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Tonic and phasic alertness training: a novel treatment for executive control dysfunction following mild traumatic brain injury

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Many individuals with traumatic brain injury (TBI) suffer difficulty regulating fundamental aspects of attention (focus, sustained attention) and may also exhibit hypo- or hyper-states of alertness. Deficits in the state of attention may underlie or exacerbate higher order executive dysfunction. Recent studies indicate that computerized cognitive training targeting attentional control and alertness can ameliorate attention deficits evident in patients with TBI or acquired brain injury. The current study examined whether improvements in attentional state following training can also influence performance on higher-order executive function and mood in individuals with mild TBI (mTBI). The current study examined five patients with executive control deficits as a result of mTBI, with or without persistent anxiety. Three patients engaged in ~5 hours of an executive control training task targeting inhibitory control and sustained attention; two additional patients were re-tested following the same period of time. Performance on standard neuropsychological measures of attention, executive function, and mood were evaluated pre- and post-training. The results indicate that tonic and phasic alertness training may improve higher-order executive function and mood regulation in individuals with TBI.

Keywords: attention; traumatic brain injury; rehabilitation; executive function; sustained attention

A common and often persistent outcome of traumatic brain injury (TBI) is disruption in core aspects of attention and executive function, such as difficulty sustaining attention, maintaining relevant information in short-term memory, and disregarding distracting or irrelevant information. These deficits contribute to problems with goal management, even in cases of mild TBI (mTBI) (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Binder, Rohling, & Larrabee, 1997; Cicero & Azulay, 2002; Frenchman, Fox, & Maybery, 2005; Mathias, Beall, & Bigler, 2004; Vanderploeg, Curtiss, & Belanger, 2005) (see also Chan, 2005; Niogi et al., 2008; Pontifex, O’Connor, Broglio, & Hillman, 2009) and may also impede the attainment of educational and occupational goals (Doctor et al., 2005; Drake, Gray, Yoder, Pramuka, & Llewellyn, 2000; Machamer, Temkin, Fraser, Doctor, & Dikmen, 2005; Ownsworth & McKenna, 2004) or contribute to long-term disability (Hirtz et al., 2007; Rutland-Brown, Langlois, Thomas, & Xi, 2006).

An important mediator of cognitive function in patients with mTBI is the regulation of attentional state (Dockree et al., 2006; Tang & Posner, 2009). Attentional state has been conceptualized as the quality of alertness and influences performance in many cognitive domains and progress in conventional forms of rehabilitation (Fischer, Gauggel, & Trexler, 2004; Hyndman & Ashburn, 2003; Özdemir, Birtane, Tabatabaeei, Ekuiklu, & Kokino, 2001; Prigatano & Wong, 1999; Tatemichi et al., 1994). Patients with TBI often exhibit fluctuations in alertness, in some cases exhibiting hypo-alertness, as evidenced by greater variability in performance than controls on tasks that require sustained attention and inhibitory control (e.g., slower and more variable reaction time and poor accuracy) (Manly, Robertson, Galloway, & Hawkins, 1999; Whyte, Polansky, Fleming, Coslett, & Cavallucci, 1995). Conversely, patients with co-morbid TBI and post-traumatic stress disorder (PTSD) often exhibit hyper-alertness and/or cycle between hypo- or hyper-alertness (Amick et al., 2013) (also, see discussion of deficits related to TBI versus PTSD, Honzel, Justus, & Swick, 2013; Swick, Honzel, Larsen, Ashley, & Justus, 2012).

Due to the physical nature of TBI (e.g., torsion, axonal shearing), patients’ poor self-regulation of alertness may be attributable to disruption in long distance connections between brainstem neuromodulatory nuclei (e.g., noradrenergic nuclei in the locus coeruleus or cholinergic nuclei in the basal forebrain) and frontal and parietal areas known to influence their activity (Büki & Povlishock, 2006; Chaumet et al., 2008; Sturm & Willmes, 2001; Thiel, Zilles, & Fink, 2004). Two well-characterized, intrinsic states of the alertness system are tonic and phasic alertness (Aston-Jones & Cohen, 2005). Tonic alertness refers to the
ongoing state of intrinsic alertness that normally fluctuates on the order of minutes to hours and is intimately involved in sustaining attention as well as providing the cognitive tone necessary for high-level cognitive functions (Posner, 2008; Sturm et al., 1999). Stability of tonic alertness is critical, as a number of studies have shown that the capacity to sustain attention is necessary for effective executive function (Chan, 2002; Chan, Hoosain, Lee, Fan, & Fong, 2003; Cicerone et al., 1996; Felmingham, Baguley, & Green, 2004; Ponsford & Kinsella, 1992; Spikman & van der Naalt, 2010; Stuss, Stethem, Hugenholtz, et al., 1989; Stuss, Stethem, Picton, et al., 1989). In contrast, phasic alertness refers to the rapid modulation in alertness due to any briefly engaging event and is vital for operations, such as orienting, selective attention, and inhibitory control (DeHaan et al., 2007; McIntire et al., 2006; Posner, 2008; Robertson et al., 1997; Sturm et al., 1999; Van Vleet & Robertson, 2006). Short-lived (phasic) bursts in alertness are dampened when the tonic alertness of the individual is too high, too low or too variable (Aston-Jones & Cohen, 2005; Chaumet et al., 2008).

While there have been several compensatory and pharmacological approaches to improving alertness and sustained attention in TBI, it is unclear whether they effectively promote greater self-regulation (Fish et al., 2007; McAllister et al., 2011). For example, the use of alerting cues to improve prospective memory is dependent on baseline executive function, and otherwise shows poor generalization outside the training context (Fish, Manly, Emslie, Evans, & Wilson, 2008). Recently, computerized behavioral therapies designed to promote greater self-regulation of alertness have shown promise (DeGutis & Van Vleet, 2010; Robertson, Tegnér, Tham, Lo, & Nimmo-Smith, 1995; Sturm et al., 2004; Thimm, Fink, Küst, Karbe, & Sturm, 2006; Van Vleet & Degutis, 2012). For example, Van Vleet and DeGutis (2012) developed a treatment that concurrently challenges both tonic and phasic alertness (tonic and phasic alertness training, TAPAT) in which participants must remain alert and engaged (tonic alertness), responding quickly to all non-target objects or tones (90% of trials) while looking (or listening) for the random presentation of an infrequent target object or tone (10% of trials). Critically, participants are challenged to inhibit the prepotent motor response (phasic alertness) when the target is presented. In these studies (\( n = 40 \)), patients with hemispatial neglect following acquired brain injury improved in sensitive measures of spatial attention (List et al., 2008) and non-spatial, speeded selective attention (Husain, Shapiro, Martin, & Kennard, 1997; Van Vleet & Robertson, 2006) following 4.5 hours of TAPAT versus active or test–retest control. Moreover, improvements in the TAPAT group extended into the age-normative range (impaired performance at baseline) versus controls, and improvements were correlated with increasing efficiency in phasic alertness (Nieuwenhuis, Aston-Jones, & Cohen, 2005).

Given the importance of sustained attention on executive function, in the current study we examined the hypothesis that TAPAT could improve performance on higher-order, executive function in mTBI. To test this hypothesis we examined five individuals with chronic mTBI: three completed 4.5 hours of TAPAT (nine 36-minute sessions) on their home computer within 3 weeks; two additional participants were re-tested on the outcome measures following the same delay period.

**Method**

**Participants**

Five participants with executive control dysfunction as a result of chronic mTBI with or without anxiety gave informed consent before participation in compliance with the Institutional Review Board of the VA Northern California Health Care System in Martinez, California. These participants were selected based on the following criteria: no evidence of neglect or distortion in spatial attention (performance on conjunction search task, List et al., 2008); a high level of pre-morbid independent functioning as verified by interview; lack of pre-existing neurological condition; absence of intoxicant abuse as verified by interview; willingness to participate in a treatment procedure; and capacity to visit the laboratory for repeated cognitive testing. Disruptions in executive function are described below, as they apply to each individual.

**P001**

Right-handed, 39-year-old, Caucasian female and former lawyer (unemployed at time of enrollment) suffered a concussive injury due to a mortar blast event 3 years prior to participation in the current study. She suffered loss of consciousness (LOC) for ~90 seconds, exhibited no retrograde amnesia and ~4 minutes of post-traumatic amnesia (PTA). Since the event, she reported problems with short-term memory, decision-making, mood regulation, and periods of hyper-vigilance marked by poor concentration and distractibility. MRI acquired 6 months prior to the current study revealed no evidence of post-traumatic encephalomalacia, infarcts, or hemorrhages and no evidence of old shear injuries. She was diagnosed with PTSD 2 years prior to the current study and participated in both individual psychotherapy and anger management. At the time of enrollment she was prescribed citalopram, bupropion, and trazadone (antidepressants), as well as alprazolam (anxiolytic). She reported 6-hours sleep/night with medication and difficulty initiating and maintaining sleep off medication.

P001’s concerns related to her injury centered on problems with productivity (i.e., difficulty reconciling her cognitive problems), emotion regulation, and relationships
change in her cognitive

2011

3

His current level of functioning represents a significant decline from her pre-morbid state.

P002

Right-handed, 22-year-old, Caucasian male with 2 years of college (unemployed at enrollment) suffered a head injury 4 years prior to the current study due to rock climbing fall (20 ft). No LOC and accurate recall of details surrounding the event. A titanium plate over his frontal lobes (bilateral) was implanted, and MRI acquired 4 months prior to the current study revealed post-traumatic encephalomalacia in orbitofrontal cortices (bilateral). He reported migraines and persistent short-term memory problems since the event. No history of psychiatric symptoms or treatment and no active medications at the time of enrollment. Reported 6-7 hours of sleep per night, with infrequent interruptions due to migraine (once/quarter).

P002’s mood was stable and his chief concern was poor short-term memory, organization and goal management. His current level of functioning represents a significant decline from pre-morbid state.

P003

Right-handed, 34-year-old, Caucasian male with a bachelor’s degree in engineering (unemployed at enrollment) suffered a head injury 2 years prior to enrollment due to motor vehicle accident in which he was ejected through the windshield. He experienced brief LOC and retrograde amnesia (<1 minute) and ~3 minutes of PTA. MRI acquired 1 month prior to enrollment was unremarkable. Reported lethargy and poor concentration since the event, and difficulty following multi-step plans (e.g., meal preparation). No history of psychiatric symptoms or treatment and no medications at the time of enrollment. Reported ~6 hours of sleep per night without difficulty.

Primary concerns related to his injury involved difficulties with divided attention, planning, and concentration, as well as periods of disengagement (“feeling flat”). While not actively seeking employment at the time of enrollment, he was enthusiastic about coaching a men’s swim team. His current level of functioning represents a significant decline from pre-morbid level.

P004

Right-handed, 54-year-old, Caucasian male with 12 years of education (part-time janitor since 2003) suffered a head injury 12 years prior to enrollment following a bike accident (no LOC) in which he suffered skull fracture (left parietal) with residual Bell’s Palsy, left-facial nerve damage, and seizure disorder (on Phenytoin). MRI acquired 2-years post-event revealed post-traumatic encephalomalacia involving most of the lateral cortex of the right-temporal lobe with a lesser involvement of inferior aspect of the right-frontal lobe. Reported headaches and mild difficulties with short-term memory post-event. History of schizoaffective disorder, asymptomatic without psychotropic medication for several years, and remote history of alcohol dependence (sober 20 years). No sleep problems reported.

P005

Right-handed, 58-year-old, Caucasian female with 12-years education (part-time caterer, 3 years) sustained a subarachnoid hematoma in 2005 with unknown etiology. She was hospitalized for 2 weeks; right-sided craniotomy to reduce intracranial pressure. Neuroimaging was not available for review. Left-sided weakness for ~1-year post-event and no “obvious” change in her cognitive functioning was self-reported. However, she reported difficulties at work (e.g., no longer able to manage her own catering company, decreased stamina for a full work-day, and challenges with sustained attention at work). She did not complete post-discharge rehabilitation and was not on any psychotropic medications at enrollment.

Study design

To examine potential replication of improvements in simple attention shown in prior studies, as well as capture an expanded range of potential transfer effects to more complex, effortful executive functions (e.g., dual tasking, short-term memory, set-shifting, verbal generative fluency), all participants were assessed 1 day before and within 48 hours post either nine sessions of TAPT (P001-3) or a time and contact-matched delay period (P004, 5).

Apparatus

All computerized assessments, as well as the training task, were presented on a widescreen LCD panel (33 cm × 21 cm) of a laptop computer. Patients viewed stimuli from a distance of 60–70 cm and responded verbally or by pressing the spacebar with their right hand depending on the task.

Tonic and phasic alertness training

Three 12-minutes blocks (360 trials/block) of a continuous performance task in which subjects’ ability to inhibit the prepotent response was challenged (see Van Vleet, Hoangduc, DeGutis, & Robertson, 2011). Images of objects acquired from the Caltech-256 Object Category data-set (Griffin & Perona, 2007) were randomly and sequentially presented at the center of the screen (subtending 4°vertical × 6° horizontal visual angle), and separated in time with “jittered” inter-stimulus intervals of 600, 1800, or 3000 ms.
Participants were required to execute a speeded response via single button press to all foil images and withhold response to the infrequent target image (10% of trials). A novel target image was given each block (see Figure 1).

Test–retest controls

To control for non-specific effects related to engagement with experimenters or software (Braunholtz, Edwards, & Lilford, 2001; McCraney et al., 2007), two patients (P004, 5) were re-tested on the outcome measures after 3 weeks.

Neuropsychological assessment

Neuropsychological assessments included letter number sequencing from Wechsler Adult Intelligence Scale-III (Wechsler, 1997); auditory consonant trigrams (ACT) at 18s and 36s (Stuss et al., 1985); verbal fluency (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001); and Trails B (Tombaugh, 2004). Performance pre and post was compared to age-matched normative sample and converted to z scores.

Mood assessment

The Post-Traumatic Stress Disorder Checklist (PCL-C or PCL-M; military version for P001, and civilian version for P002 and P003) was administered pre and post. This well-validated self-report measure probes key areas of psychiatric and cognitive function often disrupted following TBI. Discrepancies between P001 and P002 reported feeling more alert compared to age-matched normative sample and converted to z scores.

Computerized assessment

The attentional blink (AB) task (see Raymond, Shapiro, & Arnell, 1992; Van Vleet & Robertson, 2006) consisted of a rapid serial visual presentation of 14 characters at central fixation (subtending 2° of visual angle vertically and 1° horizontally); two target numbers were embedded in 12 distracter letters, and all characters was presented for 120 ms (40 ms inter-stimulus interval). The first target (T1) was white and distracter letters, as well as the second target (T2) were black. T2 appeared at 200 or 1040 ms after T1.

Results

At initial assessment, participants’ performance fell within two standard deviations of an age-matched, normative sample (i.e., z-score transformations) on most measures, and within two standard deviations of one another. Notable exceptions include P002’s poor performance in verbal fluency (z-score = −2.3). Discrepancies between semantic and phonemic fluency could not explain this deficit, nor were significant discrepancies found in other participants’ performance on this task, as previously reported (Henry & Crawford, 2004). Further, the number of repetitions or clusters of words from the same semantic or phonetic subcategory was unremarkable. Thus, total score was considered the best indication of performance.

Despite mostly normative performance on neuropsychological measures, all patients reported difficulties with executive control behaviors in their daily life. P004 performed best at baseline on most measures, and was nearly 12 years post-injury. His performance at baseline was most consistent with P003 (TAPAT group), whereas the other control patient’s performance (P005) was better matched with patients P001 and P002 in the TAPAT group.

Training

Participants 001–003 completed TAPAT within 16 days. P003 required multiple (weekly) reminders to complete the training, whereas P001 and P002 trained without assistance (i.e., weekly calls were initiated but not required for compliance). Patients 004 and 005 received weekly calls reminding them of their follow-up appointment.

Both P001 and P002 reported feeling more alert throughout the day following the third and fourth training sessions, respectively. All TAPAT patients showed improved visual updating speed (AB), consistent with prior studies (DeGutis & Van Vleet, 2010; Van Vleet & Degutis, 2012). Also, as hypothesized, all three TAPAT patients exhibited some transfer of training benefits to untrained, effortful tasks of executive function (individual results detailed below). Controls did not show any changes pre- versus post-delay period.

P001

P001’s target accuracy in TAPAT improved (session 1 = 44% vs. session 9 = 64%) and mean response time increased across sessions (session 1 = 289 ms vs. session 9 = 332 ms); this suggests that responses became more deliberate/less automated. However, mean response time variability (session 1 = 111 vs. session 9 = 108) and non-target accuracy (session 1 = 97% vs. session 9 = 98%) remained unchanged (see Figure 2). Performance on standard neuropsychological measures indicate changes pre- vs. post-training in some measures of executive function, such as spontaneous verbal fluency (controlled oral word association task (COWAT): total z-score pre = −1 vs. post = 1) and set-shifting (trails B: z-score pre = 0.2 vs. post = 1.5). A trend toward improvement in the ordering of items in working memory and immediate recall (letter number sequencing (LNS): z-score pre = 1 vs. post = 1.7), and less proactive interference (ACT, 16 ms delay: z-score pre = −0.5 vs. post = 0.4) was also evident. Also, improvements in working memory updating (T2 accuracy across lags 2 and 6 pre = 16% vs. post = 55%) and a reduction in PTSD symptoms as self-reported in the PCL-M (total score pre = 34, PTSD criteria B&D met vs. total score post = 20, PTSD criteria C met) were shown. Responses to
specific items on the PCL-M reflect improvements in concentration and reduction in hyper-vigilance: item 15, “having difficulty concentrating?” pre = 4 quite a bit, post = 2 a little bit; and item 16, “super alert or watchful, on guard?” pre = 4 quite a bit, post = 1 not at all).

**P002**

P002’s target accuracy in TAPAT improved (session 1 = 48% vs. session 9 = 64%) and mean response time variability decreased across sessions (session 1 = 192 vs. session 9 = 145). However, mean response time (session 1 = 332 vs. session 9 = 328) and non-target accuracy (session 1 = 98% vs. session 9 = 98%) remained unchanged (see Figure 2). Performance improvements in some aspects of executive function, such as the ordering of items in working memory and immediate recall (LNS: z-score pre = 0.3 vs. post = 1.7), sequencing (set-shifting; trails B: z-score pre = 0.0 vs. post = 1.0), and divided attention (ACT 16s: z-score pre = −0.13 vs. post = 0.58; ACT 36s: z-score pre = 0.58 vs. post = 0.93), but not verbal generative fluency (COWAT: z-score pre = −2.3 vs. post = −2.7) were shown. AB performance also improved (accuracy: pre = 54% vs. post = 92%). Responses to specific items on the PCL-C reflect improvements in concentration (Having difficulty concentrating? pre = 4 quite a bit, post = 2 a little bit).

**P003**

P003’s mean response time in TAPAT (session 1 = 333 ms vs. session 9 = 299 ms) decreased and target accuracy improved over time (session 1 = 19% vs. session 9 = 27%). However, mean response time variability (session 1 = 70 ms vs. session 9 = 78), and non-target accuracy (session 1 = 99% vs. session 9 = 98%) remained unchanged (see Figure 2). Performance improvements in attention and executive function, such as the ordering of items in working memory and immediate recall (LNS: pre = −1.4 vs. post = −0.4), sequencing (set-shifting; trails B: pre = 0.2 vs. post = 0.6), divided attention (ACT 16s: z-score pre = −0.16 vs. post = 0.8; ACT 36 s: z-score pre = 1.35 vs. post = 1.68), and verbal generative fluency (COWAT: pre = −1.4 vs. post = −0.4) were shown. AB performance also improved (accuracy: pre = 62% vs. post = 89%). Scores on the PCL-C were not appreciably different from baseline self-report.

**P004 and P005**

Participants P004 and P005 completed the assessments then waited 3 weeks (i.e., same amount of time as P001–003 spent training) before being reassessed; contact with study team was matched. Performance on standard neuropsychological measures indicated no “clinically significant” change following the wait period on most measures (see Table 1 and Figure 2). However, P004 demonstrated faster performance on Trails B following the wait-period, which may be attributable to his poor initial performance (i.e., Trails B at initial assessment was the only measure that P004 scored below the mean, z-score = −0.05).

**Discussion**

The results of the current study show that 4.5 h of TAPAT was sufficient to improve performance in attention and
Table 1. Participants’ baseline characterization: performance (z-scores) on neuropsychological measures of attention and executive function (attentional blink, percent correct second target across lags 2 and 6) for participants P001, P002, and P003, and test-retest difference in z-scores for P004 and P005. Despite baseline performance in the normative range, all participants reported difficulty in activities of daily living; all participants met criteria for mild TBI, characterized by a loss of consciousness <30 minutes and a period of post-traumatic amnesia extending <24-hours post-insult.

<table>
<thead>
<tr>
<th>Pt</th>
<th>Age</th>
<th>Sex</th>
<th>Hnd</th>
<th>Lesion</th>
<th>Mn Post</th>
<th>ACT-18s</th>
<th>ACT-36s</th>
<th>Trails B</th>
<th>LNS</th>
<th>COWAT</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>P001</td>
<td>39</td>
<td>F</td>
<td>R</td>
<td>No visible lesion</td>
<td>36</td>
<td>-0.48</td>
<td>-0.3</td>
<td>0.2</td>
<td>1.0</td>
<td>-1.0</td>
<td>16</td>
</tr>
<tr>
<td>P002</td>
<td>22</td>
<td>M</td>
<td>R</td>
<td>Bilateral Frontal</td>
<td>47</td>
<td>-0.13</td>
<td>0.58</td>
<td>0.0</td>
<td>0.33</td>
<td>-2.3</td>
<td>54</td>
</tr>
<tr>
<td>P003</td>
<td>34</td>
<td>M</td>
<td>R</td>
<td>No visible lesion</td>
<td>25</td>
<td>0.16</td>
<td>1.35</td>
<td>0.2</td>
<td>0.33</td>
<td>1.4</td>
<td>62</td>
</tr>
<tr>
<td>P004</td>
<td>54</td>
<td>M</td>
<td>R</td>
<td>Right temporal</td>
<td>144</td>
<td>1.13</td>
<td>1.87</td>
<td>-0.5</td>
<td>0.33</td>
<td>2.0</td>
<td>66</td>
</tr>
<tr>
<td>P005</td>
<td>58</td>
<td>F</td>
<td>R</td>
<td>Right SAH</td>
<td>72</td>
<td>-0.5</td>
<td>-0.24</td>
<td>-0.63</td>
<td>-0.33</td>
<td>0.66</td>
<td>44</td>
</tr>
</tbody>
</table>

Note: ACT = auditory consonant trigrams; LNS = letter number sequencing task, WAIS III; COWAT = controlled oral word association task; AB = attentional blink task; Mn Post = months post-injury; Hnd = handedness; Pt = participant.

Figure 2. Performance on standardized neuropsychological measures of attention and executive function pre and post 5 hours of TAPAT training (difference in z-scores) for participants P001, P002 and P003, and test-retest difference in z-scores for P004 and P005. * represents a positive, clinically significant change in z-score (≥1.0).
executive function (e.g., inhibitory control, working memory updating, multitasking, verbal generative fluency) in three patients with mTBI and executive control difficulties. Beneficial effects of TAPAT shown in the current study are consistent with prior group-level studies examining the influence of training in patients with acquired brain injury and hemispatial neglect (DeGutis & Van Vleet, 2010; Van Vleet & Degutis, 2012) and in healthy individuals with age-related cognitive decline (Zomet et al., 2013). Participants in the current study demonstrated similar improvements in working memory updating (reduction in AB) and response control (improved target accuracy, P001 and P002). Notably, all three patients in the TAPAT condition also showed improvements in untrained, complex, and effortful measures of executive function, suggesting that improvements in alertness can also facilitate improvements in higher-order cognitive operations. This is consistent with a number of prior studies that have shown that the capacity to sustain attention is necessary for effective executive function (Chan, 2002; Chan et al., 2003; Cicerone, 1996; Felmingham et al., 2004; Ponsford & Kinsella, 1992; Spikman & van der Naalt, 2010; Stuss, Stethem, Hugenholtz, et al., 1989; Stuss, Stethem, Picton, et al., 1989). Prior TAPAT studies with brief initial training epochs as in the current study, but longer-term follow up have shown benefits that persist between 48 hours and 2 weeks in most cases and beyond 4 weeks in more severe cases (DeGutis & Van Vleet, 2010; Van Vleet & Degutis, 2012).

As participants in the current study were challenged to sustain a high level of engagement (three consecutive 12-minute blocks per session), it is not surprising that two of the three participants (001,2) reported feeling more alert throughout training and endorsed items on a self-report measure consistent with improvements in concentration throughout training and endorsed items on a self-report measure consistent with improvements in concentration following training (PCL-C). These participants also demonstrated significant improvement in target accuracy (i.e., inhibitory control) across sessions, reflecting improvement in the quality of sustained attention (Cheyne, Carriere, & Smiltek, 2006; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Hester & Garavan, 2005; Manly et al., 1999; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996; Smallwood, Beach, Schooler, & Handy, 2008; Smallwood et al., 2004).

In summary, TAPAT may derive its effectiveness from training a more optimal attentional state (see Tang & Posner, 2009) and may be a useful adjunct or alternative to more time intensive, clinician-delivered training methods that exploit similar mechanisms (see Chen et al., 2011; Novakovic-Agopian et al., 2011).

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**References**


