PG), and follow-up (FU), participants were evaluated with a battery consisting of neuropsychological and complex functional performance assessment, and self-report measures of daily and emotional functioning. The assessments were administered by the same evaluator, and every attempt was made to administer them at the same time of the day.

Interventions

Goal-Oriented Attentional Self-regulation (GOALS)

Training involves 10 two-hour sessions of group-based training, three individual one-hour training sessions, and approximately 20 h of home practice, distributed over 5 weeks. The training was conducted in a small group format with two to five participants, and two therapists per group.

The GOALS training emphasizes two key components. First, regulation of distractibility is addressed with attention regulation training. Principles of applied mindfulness-based attention regulation are applied to redirect cognitive processes towards task-relevant activities even when distracted. Participants learn to use a metacognitive strategy (“STOP–RELAX–REFOCUS”, SRR) to stop activity when distracted, anxious, and/or overwhelmed; relax; and then re-focus attention on the current primary goal. They are taught to actively apply these skills to a range of situations, from simple information processing tasks to challenging low-structure situations occurring in their own lives. Homework includes practice in maintaining goal-direction during challenging real-life situations identified by participants.

The second major component of GOALS training is 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. They are then trained in applying the goal management strategies on the functional task(s) of their choice. The main objective is to allow extensive practice and application of skills, thereby linking the attentional regulation directly to goal attainment efforts. For a more detailed review of GOALS training please see Novakovic-Agopian et al. (29,30).

Measures

Structured telephone interview

Participants were asked to participate in a structured telephone interview which included questions about: 1) daily activities including: work, school, caregiving, managing daily IADLS; 2) continued use of trained strategies; 3) the impact of training on emotional and daily functioning, with items rated on a scale of 0 (much worse) to 5 (the same) to 10 (much better), and 4) the degree of change in performance of daily activities requiring attentional control and executive function.

Neuropsychological assessments

The current study used a neuropsychological battery 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: (1) Auditory Consonant Trigrams (35), and (2) the Letter Number Sequencing subtest from the Wechsler Adult Intelligence Scale, Third Edition (36). Inhibition of automatic responding was assessed with: Color Word Inhibition task (time and errors) from the Delis-Kaplan Executive Function System (DKEFS) (37). Mental flexibility was assessed with: (1) Trail Making Test-Part B (38), (2) Design Fluency-Switching (DKEFS) (37), (3) Verbal Fluency Switching (DKEFS) (37), and (4) Color-Word Inhibition-Switching (time and errors) (DKEFS) (37). Sustained Attention was assessed using the Digit Vigilance Test (38) time and error scores. A composite Overall Attention and Executive Function variable (AVXE) was constructed using Z scores on measures from the Inhibition, Working Memory, Sustained Attention, and Mental Flexibility domains.

The neuropsychological battery also contained measures of verbal and visual learning and memory, performance on which is commonly affected by TBI but is not directly targeted by the intervention. Total Recall and Delayed Recall were assessed with Hopkins Verbal Learning Test–Revised (HVLT-R) (39), and with Brief Visual Memory Test–Revised (BVMT-R) (40). A 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. All neuropsychological measures used have well-documented validity and reliability for use with individuals with brain injury and other populations (35–40).
Functional assessment

The Goal Processing Scale (GPS) \( (41) \) involves the observation and rating of a participant completing challenging task that engages executive control using a scoring system to quantify observations. 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.

Participants’ performance on Goal Processing Scale is rated in the following subdomains of executive function: Planning, Initiation, Maintenance of Attention, Self-monitoring, Sequencing and Switching, Flexibility, Memory and Execution. Functional performance in these domains is rated by trained evaluator on a scale ranging from 0 (not able) to 10 (absolutely not a problem). The GPS Overall Performance Score is also calculated as the average of the eight subdomain scores. In prior studies, the GPS has been shown to have high interrater reliability as well-concurrent validity with other complex functional assessment measures such as Multiple Errands Test \((41)\). Please see Novakovic-Agopian et al. \((31,41)\) for more information about the development and validation of this measure.

Measures of Daily and Emotional Functioning Participants also completed a battery of self-report measures of daily and emotional functioning. Participants completed the Mayo-Portland Adaptability Inventory (MPAI-4) \((42)\), a measure of common sequelae of TBI including impact on activities of daily living, emotional adjustment, and community integration. The Goal Processing Questionnaire (GPQ) \((29)\), a self-report measure of post-training improvement in ability to plan and execute aspects of complex, goal-directed behavior in daily life, was also completed. Depressive symptoms were assessed using the Beck Depression Inventory-II (BDI-II) \((43)\). Symptoms of posttraumatic stress disorder (PTSD) were evaluated with the PTSD Checklist, Military Version (PCL-M) \((44)\). Level of psychological distress was assessed using the Profile of Mood States (POMS) \((45)\). The reliability and validity of the above measures of daily and emotional functioning are well documented for use with participants with brain injury \((42–45)\).

Statistical analysis

All analyses were conducted using SPSS Version 24.0 \((46)\). Descriptive statistics were obtained for results of the follow-up telephone interview. Chi-square analyses were conducted to compare proportions of participants involved in vocational and daily activities at pre-treatment baseline vs. six-month follow-up.

Descriptive statistics were calculated for the neuropsychological (individual tests and domain scores), functional, and self-report variables for the whole sample at three timepoints: baseline, post-GOALS treatment, and long-term follow-up. Scores on neuropsychological variables were standardized via transformation to z-scores before analysis. Scores on BDI-II, GPQ, and PCL-IV-M were analyzed in their original scales; POMS raw scores were converted to z scores, and MPAI scores were converted to T scores.

A repeated measure multivariate analysis of variance (MANOVA) was used to compare performance on neurocognitive domain scores at baseline, post-GOALS training, and long-term follow-up. Similarly, a repeated measure multivariate analysis of variance (MANOVA) was used to compare performance on GPS functional task domain scores at baseline, post-GOALS training, and long-term follow-up. In addition, separate repeated measures MANOVA were conducted to compare scores at each of the three timepoints on measures of everyday and emotional functioning. Planned comparisons were used to determine the existence of statistically significant differences between mean scores at each of the three timepoints.

Although we have examined a number of cognitive domains and sub-domains, we report nominal \(p\)-values, without adjustment for multiple testing consistent with our previous work (see Novakovic-Agopian et al., 2011, 2018; Turner, Novakovic-Agopian et al., 2018) \((29,31,47)\). Such adjustments are focused on avoidance of one or more results with \(p < .05\) in the case where all differences are truly zero \((Perneger, 1998; Rothman, 1990; Savitz and Olshan, 1995) \((46,48,49)\), which is an unrealistic hypothesis about the state of nature in this context. In addition, an adjustment would require that each result detract from the others, but there are clear relationships between the domains under study, and these permit coherent sets of findings to reinforce each other rather than detract from one another.

Results

Structured telephone interview

Twenty-three participants completed a follow-up telephone interview approximately 1 year after completion of GOALS training.

Daily activities

Involvement in competitive employment or volunteering was reported by significantly more participants at six-month follow-up \((n = 14, 61\%\) compared to baseline \((n = 6, 26\%\); \(p < .01)\). The number of participants engaging in volunteer activities significantly increased from one \((4\%)\) at baseline to six \((26\%)\) at follow-up \((p < .05)\). Eleven participants \((47\%)\) reported engagement in competitive employment at follow-up, compared to six \((26\%)\) at baseline, a difference that did not reach statistical significance. Nine participants \((39\%)\) were enrolled in an academic program, compared to six \((26\%)\) at baseline, which was not a statistically significant change. There was a significant increase in caregiving activities (for a child, or older or dependent adult) in that 57\% of participants \((n = 13)\) reported being involved in caregiving activities at six-month follow-up compared with 26\% \((n = 6)\) at baseline \((p < .05)\).

In addition, 20 participants \((87\%)\) reported completing household chores, compared to 10 \((43\%)\) at baseline, a statistically significant increase \((p < .05)\). Eighteen participants \((78\%)\) reported paying bills at follow-up compared to 15 \((65\%)\) at baseline although this improvement did not reach statistical
significance. A majority of participants reported being independent in driving or using public transportation at both follow-up and baseline (22 participants at follow-up, relative to 20 at baseline). More participants reported involvement in social activities after training: Eighteen (78%) reported involvement in social activities in contrast to 12 (52%) at baseline, although this change did not reach statistical significance. There was also a significant increase in participants engaging in medical/mental health treatment from 5 (22%) at baseline to 13 (57%) at follow-up (p < .05). See Table 1 for further detail.

Use of strategies
Ninety-one percent (n = 21) of the participants surveyed indicated that they continued to use at least one of the strategies learned in GOALS training in their daily lives.

Emotional and daily functioning
Participants on average reported a positive change in each of the items queried: self-esteem, knowledge of strengths and weaknesses, self-confidence, relationships, mood, managing daily tasks at work, home, and school, and managing frustrations. The greatest overall improvements were reported in knowledge of strengths and weaknesses (mean rating = 7.52, SD = 1.83) and managing daily tasks at work/home/school (mean = 7.27, SD = 1.52).

Change on daily tasks requiring attentional control and executive function
Participants overall reported improvement in ability to complete each of the tasks queried. The greatest overall improvements were observed in ability to recall strategies that have been helpful in the past with similar tasks (mean = 7.35, SD = 1.58), ability to finish things that have been started (mean = 7.09, SD = 1.83), ability to recognize when distressed or overwhelmed (mean = 7.04, SD = 1.69) and ability to correct a noticed mistake (mean = 7.00, SD = 1.54).

When asked to describe the impact of training in an open-ended manner, one participant reported that the training was helpful in “Identifying cognitive difficulties, becoming more aware and less in denial, and allowing for more openness to getting help.” Another reported that training allowed him to “learn more about himself.” Participants also indicated they “learned new tools to help focus” and that the training “helped with school” and “helped with social interaction” and that they were “getting along with people better.” One stated that he “learned how to refocus himself, whereas before was just lost and would get mad and frustrated” According to another participant, “my memory has improved and I am much less frustrated than before.” One indicated training was helpful because “now I stop and think about things before I do them”. Participants also reported that post-training, they were able to take on projects they would not have attempted before, such as returning to college, selling a home, beginning an exercise routine, or starting a business and a family. One “enrolled in a math class.” Another noted he achieved a goal of “getting a good review at work.”

Neurocognitive outcomes
MANOVA analyses investigating the within-subjects effect of time (BL, PG, FU) on neurocognitive outcomes revealed significant differences between mean scores on Overall Attention and Executive Function composite score (p < .000) and subdomains of Working Memory (p = .02), Sustained Attention (p = .003), and Mental Flexibility (p = .003), and on Memory composite score (p = .003) and the Immediate (p = .03) and Delayed Recall (p = .002) subdomains. Planned comparisons revealed significant improvement post-GOALS relative to baseline on measures of: Overall Attention/Executive function composite (p = .002) and subdomains of Sustained Attention (p = .02), Metal Flexibility (p = .004); and on Memory composite (p = .003) and subdomains of Immediate (p = .01) and Delayed recall (p = .003). Similarly, planned comparisons revealed significant improvement at follow-up relative to baseline on measures of: Overall Attention/Executive Function (p < .000) and subdomains of Working Memory (p = .006), Sustained Attention (p = .001), and Mental Flexibility (p = .009), and on Memory Composite score (p = .01) and Delayed Recall subdomain (p = .007) (Table 2). Planned comparisons revealed no statistically significant changes between post-GOALS and follow-up on any neurocognitive outcomes (data not shown).

Functional performance outcomes
MANOVA analyses investigating the within-subjects effect of time (BL, PG, FU) on functional performance outcomes revealed significant differences between mean scores on GPS Total Score (p < .001) and the following sub-domains: Planning (p = .000), Self-Monitoring (p = .002), Sequencing/Switching (p = .02), Task Execution (p = .01) and Learning and Memory (p = .003). Planned comparisons revealed significant improvement post-GOALS relative to baseline on measures of: GPS Total Score (p = .001), and subdomains of Planning (p = .002), Self-Monitoring (p = .000), Sequencing/ Switching (p = .01), Task Execution (p = .005), and Learning and Memory (p = .002). Similarly, planned comparisons revealed significant improvement at follow-up relative to baseline on measures of: GPS Total Score (p = .01), Planning (p = .008), Self-Monitoring (p = .02), Sequencing/
Switching ($p = .02$), Task Execution ($p = .005$), and Learning and Memory ($p = .03$) (see Table 3). Compared to post-GOALS, participants’ scores on the GPS Self-Monitoring subdomain scale were lower at follow-up ($p < .05$). Significant

| Table 2. Effect of training on neurocognitive outcomes (z scores). |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Baseline (B) | Post-GOALS (PG) | Follow-up (FU) | M | SD | M | SD | M | SD | F (2,19) | $p$ | Partial $\eta^2$ |
| Overall attention/EF | $-22$ | $.52$ | $.03$ | $.56$ | $.13$ | $.54$ | $13.85$ | $^2$ | $.00$ | $.42$ |
| Working memory | $-26$ | $.75$ | $.04$ | $.82$ | $.13$ | $.80$ | $4.18$ | $^1$ | $.02$ | $.18$ |
| Sustained attention | $-60$ | $.70$ | $.32$ | $.56$ | $.25$ | $.59$ | $6.89$ | $^2$ | $.00$ | $.27$ |
| Mental flexibility | $-10$ | $.56$ | $.21$ | $.59$ | $.28$ | $.69$ | $7.00$ | $^1$ | $.00$ | $.27$ |
| Inhibition | $-05$ | $.63$ | $.05$ | $.63$ | $.18$ | $.61$ | $1.76$ | $^1$ | $.19$ | $.09$ |
| Memory | $-69$ | $.04$ | $.11$ | $.10$ | $.22$ | $.07$ | $6.78$ | $^2$ | $.00$ | $.26$ |
| Immediate recall | $-66$ | $1.13$ | $-.14$ | $1.18$ | $-.30$ | $1.00$ | $3.80$ | $^2$ | $.03$ | $.17$ |
| Delayed recall | $-72$ | $.04$ | $-.08$ | $.10$ | $-.13$ | $.10$ | $7.68$ | $^2$ | $.00$ | $.29$ |

1 $PG>BL$, $p < .05$
2 $PG>BL$, $p < .01$
3 $FU>BL$, $p < .01$ level
4 $FU>BL$, $p < .001$ level

| Table 3. Effect of training on functional task outcomes (raw scores). |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Baseline (BL) | Post-GOALS (PG) | Follow-up (FU) | M | SD | M | SD | M | SD | F (2,15) | $p$ | Partial $\eta^2$ |
| Total score | $7.30$ | $1.44$ | $8.39$ | $1.25$ | $8.16$ | $.80$ | $9.12$ | $^3$ | $.00$ | $.38$ |
| Planning | $6.60$ | $1.94$ | $8.16$ | $1.31$ | $8.01$ | $1.40$ | $9.91$ | $^2$ | $.00$ | $.40$ |
| Initiation | $9.72$ | $1.00$ | $10.00$ | $0.00$ | $10.00$ | $.00$ | $1.26$ | $^1$ | $.30$ | $.07$ |
| Self-monitoring | $6.75$ | $1.48$ | $8.28$ | $1.25$ | $7.59$ | $1.09$ | $11.96$ | $^2$ | $.00$ | $.44$ |
| Maintenance of attention | $7.90$ | $1.45$ | $8.54$ | $1.50$ | $8.28$ | $1.33$ | $2.24$ | $^2$ | $.12$ | $.13$ |
| Sequencing/switching | $7.27$ | $1.77$ | $8.27$ | $1.66$ | $8.31$ | $1.25$ | $4.45$ | $^1$ | $.02$ | $.23$ |
| Divergent thinking | $7.70$ | $2.27$ | $7.94$ | $2.67$ | $7.70$ | $2.88$ | $.29$ | $^1$ | $.93$ | $.00$ |
| Task execution | $6.33$ | $2.08$ | $7.70$ | $2.21$ | $7.41$ | $1.61$ | $4.96$ | $^2$ | $.01$ | $.24$ |
| Learning and memory | $6.16$ | $2.25$ | $8.24$ | $1.67$ | $7.51$ | $1.34$ | $7.06$ | $^2$ | $.00$ | $.32$ |

1 $PG>BL$, $p < .05$
2 $PG>BL$, $p < .01$
3 $FU>BL$, $p < .001$ level
4 $FU>BL$, $p < .01$
5 $PG>FU$, $p < .05$

| Table 4. Effect of training on daily functioning outcomes (T scores; lower T scores indicate better functioning). |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Baseline (BL) | Post-GOALS (PG) | Follow-up (FU) | M | SD | M | SD | M | SD | F (2,12) | $p$ | Partial $\eta^2$ |
| Total | $54.08$ | $5.77$ | $52.38$ | $6.81$ | $49.77$ | $5.60$ | $3.23$ | $^A$ | $.05$ | $.21$ |
| Ability | $53.15$ | $7.70$ | $51.69$ | $11.66$ | $50.15$ | $6.91$ | $.977$ | $a$ | $.39$ | $.08$ |
| Adjustment | $56.92$ | $5.85$ | $55.46$ | $7.46$ | $52.00$ | $6.86$ | $2.82$ | $^A$ | $.08$ | $.19$ |
| Participation | $48.46$ | $9.62$ | $45.31$ | $5.39$ | $41.38$ | $8.10$ | $3.80$ | $^A,a$ | $.04$ | $.24$ |

$^A FU>BL$, $p < .05$
$^a FU >PG, p < .05$

| Table 5. Effect of training on emotional functioning outcomes. |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Baseline (BL) | Post-GOALS (PG) | Follow-up (FU) | M | SD | M | SD | M | SD | F (2,11) | $p$ | Partial $\eta^2$ |
| BDI-II (raw) | $24.62$ | $9.54$ | $18.92$ | $9.42$ | $17.92$ | $11.56$ | $1.9$ | $.18$ | $.13$ |
| PCL-M | | | | | | | | | | |
| Total (raw) | $51.08$ | $15.95$ | $44.58$ | $18.64$ | $44.42$ | $14.05$ | $2.58$ | $^A$ | $.09$ | $.19$ |
| POMS (z score) | | | | | | | | | | |
| Total | $-1.51$ | $1.16$ | $-1.78$ | $1.10$ | $-1.54$ | $.98$ | $3.40$ | $^A$ | $.05$ | $.22$ |
| Tension | $-6.11$ | $.96$ | $-1.12$ | $.88$ | $.05$ | $.79$ | $3.49$ | $^A$ | $.05$ | $.22$ |
| Depression | $-1.67$ | $1.61$ | $-1.67$ | $1.36$ | $-1.33$ | $1.16$ | $4.20$ | $^1$ | $.03$ | $.26$ |
| Anger | $-10.09$ | $1.62$ | $-8.54$ | $1.33$ | $-10.31$ | $1.15$ | $3.80$ | $^1$ | $.19$ | $.13$ |
| Confusion | $-1.45$ | $8.00$ | $-9.20$ | $.93$ | $-8.50$ | $.68$ | $6.67$ | $^B$ | $.00$ | $.36$ |
| Vigor | $-1.05$ | $1.07$ | $-7.62$ | $1.28$ | $-1.02$ | $1.01$ | $.93$ | $^A$ | $.41$ | $.07$ |
| Fatigue | $-1.19$ | $.96$ | $-6.22$ | $.87$ | $-1.57$ | $.98$ | $2.05$ | $^A$ | $.15$ | $.15$ |

1 $PG>BL$, $p < .05$
2 $PG>BL$, $p < .01$
3 $FU>BL$, $p < .05$
4 $FU>BL$, $p < .01$
change post-GOALS to follow-up was not observed on any other GPS subdomains.

**Daily and emotional functioning outcomes**

MANOVA analyses investigating the within-subjects effect of time (BL, PG, FU) on daily functioning outcomes revealed a significant difference between mean scores on the Mayo-Portland Adaptability Inventory Total Score ($p = .05$) and Participation subscale ($p = .04$). Planned comparisons revealed significant improvement at follow-up relative to baseline on Total Score ($p = .04$) and Participation ($p = .04$) subdomains. (Table 4). Compared to post-GOALS, participants reported higher scores at follow-up on the MPAI Participation scale ($p < .05$), suggesting continued improvement in this domain after treatment ends. Planned comparisons showed no other statistically significant changes between post-GOALS and follow-up on any daily functioning outcomes.

MANOVA analyses investigating the within-subjects effect of time (BL, PG, FU) on emotional functioning outcomes (Table 5) showed no significant differences between timepoints on PCL Total score or on BDI Total score. These analyses showed significant differences between timepoints on POMS scales of Overall Mood Disturbance ($p = .05$), Tension ($p = .05$), Depression ($p = .03$) and Confusion ($p = .005$). Post-hoc planned comparisons revealed that participants reported significant improvement at follow-up relative to baseline on POMS scales of Overall Mood Disturbance ($p = .04$), Tension ($p = .05$), Depression ($p = .03$) and Confusion ($p = .005$). There were no significant differences observed between baseline and post-GOALS, nor between post-GOALS and follow-up.

**Discussion**

The objective of this study was to investigate the long-term impact of executive function training for Veterans with chronic brain injury and cognitive complaints on neuropsychological and complex functional performance assessment, self-report of daily and emotional functioning, and important life domains such as work and school.

Our results suggest that Veterans with chronic TBI continue to demonstrate significant gains relative to their baseline performance in multiple functional domains, including neuropsychological measures of complex attention/executive function, complex functional task performance, and emotion regulation; and report significant improvements in their daily functioning. These benefits were found at a follow-up evaluation at least 6 months and on average 13 months after training. Our results also show that participants maintain post-training gains, with the exception of one functional performance domain score, and continue to improve on a measure of community participation, from post-GOALS to follow-up. We suspect that participants have maintained cognitive improvements in the absence of active training due to continued use of trained strategies in their daily lives, which the majority (91%) of our sample reported. In particular, participants reported continued use of strategies to regulate attention (stop-relax-refocus, mindfulness) and to manage goals and daily tasks.

Additionally, GOALS training may result in a meaningful increase in perceived self-efficacy through experiential demonstration of success in personal and group goals during training. In addition to the specific targets of training, several participants reported deriving significant benefit via improved self-esteem and increased self-awareness. While GOALS training did not explicitly attempt to modify participants’ self-perceptions, it may be that the repeated experience of applying trained strategies in their lives and achieving positive outcomes increased participants’ self-confidence and awareness of personal challenges for which strategy use might be beneficial. Reduced self-efficacy is a documented consequence of TBI, and increased self-efficacy in individuals recovering from brain injury has been linked with increased motivation to work toward a goal (50,51). Cicerone et al. (52,53) suggested that perceived self-efficacy may be a moderator of outcomes following rehabilitation of traumatic brain injury, in that self-efficacy for the management of cognitive symptoms may mediate the relationship between the individual’s expectations and achievements and thereby contribute to overall subjective well-being. Others (54–57) have noted that these experiential and motivational factors are critical for successful rehabilitation after brain injury, emphasizing that cognitive training with an explicit focus on addressing objective cognitive deficits is often insufficient for yielding meaningful clinical improvements without simultaneously addressing the subjective experience of the individual.

A majority of participants reported resuming important life roles following training involving work, volunteering, school, and/or caregiving. This finding may be of particular importance given the challenges many Veterans face with reintegrating into meaningful roles in civilian life even without the added challenges of brain injury. While we lack evidence of direct effects of training on role resumption, these self-reported changes are still encouraging. For instance, many of our participants reported that they would not have considered taking on certain responsibilities if they had not participated in training and gained confidence in their ability to utilize trained strategies in daily life.

Important limitations of this study include small sample size and no comparison condition for the follow up evaluation. Additional limitations include variability in follow-up time, and high non-follow-up rate for in-person (neuropsychological, complex functional, and self-report of emotional and daily functioning) assessments. Replication of this research using a larger sample and a study design that also measures the long-term impact of comparison training is needed. Finally, more extensive evaluation, including neuroimaging, may be helpful in specifying injury-specific details and their association with outcomes, as well as and the potential neuroplastic effects of training.

In conclusion, our results suggest that meaningful, long-term improvement in cognitive skills as well as emotion regulation and daily functioning is possible for individuals with chronic TBI and cognitive complaints after executive function training. Training self-regulatory cognitive and emotional control strategies applied to actual situations in participant lives and personally relevant goals may provide meaningful and lasting improvements in cognitive, emotional, and daily functioning.
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References


