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Criterion validity of the brief test of adult cognition by telephone (BTACT) for mild traumatic brain injury

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ABSTRACT

Objectives: There is a growing demand for remote assessment options for measuring cognition after mild traumatic brain injury (mTBI). The current study evaluated the criterion validity of the Brief Test of Adult Cognition by Telephone (BTACT) in distinguishing between adults with mTBI and trauma controls (TC) who sustained injuries not involving the head or neck.

Methods: The BTACT was administered to the mTBI ($n = 46$) and TC ($n = 35$) groups at 1–2 weeks post-injury. Participants also completed the Rivermead Post Concussion Symptoms Questionnaire.

Results: The BTACT global composite score did not significantly differ between the groups ($t(79) = -1.04$, $p = 0.30$); the effect size was small ($d = 0.23$). In receiver operating characteristic curve analyses, the BTACT demonstrated poor accuracy in differentiating between the groups (AUC = 0.567, SE = 0.065, 95% CI [0.44, 0.69]). The BTACT's ability to discriminate between mTBI and TCs did not improve after excluding mTBI participants ($n = 15$) who denied ongoing cognitive symptoms (AUC = 0.567, SE = 0.072, 95% CI [0.43, 0.71]).

Conclusions: The BTACT may lack sensitivity to subacute cognitive impairment attributable to mTBI (i.e., not explained by bodily pain, post-traumatic stress, and other nonspecific effects of injury).

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Cognitive impairment is a common consequence acutely following mild traumatic brain injury (mTBI). As such, cognition is often a core clinical outcome in mTBI research (1,2). Cognitive domains most often affected by mTBI are working memory, verbal, and visual memory, processing speed, and attention/concentration (3,4). Cognition tends to be impaired within the first week following mTBI but improves over time, with most studies reporting non-significant differences between groups with mTBI versus traumatic orthopedic injury not involving the head on neuropsychological test performance by 3-month post-injury (5,6).

Traditional in-person neuropsychological assessment is the gold standard for measuring cognitive performance (7), but is not always feasible; for example, in-person assessment is unlikely to be possible in epidemiological studies recruiting


patients from rural areas or during an infectious disease pandemic (e.g., COVID-19). In recent years, cognitive assessments that can be administered remotely (e.g., over the telephone) have been developed. One such measure is the Brief Test of Adult Cognition by Telephone (BTACT (8)). The BTACT is a telephone-administered measure of cognition that assesses multiple domains of functioning (i.e., episodic memory, working memory, reasoning, verbal fluency, and executive function) in under 30 minutes, making it an especially pragmatic tool. The BTACT was originally developed to measure cognitive changes in normal aging (8). It has good construct validity and is sensitive to age-related changes in cognition across adulthood (9).

The BTACT is increasingly used in TBI research. Examples include the large-scale Transforming Research and Clinical

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Knowledge in TBI (10) and the Chronic Effects of Neurotrauma Consortium (11) studies. Emerging evidence supports the BTACT's validity in TBI samples. In participants recruited from inpatient rehabilitation settings, TBI severity has been associated with BTACT performance 1–2 years following injury (12). With regard to convergent validity, the BTACT subtest scores are related to performance on in-person neuropsychological assessments of the same cognitive domains at 1-month and 6-months post-injury (13). One year after moderate-to-severe TBI, the BTACT has been associated with return to work status (14). Most relevant to the present study, Nelson et al. (15) examined how well the BTACT discriminated between individuals with varying severity levels of TBI and those with traumatic orthopedic injuries. They found statistically significant, but modest differences between participants with mTBI (and clinical indication for neuroimaging) and orthopedic controls at 6 months post-injury (Cohen's $d = -0.25$ to -0.31). These effect sizes were at least as large for the BTACT as for traditional in-person neuropsychological tests (15). Considering that cognitive deficits tend to be much more prominent within the first days to weeks following mTBI (5,6), the criterion validity of the BTACT (i.e., how well the BTACT discriminates between those with mTBI and those without mTBI) should be stronger during this subacute period.

The aim of the current study was to evaluate the criterion validity of the BTACT in differentiating individuals with an mTBI compared to those with an orthopedic injury or soft tissue injury not involving the head or neck (referred to as the trauma control group, or TC hereafter) in the subacute recovery phase (i.e., during the first 1–2 weeks following injury). Demonstrating that the BTACT can detect cognitive impairment associated with mTBI is an important step in establishing its utility for mTBI research. Many factors other than brain injury can contribute to poor cognitive test performance, including bodily pain and post-traumatic stress. A TC comparison group was used to account for these nonspecific factors (16). We hypothesized that the mTBI group would obtain lower BTACT global composite scores than the TC group acutely post-injury.

Methods

Participants and procedures

The study was approved by the University of British Columbia Clinical Research Ethics Board and Vancouver Coastal Health Research Institute. In the current cross-sectional study, we used data from an ongoing multisite, longitudinal study, the Canadian biobank and database for patients with TBI (CanTBI) study. In CanTBI, children and adults who sustained a mild, moderate, or severe TBI were recruited from emergency departments, hospital wards, and intensive care units at seven Canadian hospitals. Participants were interviewed to obtain demographic information. Medical chart reviews were conducted to obtain injury details, which were verified by interview with the participant or collateral source when required. Participants were contacted by telephone 7–10 days after their emergency department visit, and at subsequent timepoints not analyzed in the present study, to complete follow-up

assessments via the telephone. In the current study, we only used data from the first follow-up (i.e., 7–10 days). Eligibility criteria for CanTBI included (1): age 0–90 years (2), arrival to hospital within 24 hours of injury (3), a diagnosis of TBI made by a physician (4), blood samples collected for study purposes (5), vision and hearing adequate for assessment, and (6) fluency in English. Participants were excluded if they (1): had a history of premorbid neurological disease (prior mTBI was not an exclusion criterion) (2), had low or no likelihood of follow-up (i.e., no phone, no fixed address, out of country) (3), were in police custody, or (4) were participating in an ongoing drug treatment trial. Patients sustaining a traumatic injury not involving the head or neck (TC) were recruited at one of the recruitment sites (Vancouver General Hospital; VGH) to serve as a comparison group. Patients with traumatic injury were deemed eligible using the same inclusion and exclusion criteria as the CanTBI study, but could not have sustained an injury involving the head or neck, or received a clinical diagnosis of mTBI.

For the current study, adults aged 17–90 who sustained an mTBI (i.e., Glasgow Coma Scale score 13–15 at arrival to the Emergency Department) or met criteria for the TC group and completed the BTACT at the first follow-up were included. The BTACT was piloted as part of the CanTBI assessment battery for participants recruited between January 16, 2017 and September 27, 2018. Because most adults (91.5%) enrolled in CanTBI during this time period came from a single site (VGH), before other sites began actively recruiting, and because this same site was the only one to recruit a TC group, we restricted the present study to patients recruited from VGH.

Measures

The brief test of adult cognition by telephone (BTACT)

The BTACT (8) is a telephone-based assessment of cognitive functioning. It includes six subtests, administered in a fixed order. The subtests are described below. To minimize practice effects from repeat testing in the parent CanTBI study, we incorporated alternate forms of the BTACT. One alternative form was previously created by Lachman et al (9). We created two additional alternate forms by reordering trials (Red/Green), reordering stimuli (Digits Backwards), and using stimuli from previously validated alternative forms of the legacy instruments that the BTACT subtests are based on (Word List, Category Fluency). For test security, the stimuli from the novel alternate forms are not provided here but are available upon request from the corresponding author. We randomly assigned (both mTBI and TC) participants to one of the four BTACT forms at each time-point in the larger, longitudinal study (original Form A (8), Lachman et al.'s Form B (9), and two novel alternate forms) and assessed form equivalency by comparing each novel alternate form to the original BTACT (results below). The BTACT was administered by trained research assistants.

Word Recall

The BTACT Word Recall subtest is a measure of episodic verbal memory that uses the format and stimuli from the Rey Auditory Verbal Learning Test (17), with only one learning trial. The participant is asked to recall a 15-item word list

immediately after administration (i.e., immediate recall) and then following a 15-min delay (i.e., delayed recall). The conventional score is the total number of words correctly recalled for both immediate and delayed recall (range 0–30).

Digits Backward

Digits backward was adapted from the WAIS-III Digit Span subtest (18). This subtest assesses working memory by asking participants to repeat a series of digits in reverse order. The test consists of a total of seven number series, with each series consisting of two trials of equal length. In each successive series, the length of the number span increases, up to a total of eight numbers. The task is terminated when participants are unable to successfully repeat a span backwards for both consecutive trials of a series. The total score represents the number of digits in the longest span the participant could successfully repeat (range 0, 2–8).

Category Fluency

Category fluency measures verbal fluency, which is a multifaceted cognitive domain that requires crystallized intelligence, expressive language skills, processing speed, and executive functioning. The participant is asked to generate the names of as many members of a given semantic category (e.g., kinds of fruit) as possible in 60 seconds. The total score is the number of unique words produced.

Red/Green Test

The red/green test is a measure of task switching used to assess reaction time. It consists of three trials. In the first trial, participants hear the stimulus words “red” and “green,” and respond with the words “stop” and “go,” respectively (“normal trial”). On the second trial participants must respond “go” when they hear “red” and “stop” when they hear “green” (“reverse response” trial). The third trial alternates between normal and reverse response (“mixed trial”). The conventional score for task-switching represents the number of correct responses on the mixed trial (range 0–32).

Number Series

This subtest assesses inductive reasoning as a measure of fluid intelligence. The participant hears a series of five numbers. They have 15 seconds to respond with the next number that continues the sequence or best fits the pattern. A total of five number series are presented. The conventional score represents how many of the five number series participants correctly completed (range 0–5).

Backward Counting

Backward Counting assesses processing speed. The participant is given 30 seconds to count backward from 100 as rapidly as they can. The score is the total number correctly reported in sequence.

Global Composite Score

In the current study, we used a global composite score that reflects overall performance on the BTACT that was developed by Gavett et al. using a multidimensional item-response theory approach (19). It may be more sensitive to the effects

of aging and recent history of neurological disease than the conventional scoring (19). This global composite score differentially weighs item- and subtest-level variables to achieve linear scaling properties and does not rely on the assumptions of classical test theory-based composite scores that simply sum item or subtest scores. The global composite score incorporates a combination of 18 variables from all components of the BTACT. These include subtest total scores from Category Fluency, Number Series, and Backward Counting, as in conventional scoring. Variables from the RAVLT include the total words recalled early (first five words), in the middle (middle five words), and late (last five words) in the list for both immediate and delayed recall. For Digits Backwards, the subtest total score, which represents the number of digits in the longest span accurately recalled (i.e., 0, 2–8), is recoded to 0–7. This recoded score represents the number of the series accurately recalled of the total eight number sequences, not the length of the span. Four scores from the mixed trial of the Red/Green Test are included in the global composite scoring. Two reflect the number of correct responses when participants had to switch conditions between items (the item required a response type that was different from the previous item) for normal (green = go, red = stop) and reverse (green = stop, red = go) items (i.e., Normal/Switch and Reverse/Switch). Two other scores reflect the number of correct responses for items that do not require a “switch” (the response was the same type as the previous item) for normal and reverse items (i.e., Normal/Other and Reverse/Other). This item response theory-based global composite score was used in the present study to assess the BTACT’s criterion validity.

Injury severity score

The Injury Severity Score (ISS) quantifies the severity of all bodily injuries. The ISS is based on the Abbreviated Injury Scale (20). The body is divided into six regions: head/neck, face, chest, abdomen, extremity, and external. If a participant has an injury in one of these regions the severity is scored: 1 (Minor; no treatment needed), 2 (Moderate; requires only outpatient treatment), 3 (Serious; requires non-ICU hospital admission), 4 (Severe; requires ICU observation and/or basic treatment), 5 (Critical; requires intubation, mechanical ventilation, or vasopressors for blood pressure support), or six (Maximal; not survivable). To calculate the ISS score, the most severe injury scores from the three most severely injured areas of the body are squared and then summed. The ISS score ranges from 0 to 75. In the present study, the ISS was used to check that the mTBI and TC groups had comparable overall injury severity, and to statistically control for group differences in overall injury severity if the mTBI and TC groups were not well-matched.

Rivermead post-concussion symptoms questionnaire (RPQ)

The RPQ (21) is a self-report measure of post-concussion symptoms. It was administered by telephone in the present study. The RPQ includes 16 items that reflect common physical (e.g., headaches, dizziness), cognitive (e.g., forgetfulness, poor concentration), and emotional (e.g., irritability) symptoms post-mTBI. Participants are asked to rate the severity of each

symptom in the past 24 hours compared to before the injury on a scale from 0 (“not experienced at all”) to 4 (“a severe problem”). The item severity ratings are tallied (excluding item ratings of 1, which mean “no worse than before” the injury) to obtain a total score. Factor analytic studies support the clustering of three cognitive items (i.e., taking longer to think, poor concentration, forgetfulness/poor memory (22–24)). We used the RPQ to quantify post-concussion symptom severity. The cognitive items of the RPQ were also used in a sensitivity analysis to identify participants that were still reporting subjective cognitive symptoms at the first follow-up assessment. The three cognition items were dichotomized into present/absent. An item was considered endorsed (present) if the participant rated it as a mild, moderate, or severe problem as compared to before their injury.

Statistical analysis

Demographic and injury characteristics were described with central tendency and frequency. Generalized linear modeling was used to check BTACT form equivalency, comparing performance across the four versions of the BTACT using the composite score while adjusting for potential confounding variables, i.e., demographic variables (age, sex, education, ethnicity) and injury type (mild TBI vs. traumatic injury without TBI). Effect sizes of mean differences between BTACT versions using Hedges’ g were calculated. Hedges’ g values < 0.3 standard deviations (conventionally interpreted as small to negligible) between groups were considered evidence for test version equivalency. T-tests and chi-square tests were conducted to determine if the mTBI and TC groups showed significant differences on relevant characteristics (e.g., age, sex, education, time from injury to assessment), as well as the BTACT global composite score and subtest scores. Effect sizes were calculated for the RPQ, BTACT individual subtests, and BTACT global composite score to quantify the magnitude of group differences.

The criterion validity of the BTACT, or the ability of the BTACT to discriminate between the mTBI and TC groups, was tested with a receiver operating characteristic (ROC) curve analysis. ROC curve analyses are used to determine the criterion validity of a test as measured against a gold-standard outcome (e.g., disease status). In other words, the analysis quantifies how accurately a continuous measure differentiates between individuals with and without a known condition of interest. In this study, the continuous measure was the BTACT and the condition of interest, or gold-standard outcome, was a diagnosis of mTBI. The area under the curve (AUC) reflects discriminability across the entire range of possible cut points on the continuous measure. An AUC of 0.5 would mean that the BTACT is equivalent to chance in discriminating between participants with mTBI vs the TC group, while an AUC of 1.0 would mean that the BTACT is able to discriminate between the groups with 100% accuracy, i.e., perfect sensitivity and specificity (25).

We repeated the independent samples t-test and ROC curve analysis including only participants from the mTBI sample who endorsed at least one ongoing cognitive symptom on the RPQ at first follow-up assessment. The purpose of this

sensitivity analysis was to determine whether the BTACT was better able to discriminate between the mTBI and TC groups after removing individuals whose self-reported cognitive symptoms had already resolved by the time of testing. All statistical analyses were conducted using SPSS software ver. 26.0 (26).

Results

The present study included 46 participants with mTBI and 35 in the TC group (see Figure 1 and Figure 2 for a flow diagram). See Table 1 and Table 2 for the demographic and clinical characteristics of the sample. In the combined sample, the effect of test version was non-significant, with comparable global composite scores in participants who completed the original ($M = 0.58$, $SD = 0.89$), Form B ($M = 0.76$, $SD = 0.63$, $B = 0.29$, 95% CI $(-0.15, 0.72)$, Hedges’ $g = 0.23$), or novel alternate forms of the BTACT ($M = 0.68$, $SD = 0.66$, $B = 0.30$, CI $(-0.22, 0.82)$, Hedges’ $g = 0.12$; $M = 0.47$, $SD = 0.67$, $B = -0.19$ CI $(-0.68, 0.31)$, Hedges’ $g = 0.13$). All of the analyses reported below are collapsed across test version.

The mTBI and TC groups did not differ significantly on any demographic variables. The TC group ($M = 12.31$ days, $SD = 5.95$; Median = 11) had significantly longer time between injury and assessment than the mTBI group ($M = 8.61$ days, $SD = 3.33$, Median = 8; $t = -3.56$, $p < 0.01$). However, time since injury and BTACT global composite scores were not significantly associated in the mTBI group ($r = -0.15$, $p = 0.32$) or the TC group ($r = 0.22$, $p = 0.21$). Individuals in the mTBI group reported more post-concussion symptoms ($M = 17.55$ vs $M = 6.64$, $t = -4.24$, $p < 0.01$, Cohen’s $d = 0.98$, mean difference [MD] = 10.91) and more severe cognitive symptoms (sum of taking longer to think, poor concentration, forgetfulness/poor memory items from the RPQ) compared to the TC group ($M = 3.76$ vs $M = 0.74$, $t = -4.46$, $p < 0.001$, Cohen’s $d = 1.05$, MD = 3.02).

Based on visual inspection of the histogram, the BTACT global composite scores were approximately normally distributed in both groups. There were no significant differences between mTBI and TC on BTACT subtests (see Table 2). The BTACT global composite scores of the mTBI ($M = 0.57$, $SD = 0.74$) and TC groups ($M = 0.74$, $SD = 0.71$) were not significantly different ($t = -1.04$, $p = 0.30$, $d = 0.23$, MD = 0.17). Given the group imbalance on time since injury, we adjusted for this covariate (with ANCOVA) and similarly found a null effect for group on the BTACT global composite score ($F = 0.60$, $p = 0.44$, $\eta^2 = 0.008$). Additionally, no significant differences were found between the mTBI and TC groups on any of the BTACT subtest scores (see Table 2).

In the ROC analysis comparing mTBI and TC participants, the AUC for the BTACT global composite score was 0.567 ($SE = 0.065$, 95% CI $[0.44, 0.69]$; see Figure 3). The enriched mTBI sample (excluding those who denied all cognitive symptoms on the RPQ) reported more severe cognitive symptoms ($N = 31$, $M = 5.59$, $SD = 3.24$) than the TC group ($N = 35$, $M = 0.74$, $SD = 1.62$; $t = 7.81$, $p < 0.001$, $d = 1.05$, MD = 4.85). However, the BTACT global composite scores for the enriched mTBI sample ($M = 0.58$, $SD = 0.75$) and TC groups ($M = 0.74$, $SD = 0.71$) were not significantly different ($t = 0.88$, $p = 0.38$,

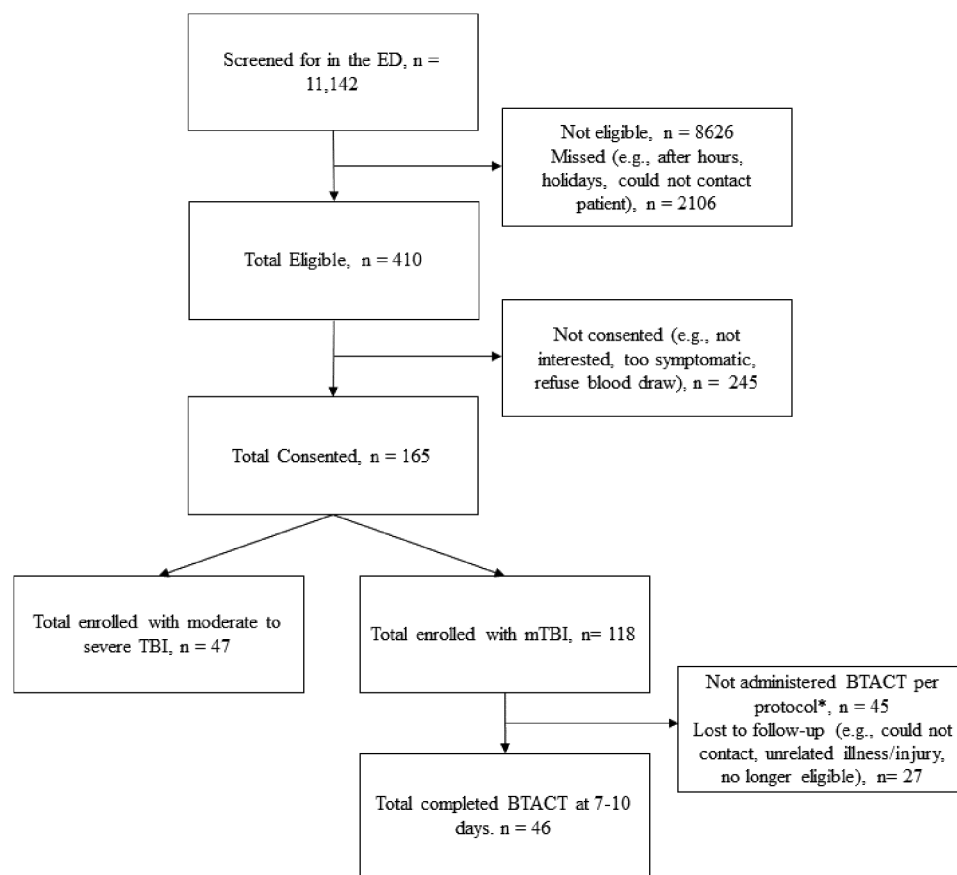


Figure 1. Participant Flow Diagram for mild traumatic brain injury group. * The BTACT was removed from the protocol of the larger study, therefore a number of participants were not offered the BTACT. They were excluded from the current study.

$d = 0.22$, $MD = 0.16$). The AUC for the BTACT global composite score for the enriched mTBI sample versus the TC group was 0.579 ($SE = 0.07$, 95% CI [0.45, 0.70]; see Figure 3).

Discussion

Building on prior research demonstrating that the BTACT was sensitive to indicators of TBI severity (12,15), we evaluated whether the BTACT could differentiate between patients with mTBI versus a TC group during the subacute phase of recovery (Median = 8–11 days after injury). The mTBI and TC groups did not significantly differ on the BTACT global composite score or any BTACT subtest. The observed effect size of the group mean difference was small, which our study was likely underpowered to detect. The BTACT global composite score showed poor discrimination (i.e., low AUC) in the ROC curve analysis. The AUC was no higher in our supplementary analysis with an enriched sample that included only patients with mTBI who continued to report cognitive symptoms on the RPQ at the time of assessment.

The lack of significant group differences could be because (1) the BTACT is not a sensitive enough instrument for mTBI (2), our sample of patients with mTBI-achieved near-complete resolution of neuropsychological impairment by the time of

assessment, and/or (3) factors not specific to the mTBI group (e.g., aging, bodily pain, traumatic stress, sleep disturbance) were more important determinants of neuropsychological performance, overshadowing any specific effect of brain injury. Based on the prior finding of Cohen's $d = -0.25$ to -0.31 between mTBI and TC groups on the BTACT at 6 months post-injury (15), we would have expected larger effect sizes at 1–2 weeks post-injury. Instead, we found similar magnitude differences between our mTBI and TC groups (Cohen's $d = -0.23$). Our finding is consistent with prior studies involving in-person neuropsychological testing during a similar subacute time frame ($d = 0.32$ – 0.39 (4);).

Differences between mTBI and comparison groups on measures of memory, processing speed, and attention/concentration have been consistently observed within the first few days following injury (27,28). To maximize statistical efficiency, we focused our analyses on the BTACT global composite score, which may have washed out a signal on selected subtests by aggregating them with subtests that are less sensitive to mTBI (2). The largest mTBI-related effects have been found on measures of processing speed (3). The BTACT global composite score does not incorporate any specific measure of processing speed, which may further explain its lack of sensitivity in this context. However, no BTACT subtest scores differed significantly between the mTBI and TC groups, even on tasks that

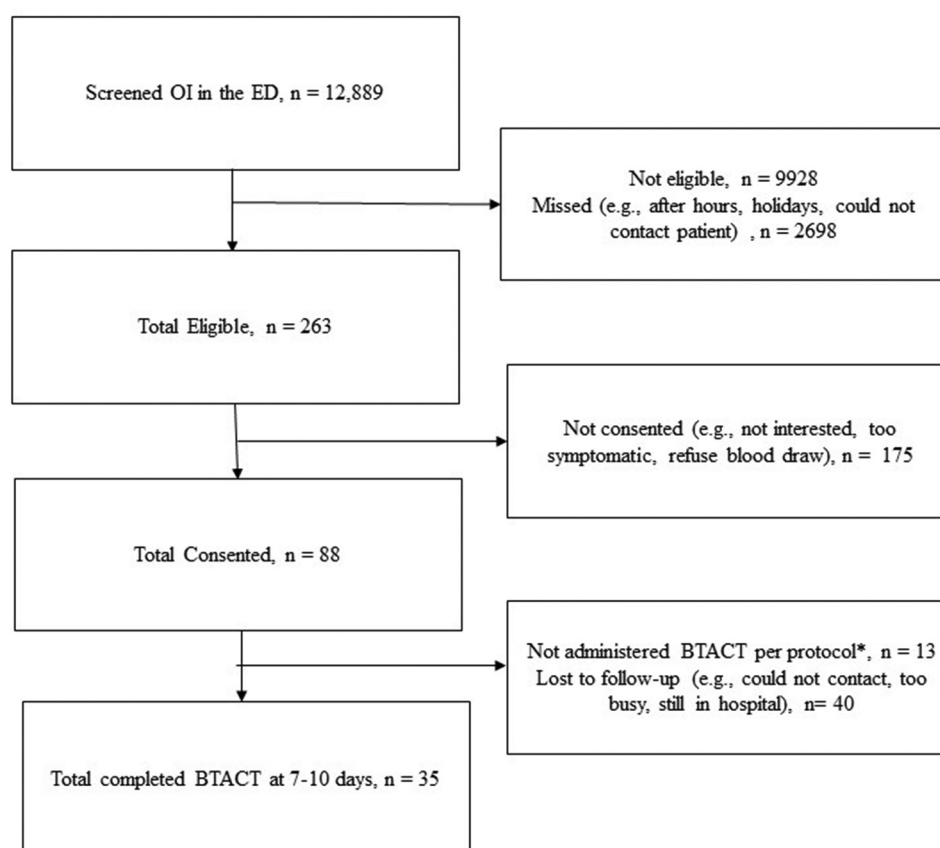


Figure 2. Participant flow diagram for trauma control group. * The BTACT was removed from the protocol of the larger study, therefore a number of participants were not offered the BTACT. They were excluded from the current study.

required processing speed, although the effect size was small to medium on one of those tasks (i.e., Category Fluency). Note that although the original BTACT uses voice recognition software to record response times on the Red/Green Test, this technology has been dropped in many subsequent studies and is not included in the global composite score due to feasibility concerns (19). A useful telephone-based cognitive assessment tool for mTBI may need to integrate this technology or some other computerized approach to measuring processing speed.

The present study has several limitations. In the parent study (CanTBI), the assessors who administered the BTACT were not blinded to group membership (TBI vs. TC). Lack of blinding could have biased the assessments, but likely in the direction away from the null hypothesis, which would not explain our findings. Due to the longitudinal design of the larger parent study, we used four different BTACT forms. We demonstrate form equivalency, nevertheless, the use of two novel BTACT forms is a limitation. Participants eligible for this study were recruited from one hospital and do not necessarily reflect the broader population of individuals with mTBI. Patients with initial GCS < 15 and with LOC were likely over-represented in our sample. However, this bias toward including relatively “severe” mTBIs should have enhanced group differences on the BTACT. Patients with mTBI were

identified by physician diagnosis. Because the gold standard approach to diagnosis is recognition of acute signs and symptoms attributable to head trauma, it is fallible. Until objective diagnostic tests are available, this will remain a shortcoming in the field. Despite careful screening to rule out mTBI in the TC group, it is also possible that some individuals in this group did in fact sustain a mTBI that went undetected. We did not measure nonspecific factors that may have impacted cognitive functioning, such as post-traumatic stress, sleep, and pain. We cannot rule out these factors as potential reasons for small group differences on the BTACT. However, the use of a trauma control group minimizes the likelihood of large group differences on these factors. Finally, we did not concurrently administer a comprehensive in-person neuropsychological assessment battery to confirm the presence/absence of cognitive impairment in our mTBI group. Future research should directly compare the sensitivity of the BTACT in this post-acute time frame to traditional neuropsychological testing.

Notably, our sample’s overall mean BTACT composite score ($M = 0.64$, $SD = 0.73$) were two-thirds of a standard deviation higher than the normative sample (19). Our sample was somewhat younger ($M = 44.5$) than that of the normative sample ($M = 55.8$), and this difference may help to account for the higher composite scores, as the BTACT is sensitive to age-

Table 1. Participant and injury characteristics.

Outcome	Full Sample (N = 81)	mTBI (n = 46)	TC (n = 35)	<i>t</i> or χ^2	<i>p</i> value
Age, M (SD), Range	44.5 (16.6), 17–83	44.8 (17.2), 19–88	44.1 (16.1), 17–83	0.18	0.86
Sex, n (% female)	44 (54.3)	22 (47.8)	22 (62.9)	1.81	0.18
Ethnicity, n (%)				0.00	1.00
White	67 (82.7)	38 (82.6)	29 (82.9)		
Asian	7 (8.6)	4 (8.7)	3 (8.6)		
Mixed race or Other	7 (8.6)	4 (8.7)	3 (8.6)		
Years Education, M (SD)	15.8 (3.1)	16.1 (3.3)	15.3 (2.9)	1.03	0.31
Missing, n (%)	2 (2.5)	2 (4.3)	0 (0)		
Current Student, n (% yes)	8 (9.9)	5 (10.9)	3 (8.6)	5.24	0.07
Missing, n (%)	6 (7.4)	6 (13)	0 (0)		
Psychiatric History, n (%)				1.81	0.41
Yes	27 (33.3)	14 (30.4)	13 (37.1)		
No	52 (64.2)	30 (65.2)	22 (62.9)		
Unknown	2 (2.5)	2 (4.3)	0 (0)		
Developmental Disorders, n (%)				2.85	0.24
Yes	5 (6.2)	4 (8.7)	1 (2.9)		
No	74 (91.4)	40 (87.0)	34 (97.1)		
Unknown	2 (2.5)	2 (4.3)	0 (0)		
Previous mTBI, n (%)				2.14	0.34
Yes	7 (8.6)	5 (10.9)	2 (5.7)		
No	18 (22.2)	7 (15.2)	11 (31.4)		
Unknown	4 (4.9)	2 (4.3)	2 (5.7)		
Missing	52 (64.2)	32 (69.6)	20 (57.1)		
Mechanism of Injury, n (%)					
Motor Vehicle	18 (22.2)	13 (28.3)	5 (14.3)	1.50	0.14
Hit by Object	8 (9.9)	6 (13)	2 (5.7)	1.20	0.27
Sports	23 (28.4)	10 (21.7)	13 (37.1)	2.32	0.13
Fall	28 (34.6)	13 (28.3)	15 (42.9)	1.87	0.17
Other	6 (7.4)	4 (8.7)	2 (5.7)	0.26	0.61
LOC, n (%)				26.06	<0.01
Yes	17 (21)	17 (37)	0 (0)		
Suspected	7 (8.6)	7 (15.2)	0 (0)		
No	55 (67.9)	21 (45.7)	34 (97.1)		
Unknown	2 (2.5)	1 (2.2)	1 (2.9)		
PTA, n (%)				22.95	<0.01
Yes	15 (18.5)	15 (32.6)	0 (0)		
Suspected	1 (1.2)	1 (2.2)	0 (0)		
No	56 (69.1)	22 (47.8)	34 (97.1)		
Unknown	9 (11.1)	8 (17.4)	1 (2.9)		
Arrival GCS in ED				−1.45	0.15
GCS 13	1 (1.2)	1 (2.2)	0 (0)		
GCS 14	9 (11.1)	9 (19.6)	0 (0)		
GCS 15	36 (44.4)	29 (63.0)	7 (20)		
Missing	35 (43.2)	7 (15.2)	28 (80)		
Time since injury (days), M (SD)	10.21 (4.97)	8.61 (3.33)	12.31 (5.95)	−3.56	<0.01
Injury Severity Score, M (SD)	6.3 (5.00)	6.2 (6.06)	6.4 (3.18)	−0.16	0.99

Table 2. Brief test and adult cognition by telephone and rivermead post-concussion symptoms questionnaire scores.

Outcome	Full Sample (N = 81)	mTBI (n = 46)	TC (n = 35)	<i>t</i> or χ^2	<i>p</i> value	Cohen's <i>d</i>	MD
BTACT Global Composite Score	0.64 (0.73)	0.57(0.74)	0.74(0.71)	−1.04	0.30	0.23	0.17
BTACT Subtest scores							
Word List Recall – Immediate	8.06(2.49)	7.98(2.55)	8.17(2.44)	0.34	0.73	0.08	0.19
Word List Recall – Delayed	5.95(2.86)	5.71(2.78)	6.23(2.96)	0.84	0.40	0.18	0.52
Digits Backward	5.38(1.38)	5.35(1.43)	5.43(1.34)	0.26	0.80	0.06	0.08
Category Fluency	23.79(6.13)	23.09(6.56)	24.71(5.46)	0.38	0.24	0.27	1.62
Red/Green Test	31.43(1.31)	31.37(1.24)	31.51(1.42)	−0.49	0.63	0.11	0.14
Number Series	3.48(1.25)	3.48(1.24)	3.49(1.27)	0.03	0.98	<0.01	<0.01
Backward Counting	39.85(10.05)	60.37(8.92)	59.29(11.12)	0.36	0.63	0.11	1.08
RPQ Total, M (SD)	12.93(12.87)	17.55(14.42)	6.64(6.46)	4.24	<0.01	0.98	10.91

BTACT = Brief Test of adult Cognition by Telephone; GCS = Glasgow Coma Scale; LOC = Loss of consciousness; PTA = Post-traumatic amnesia; MD = Mean difference (unstandardized effect size).

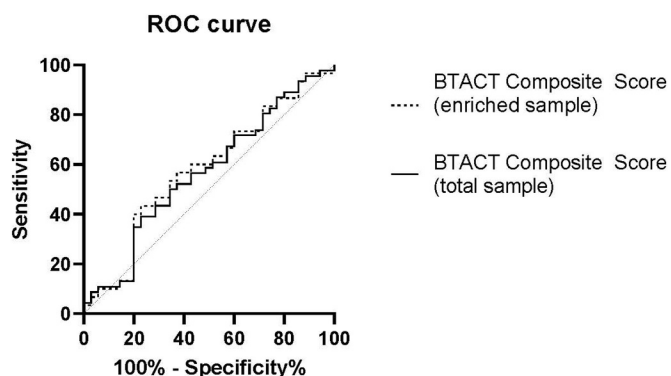


Figure 3. Receiver Operator characteristic curve of global composite scores of mTBI vs. TC in the total sample and enriched sample. BTACT total sample area under the curve (AUC) = 0.567. BTACT enriched area under the curve = 0.579. Reference line indicates $AUC=0.5$. BTACT= Brief Test of Adult Cognition by Telephone

related cognitive changes (8). Prior evidence indicates that Canadians tend to score higher than Americans on at least some cognitive tests (29). Regional differences may therefore also help explain the high normed-referenced scores observed in both our mTBI and TC groups.

In conclusion, the BTACT global composite score did not discriminate between individuals with an mTBI versus a traumatic injury not involving the head or neck at 1–2 weeks post-injury in our sample. Accumulating evidence supports the feasibility and validity of the BTACT among individuals with more severe forms of TBI (12,15), however, additional research is warranted to support its use in mTBI. Supplementing the BTACT with other measures of processing speed may be helpful.

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Declarations of Interest

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