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Regression-Based Norms for a Bi-factor Model for Scoring the Brief Test of Adult Cognition by Telephone (BTACT)

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Abstract

The current study developed regression-based normative adjustments for a bi-factor model of the The Brief Test of Adult Cognition by Telephone (BTACT). Archival data from the Midlife Development in the United States-II Cognitive Project were used to develop eight separate linear regression models that predicted bi-factor BTACT scores, accounting for age, education, gender, and occupation-alone and in various combinations. All regression models provided statistically significant fit to the data. A three-predictor regression model fit best and accounted for 32.8% of the variance in the global bi-factor BTACT score. The fit of the regression models was not improved by gender. Eight different regression models are presented to allow the user flexibility in applying demographic corrections to the bi-factor BTACT scores. Occupation corrections, while not widely used, may provide useful demographic adjustments for adult populations or for those individuals who have attained an occupational status not commensurate with expected educational attainment.

Keywords: Occupational status; Cognitive assessment; Statistical norms; Neuropsychology; Test norms; Statistical regression

Introduction

Screening measures are a relatively inexpensive way of obtaining a quick estimate of one's cognitive functioning in comparison to in-person neuropsychological assessments (Knopman et al., 2010). Telephone cognitive instruments can help mitigate some of the practical challenges encountered with in-person evaluations, thereby increasing the feasibility of performing initial and follow-up evaluations (Knopman et al., 2010). Telephone cognitive instruments have been used to monitor recovery post-discharge from in-patient rehabilitation units (Guerini et al., 2008; Jones, Miller, & Petrella, 2002). Health care reimbursement often dictates early discharge from hospitals (Gillen, Tennen, & McKee, 2007); in such instances, telephone instruments are a cost-effective and efficient way of monitoring recovery. In addition, telephone cognitive measures have been effective in the identification of cognitive impairment when used as screening measures and have utility in discerning the need for more comprehensive in-person neuropsychological testing (e.g., Hill et al., 2005; Lipton et al., 2003).

One commonly used telephone administered cognitive assessment is the Brief Test of Adult Cognition by Telephone (BTACT; Tun & Lachman, 2006). The BTACT consists of six-individual tests that provide a brief (15–20 min) measure of memory and various aspects of cognitive functioning, including verbal episodic memory, working memory span, verbal fluency, inductive reasoning, speed of processing, and task switching ability (Tun & Lachman, 2006). Many telephone cognitive assessments are designed to detect specific clinical deficits and are useful at distinguishing between clinical syndromes in a relatively older population (Duff, Beglinger, & Adams, 2009). In contrast, their ability to identify those at risk of developing specific cognitive disorders in younger cohorts and detecting subtle differences in cognitive functioning within the general population is decreased (Lopez & Kuller, 2010). The BTACT differs from other telephone cognitive instruments in that it is appropriate for use in both well-functioning and cognitively impaired individuals (Ryff & Lachman, 2007; Tun & Lachman, 2006). Typically, telephone cognitive

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instruments are normed only in adults with relatively small sample sizes and limited age ranges; in contrast, the BTACT data were collected from a large and diverse sample, including individuals ranging in age from 25 to 84 (Brim, Ryff, & Kessler, 2004). It also provides a global composite score that is representative of an individual's overall performance, increasing its utility as a quick screening measure for use by clinicians and researchers (Tun & Lachman, 2006).

The BTACT has demonstrated good test–retest and alternate forms reliability. It has been validated against an in-person cognitive battery that differs from the BTACT with respect to the mode of stimuli presentation and response, length of test, as well as specific subtests administered (Lachman, Agrigoroaei, Tun, & Weaver, 2013). Recent studies examining the psychometric properties of the BTACT yielded a good model fit with a two-factor solution consisting of episodic memory and executive functioning (Lachman, Agrigoroaei, Murphy, & Tun, 2010; Lachman et al., 2013). Psychosocial and behavioral variables have been found to affect performance on the episodic memory and executive functioning factors of the BTACT in middle age and older adults (Agrigoroaei & Lachman, 2011). Engaging in frequent cognitive activity has been found to offset the negative effects of low education on performance on the episodic memory factor of the BTACT (Lachman et al., 2010). Although a two factor model has produced a suitable fit to the BTACT data, other research has suggested that the individual test scores produced by the BTACT are also modeled well by a bi-factor model (Gavett, Crane, & Dams-O'Connor, 2013). One relative weakness of the two-factor model for the BTACT relative to the bi-factor model is that the standard approach to obtaining the two specific domain scores (i.e., episodic memory and executive functioning) for the BTACT is based in classical test theory (CTT), whereas the approach to obtaining a global cognitive ability estimate with the bi-factor model is based in more modern approaches to test scaling.

CTT can limit the ability of a test such as the BTACT to track changes over time and accurately measure individual differences in cognitive ability. It assumes dependency between item and person statistics, resulting in a composite score that neither reflects item difficulty nor individual ability (Crane et al., 2008; MacDonald & Paunonen, 2002). To facilitate interpretation of the BTACT, Gavett et al. (2013) used confirmatory factor analysis (CFA) with a bi-factor structure to validate a model for the BTACT to measure global cognitive ability. In contrast to CTT, factor scores estimated from this model have interval measurement properties and a linear relationship with respect to the ability being assessed (e.g., Crane et al., 2008; Mungas & Reed, 2000). Unlike the global composite and domain scores produced by conventional BTACT scoring, the bi-factor score includes performance on a task-switching (Red/Green test) test, thereby allowing for the inclusion of a broader range of abilities in the estimate of global cognition. Similar to the conventional BTACT scores, the bi-factor scores have the same mean of 0 and standard deviation of 1. (For an in-depth summary and depiction of the bi-factor model of the BTACT, see Gavett et al., 2013.)

The bi-factor model for the BTACT estimates global cognitive ability without adjusting for demographic variables. However, demographic variables alone and in combination can have a robust effect on test score variance in neuropsychological tests, suggesting that norms accounting for various demographic variables may wish to be considered when interpreting results (Marcopulos, McLain, & Giuliano, 1997). Age, education, gender, ethnicity, and occupation have been found to significantly affect performance on a variety of cognitive and neuropsychological measures in healthy adults (Reynolds, Chastain, Kaufman, & McLean, 1988). Normative data can be useful for accurate identification of the cognitive changes that occur due to normal aging as well as abnormal cognitive changes caused by neurodegenerative disease. Because normative corrections for various demographic variables increase the specificity of classification (O'Connell & Tuokko, 2010), it is best practice to include them when validating new models of existing cognitive measures (Busch, Chelune, & Suchy, 2006).

Though the direct effects of demographic variables such as age, education, race/ethnicity, and gender on neuropsychological test performance have been well studied, a limited number of studies have examined the relationship between occupational status and cognitive test performance. Existing evidence supports a connection between the two, such that occupational attainment may serve as either a proxy variable for another demographic variable (e.g., education level) or reflect the influence of other factors, such as socioeconomic status and diet (Low et al., 2004). Occupational attainment is an easily measured proxy variable for lifetime exposure to cognitive activity that may potentially lead to increased efficiency of brain networks and cognitive strategies that result in a higher probability of effective performance even in the presence of disease pathology (Barulli & Stern, 2013; Stern, 2003; 2012). Accounting for occupational experience when interpreting cognitive test scores may have value, especially because high levels of cognitive reserve can make it difficult to diagnose dementia during the early stages of the disease process when reserve may be masking the effects of pathology (Stern, 2002; 2012).

In deriving normative data for the bi-factor BTACT, we sought to include all relevant variables for group comparison while also allowing for variability in the types of demographic corrections that users of the test can choose to apply. The continuous norming approach used in the current study can overcome challenges that occur with unequal group numbers such as unstable group means and non-normal distributions within age bands (Busch et al., 2006). Continuous norming uses polynomial regression models to predict standard scores or percentile ranks (Busch et al., 2006). This method utilizes descriptive statistics from the entire normative group to create normalized distributions within each age band. Continuous norms provide better estimates for each age level, increases stability of group means, and corrects inequalities between age bands, while also taking into account practice effects, measurement error, and regression to the mean (Busch et al., 2006).

The purpose of this study was to develop regression-based norms for the bi-factor model of scoring the BTACT. Normative adjustments for age, gender, education, and occupation were explored. The data for the BTACT were obtained from participants in the National Survey of Midlife Development in the United States (MIDUS II): Cognitive Project (Ryff & Lachman, 2007). The MIDUS II data includes various occupation classes with relatively large sample sizes in each class. As a result, normative adjustments for occupation level or attainment were also explored. Based on prior literature, we expect that demographic variables are associated with score differences on the BTACT. Thus, we hypothesize that correcting for age, gender, education, and occupation will provide an important context for interpreting the BTACT factor scores for estimating global cognitive ability.

Method

Participants

We obtained archival data from the MIDUS-II Cognitive Project (Ryff & Lachman, 2007). Participants were volunteers selected by random digit dialing as part of a follow-up to a national survey of non-institutionalized adults and were administered the BTACT as part of the MIDUS II study between the years of 2004 and 2006 (Brim et al., 2004). A total of 4,963 participants were part of the original data set. We excluded 1,867 participants who endorsed medical conditions that may have affected performance on the measure (e.g., neurological disorders, head injury, and stroke). Global factor scores on the BTACT were generated for 3,096 participants, which included 1,378 men and 1,718 women. Participants' highest level of education and description of their "main job" were used to code their education and occupation, respectively. Occupation was classified according to the 1990 Alphabetic Index of Industries and Occupations and the Production Coder Manual published by the US Census Bureau.

Materials

The following subtests are components of the BTACT:

Rey Auditory Verbal Learning Test (RAVLT; Rey, 1964): The RAVLT is a 15-item word list that uses free recall to measure immediate and delayed episodic memory. The BTACT protocol involves one immediate and one delayed recall trial with a delay interval of 15 min. Participants are given 90 s to recall as many words as they can after the administration of each trial.

Digits Backward: The backward digit span test used in the BTACT paradigm is adapted from the WAIS-III (Wechsler, 1997). In this test, participants are asked to orally reproduce a series of digits read to them in the reverse order. Two trials of the same span length are administered with the span length increasing to a maximum of 8 digits.

Category Fluency (Animals): This task is used to assess executive functioning by asking participants to verbally generate as many animals as possible in 1 min.

Red/Green Test: This is a two-choice response task consisting of three trials that is used to measure reaction time in task-switching. In the normal trial, participants are asked to respond with either "stop" or "go," when they hear either the word "red" or the word "green," respectively. The reverse trial requires that the participants respond with "stop" when they hear the word "green" or with "go" when they hear either the word "red." The mixed trial alternates unexpectedly between the normal and the reverse phases. Only accuracy data were used for the analysis of performance on the Red/Green test due to the potential for confounding factors when measuring reaction time over the telephone.

Number Series: This task measures inductive reasoning and involves asking the participant to provide the sixth number to a series of five digits read to the participant within 15 s. A total of five series that represent three levels of difficulty are presented.

Backward Counting: This task assesses processing speed by asking participants to count backwards from 100 by ones, as fast as possible, for a total of 30 s.

For more information on administration and scoring the BTACT, refer to Lachman and Tun (2012). The BTACT materials are available at http://www.brandeis.edu/departments/psych/lachman/instruments/index.html.

Procedure and Data Analysis

We obtained archival BTACT data that were gathered through an individually administered telephone evaluation. Data were analyzed using *R* version 3.0.2 (R Core Team, 2013). Scores generated from each of the BTACT subtests were converted into a

Table 1. Participant characteristics

Variable	Group	n	M_{Age}	SD_{Age}	M_{BTACT}	SD_{BTACT}
Education						
	No school—junior high school (0–8 years)	36	63.89	12.08	−1.22	0.76
	Some high school (9–12 years, no diploma/no GED)	114	62.10	12.31	−0.85	0.83
	GED	38	54.71	12.32	−0.32	0.89
	Graduated from high school	790	58.27	12.2	−0.30	0.81
	1–2 years of college, no degree yet	524	56.09	12.02	−0.05	0.84
	3 or more years of college, no degree yet	117	53.14	12.73	0.20	0.83
	Graduated from 2-year college, vocational school, or Associate's degree	236	54.22	12.01	0.06	0.85
	Graduated from 4- or 5-year college, or Bachelor's degree	626	53.26	12.09	0.35	0.75
	Some graduate school	102	56.20	10.83	0.33	0.84
	Master's degree	352	54.61	11.67	0.45	0.75
	Ph.D., Ed.D., MD, DDS, LLB, LLD, JD, or other professional degree	157	55.03	10.55	0.46	0.79
Occupation						
	Operator, laborer, and military	236	57.63	12.03	−0.43	0.89
	Executive, administrative, and managerial	665	54.38	11.57	0.24	0.81
	Professional specialty	639	54.92	11.81	0.38	0.78
	Technician and related support	115	53.97	12.14	0.15	0.91
	Sales occupation	294	57.68	12.73	−0.13	0.8
	Administrative support, including clerical	494	56.62	12.39	0.02	0.84
	Service occupation	291	56.33	12.81	−0.31	0.93
	Farming, forestry, and fishing	58	60.21	13.28	−0.2	0.77
	Precision production, crafts, and repair	246	55.99	12.06	−0.27	0.84

Notes: n = sample size; M_{age} = mean age (years); SD_{age} = standard deviation of age (years). M_{BTACT} = average bifactor BTACT factor scores; SD_{BTACT} = standard deviation of bifactor BTACT factor score.

global composite score using the bi-factor model (for a more comprehensive discussion, see Gavett et al., 2013). Eight separate linear regression models accounting for age, gender, education, and occupation, alone and in various combinations were used to predict bi-factor BTACT scores. The residuals from these models were used to develop normative data for the bi-factor BTACT.

Results

The total sample used in the current analyses consisted of 3,096 participants, including 1,378 men and 1,718 women. The 1,867 excluded participants who endorsed medical conditions were significantly younger ($t = 3.28$, $df = 3{,}771.46$, $p < .05$), less educated ($t = 3.37$, $df = 3719.03$, $p < .05$), and scored significantly lower on the BTACT ($t = 7.26$, $df = 1{,}650.68$, $p < .05$) than individuals who did not endorse medical conditions capable of interfering with cognitive functioning. The age of the sample ranged from 32 to 84 years ($M = 55.90$, $SD = 12.20$) and was made up of 2,802 white participants (90.5%), 78 black and/or African-American participants (2.52%), 17 Native American participants (0.55%), 13 Asian participants (0.42%), 2 Native Hawaiian participants (0.06%), 104 participants of mixed racial origin (3.36%), 61 participants of other racial origins not described above (1.97%), and 19 participants who reported not knowing their race. Of the 3,096 participants, 80 (2.58%) reported a Hispanic ethnic background. Participants were grouped into 11 different education categories and 9 different major occupation groups, as shown in Table 1. Table 2 shows the frequencies of each education-occupation pairing observed in the sample.

Age, education, gender, and occupation served as the predictor variables for the bi-factor BTACT global composite score, the dependent measure of interest. Age and the bi-factor global cognition score were continuous variables whereas education, gender, and occupation were categorical variables. Dummy coding was applied to the categorical variables, such that high school education; male gender; and the "Operator, Laborer, and Military" occupation were the reference groups for their respective demographic categories. The regression-based algorithms to apply demographic corrections to the bi-factor BTACT scores are listed below. Values for each predictor in these models are listed in the Appendix. Using the regression-based equations converts bi-factor BTACT global composite scores into standardized z-scores. For the convenience of users, a web-based scoring program has been created to calculate the bi-factor BTACT global composite score along with the various combinations of demographic corrections listed below. The calculator can be accessed at https://begavett.shinyapps.io/BTACT.

Table 2. Cross-tabulated frequencies of education and occupation status in the current sample

Education	Occupation, n (%)									
	Labor	Exec	Prof	Tech	Sales	Admin	Service	FFF	Repair	Total
Junior	7 (0.23%)	5 (0.16%)	2 (0.06%)	1 (0.03%)	7 (0.23%)	6 (0.19%)	5 (0.16%)	1 (0.03%)	4 (0.13%)	38 (1.23%)
SomeHigh	9 (0.29%)	1 (0.03%)	1 (0.03%)	1 (0.03%)	7 (0.23%)	3 (0.10%)	6 (0.19%)	2 (0.06%)	3 (0.10%)	33 (1.07%)
GED	30 (0.97%)	14 (0.45%)	1 (0.03%)	2 (0.06%)	9 (0.29%)	8 (0.26%)	25 (0.81%)	1 (0.03%)	21 (0.68%)	111 (3.59%)
High	117 (3.78%)	106 (3.42%)	23 (0.74%)	17 (0.55%)	99 (3.20%)	179 (5.78%)	105 (3.39%)	15 (0.48%)	106 (3.42%)	767 (24.77%)
SomeCol1–2	33 (1.07%)	104 (3.36%)	39 (1.26%)	28 (0.90%)	52 (1.68%)	133 (4.30%)	66 (2.13%)	13 (0.42%)	49 (1.58%)	517 (16.70%)
SomeCol3+	4 (0.13%)	23 (0.74%)	25 (0.81%)	3 (0.10%)	17 (0.55%)	21 (0.68%)	16 (0.52%)	1 (0.03%)	6 (0.19%)	116 (3.75%)
Assoc	14 (0.45%)	44 (1.42%)	33 (1.07%)	21 (0.68%)	20 (0.65%)	38 (1.23%)	27 (0.87%)	8 (0.26%)	28 (0.90%)	233 (7.53%)
BA	11 (0.36%)	192 (6.20%)	202 (6.52%)	24 (0.78%)	56 (1.81%)	77 (2.49%)	19 (0.61%)	12 (0.39%)	21 (0.68%)	614 (19.83%)
SomeGrad	3 (0.10%)	42 (1.36%)	32 (1.03%)	4 (0.13%)	2 (0.06%)	8 (0.26%)	6 (0.19%)	0 (0.00%)	5 (0.16%)	102 (3.29%)
MA	6 (0.19%)	101 (3.26%)	184 (5.94%)	11 (0.36%)	14 (0.45%)	15 (0.48%)	14 (0.45%)	4 (0.13%)	1 (0.03%)	350 (11.30%)
PhD	2 (0.06%)	33 (1.07%)	96 (3.10%)	3 (0.10%)	10 (0.32%)	4 (0.13%)	2 (0.06%)	1 (0.03%)	2 (0.06%)	153 (4.94%)
Total	236 (7.62%)	665 (21.48%)	638 (20.61%)	115 (3.71%)	293 (9.46%)	492 (15.89%)	291 (9.4%)	58 (1.87%)	246 (7.95%)	3034 (98.00%)

Notes: Occupation: Labor = Operator, Laborer, and Military; Exec = Executive, Administrative, and Managerial; Prof = Professional Specialty; Tech = Technician and Related Support; Sales = Sales Occupation; Admin = Administrative Support, Including Clerical; Service = Service Occupation; FFF = Farming, Forestry, and Fishing; Repair = Precision Production, Crafts, and Repair. Education: Junior = No school—junior high school (0–8 years); SomeHigh = (9–12 years, no diploma/no GED); High = Graduated from high school; SomeCol1–2 = 1–2 years of college, no degree yet; SomeCol3+ = 3 or more years of college, no degree yet; Assoc = Graduated from 2-year college, vocational school, or Associate's Degree; BA = Graduated from 4- or 5-year college, or Bachelor's Degree; MA = Master's degree; PhD = Ph.D., Ed.D., MD, DDS, LLB, LLD, JD, or other professional degree.

Age corrections:

$$p(\text{BTACT}_{\text{bifactor}}) = 1.83 + -0.03 \times \text{Age}$$
$$Z_{\text{Age}} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.79} \tag{1}$$

Education corrections:

$$p(\text{BTACT}_{\text{bifactor}}) = -0.03 + \text{Appendix } A$$
$$Z_{\text{Edu}} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.80} \tag{2}$$

Gender corrections

$$p(\text{BTACT}_{\text{bifactor}}) = -0.02 + \text{Appendix } B$$
$$Z_{\text{Gender}} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.88} \tag{3}$$

Occupation corrections

$$p(\text{BTACT}_{\text{bifactor}}) = -0.43 + \text{Appendix } C$$
$$Z_{\text{Occ}} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.83} \tag{4}$$

Age and education corrections

$$p(\text{BTACT}_{\text{bifactor}}) = 1.32 + -0.43 \times \text{Appendix } D$$
$$Z_{A+E} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.73} \tag{5}$$

Age and occupation corrections

$$p(\text{BTACT}_{\text{bifactor}}) = 1.32 + -0.03 \times \text{Age} + \text{Appendix } E$$
$$Z_{A+O} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.75} \tag{6}$$

Education and occupation corrections

$$p(\text{BTACT}_{\text{bifactor}}) = -0.45 + \text{Appendix } F_{\text{Edu}} + \text{Appendix } F_{\text{Occ}}$$
$$Z_{E+O} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.79} \tag{7}$$

Age, education, and occupation corrections

$$p(\text{BTACT}_{\text{bifactor}}) = 1.18 + -0.03 \times \text{Age} + \text{Appendix } G_{\text{Edu}} + \text{Appendix } G_{\text{Occ}}$$
$$Z_{A+E+O} = \frac{\text{BTACT}_{\text{bifactor}} - p(\text{BTACT}_{\text{bifactor}})}{0.72} \tag{8}$$

Overall Results

The regression model with age, education, and occupation accounted for the greatest proportion of variance when compared with other combinations of predictor variables. The model explained 32.8% of the variance in the bi-factor BTACT global cognition score $F(19, 3014) = 77.49, p < .001$. Education and occupation were largely redundant, as the ΔR^2 values for occupation added to education were small (i.e., 0.01). When occupation was not considered, 31.5% of the variance in bi-factor BTACT scores

Table 3. Eight linear regression models predicting bi-factor BTACT scores

Model	Multiple R^2	Adjusted R^2	SEE
A	0.20	0.20	0.79
E	0.17	0.17	0.80
G	0.00	0.00	0.88
O	0.10	0.10	0.83
A + E	0.32	0.31	0.73
A + O	0.27	0.27	0.75
E + O	0.18	0.18	0.79
A + E + O	0.33	0.32	0.72

Notes: A = age, E = education, G = gender, O = occupation. *SEE* = standard error of estimate.

was accounted for by a combination of age and education. When education was not considered, a model including age and occupation explained 27.4% of the variance in bi-factor global cognition scores. Gender provided virtually no incremental improvement in model fit (see Table 3), which suggests that bi-factor BTACT scores are not influenced by gender; therefore, normative corrections for gender are likely to be unnecessary.

Discussion

The aim of the current study was to develop regression-based norms accounting for various combinations of age, education, gender, and occupation for scoring the bi-factor BTACT. All eight regression models were statistically significant, but the practical significance of gender corrections is negligible at best. The model accounting for age, education, and occupation explained 32.8% of the variance in the overall bi-factor BTACT score. Gender did not have a strong effect on BTACT scores. Thus, adjusting bi-factor BTACT scores to account for age, education, or occupation may facilitate test score interpretation.

The BTACT is a telephone-administered measure that offers a global composite score derived from measures of immediate and delayed episodic memory, working memory, semantic fluency, inductive reasoning, processing speed, and mental flexibility (Tun & Lachman, 2006). Telephone-administered cognitive instruments can minimize examinee burden and provide a less costly alternative to in-person neuropsychological testing. In fact, the auditory tests of the BTACT were recently validated against an in-person cognitive battery with results showing the two tests to be highly correlated, suggesting that the results are not affected by mode of administration and length of test (Lachman et al., 2013). However, many telephone batteries rely predominantly on memory assessment for detection of dementia, limiting their usefulness for characterizing impairment and making differential diagnoses (Crooks, Clark, Petitti, Chui, & Chiu, 2005). In contrast, the bi-factor BTACT includes measures of set shifting, response inhibition, and attention, in addition to memory, adding to the comprehensiveness of the global cognitive score (Gavett et al., 2013). The bi-factor BTACT scores possess linear measurement properties, which is an advantage of that approach over the traditional method for scaling the BTACT. The scores produced by the bi-factor BTACT model represent a person's cognitive status, scaled as a *z*-score ($M = 0$, $SD = 1$). In many situations (e.g., identifying unsafe drivers in an older adult sample), it may be preferable to interpret this score without consideration of the examinee's standing on a number of demographic variables known to affect cognition. In contrast, there may be circumstances where it may be desirable to contextualize an examinee's global cognitive ability estimate based on aspects of his or her demographics (e.g., identifying subtle processing speed changes in a highly educated individual). The present study adds to the utility of the bi-factor BTACT by providing normative adjustments, which may be desirable in clinical or research use.

Gender, age, education, and ethnicity have been shown to significantly impact performance on word list learning tests as well as frequently used neuropsychological test batteries such as the Wechsler Adult Intelligence Test- Revised (WAIS—III) and Wechsler Memory Scale (WMS—III; Lange, Chelune, Taylor, Woodward & Heaton, 2006; Norman, Evans, Miller, & Heaton, 2000). The WAIS-III, WAIS-IV, WMS-III, and WMS-IV index scores are differentially affected by various demographic variables, which impacts the sensitivity of diagnostic classification (Drozdick, Holdnack, & Hilsabeck, 2011; Lange et al., 2006; Lichtenberger & Kaufman, 2013; Weiss, Salkofske, Coalson, & Raiford, 2010). Indices of the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) are also affected by age and education, and regression-based normative corrections for the same are needed for appropriate adjustment of scores (Gontkovsky, Mold, & Beatty, 2002). Even though demographic variables affect neuropsychological test performance, it is important to note that demographic corrections should only be used when an individual's demographic characteristics are represented by the normative sample. With respect to diagnostic accuracy, it is important to bear in mind that demographically corrected scores tend to be more specific than raw scores whereas raw scores tend to maximize sensitivity when compared with demographically corrected scores (O'Connell & Tuokko, 2010).

A substantial body of research has examined the level of agreement between in-person cognitive testing and telephone instruments (Rapp et al., 2012; Wilson et al., 2010). Although mode of test administration has shown little effect on telephone cognitive test performance, education, premorbid IQ, and age all influence cognitive test scores (Crooks et al., 2005; Rapp et al., 2012;

Wilson et al., 2010). The present study provides normative adjustments for age, gender, education, and occupation for the bi-factor BTACT global composite score. The model comprising three demographic variables (age, education, and occupation) accounted for the largest amount of variance (33%) in BTACT scores. The amount of variance accounted for by this model is comparable with other regression-based normative systems (e.g., the Boston Naming Test; Fastenau, Denberg, & Mauer, 1998). Gender did not provide any meaningful improvement in the fit of the linear models to the data; therefore, it is not necessary for users of the bi-factor BTACT to apply demographic corrections for gender. Although education and occupation are closely linked, occupation corrected normative data may be advantageous in situations where educational attainment is unclear or when occupational and educational attainment are markedly different. In addition, because education and occupational attainment have been shown to contribute collectively and independently to greater cognitive reserve (Evans et al., 1993; Stern et al., 1994, 1995; Tucker & Stern, 2011), adjusting for occupational attainment in addition to education can allow for adjustments that comprehensively cover both areas of attained reserve: early life learning through formal education and later life learning through occupational gains (Stern, 2002). It remains to be seen whether correcting bi-factor BTACT scores for education and occupation together allows for better characterization of cognitive changes in older adults than separate education or occupation corrections.

Consistent with earlier studies, individuals with at least a few years of college education tended to obtain higher scores on the BTACT than those with only a year or less of college education (Agrigoroaei & Lachman, 2011). In addition, our results indicate that occupations involving service and skills trade are associated with lower cognitive ability than those involving professional and executive positions (Jorm et al., 1998). One hypothesized reason for this finding is that occupations such as service and skills trade primarily involve manual labor, with a decreased psychological and cognitive load. On the other hand, occupations involving professional and executive roles tend to have greater cognitive demands since they utilize greater literacy and intellectual skills (Jorm et al., 1998). Though occupational attainment may partially reflect one's age and education, studies have found that, independent of age and education, occupation is a significant predictor of performance on cognitive screening measures such as the MMSE (Mini Mental State Examination; Alvarado, Zunzunegui, Del Ser, & Beland, 2002; Frisoni, Rozzini, Bianchetti, & Trabucchi, 1993). In addition, education corrections can be imprecise or misleading, since variability exists in intelligence, quality of education, and literacy within a given level of education attainment (Fine, Delis, & Holdnack, 2011; Manly, Touradji, Tang, & Stern, 2003; Sisco et al., 2014). As such, in some situations, it may be advantageous for neuropsychologists to have a choice between applying education corrections, occupation corrections, or both. For example, one person in the current sample was a 45-year-old individual with an educational classification of Ph.D. or related degree whose employment classification was Operator, Laborer, and Military. This person's uncorrected global cognitive ability estimated by the bi-factor BTACT was $z = -0.009$. Correcting this score based on age and educational attainment resulted in a z-score of -0.889. On the other hand, correcting this score based on age and occupation resulted in a normed z-score of 0.028. These two demographic corrections produce discrepant values, which highlights the potential benefits of both education-based and occupation-based norms in some situations. Of course, it is up to the individual clinician using this test to make the appropriate clinical judgment about which demographic corrections are most suitable for a given examinee.

There are several limitations of the study. The demographic corrections provided in this study are limited in that the data lack racial heterogeneity, thereby precluding the use of race-based normative corrections for the bi-factor BTACT. Similarly, participants were assigned to traditional gender categories (i.e., women and men) based on self-report, which did not capture other gender identities, if present in the current sample. The study sample may have included participants with undiagnosed mild cognitive impairment or early dementia, since exclusion of individuals with medical or neurological conditions was based solely on self-report. Though occupation corrections are a novel feature of this study, this variable does not explain much variance beyond what is explained by education. Occupation corrections, therefore, may be most useful in situations where education and occupation levels are discrepant or when education is difficult to determine. Further, the clinical utility of occupation corrections may be limited by the potential for ambiguity associated with coding an individual's occupation. It is also important to note that the BTACT is limited in its ability to measure global cognition due to the lack of a visual component in testing. Telephone cognitive instruments may not always remain standardized, as there is no way to ensure that participants are in a distraction free area and working independently of external tools during the administration of the BTACT. The BTACT does not assess mood, which may impact performance.

Our normative adjustments provide a useful resource for assessment of global cognitive functioning of adults via telephone. The use of a large sample that includes participants of varying ages from diverse geographical locations and occupational backgrounds increases the generalizability of these normative adjustments. The ability to apply occupation-based norms makes the BTACT unique as a screening measure of global cognition. The demographic corrections provided in this study offer clinicians the opportunity to select the combination of normative adjustments they deem appropriate for each examinee. Though efforts are underway to validate the BTACT in different samples, one of the next steps should be to establish the clinical validity of the norms presented in this study for the bi-factor BTACT.

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Conflict of interest

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Appendix

Table A1. Regression Coefficients for Equation (2) (Education)

Education	*b*
No School—Junior High School (0–8 years)	−0.92
Some High School (9–12 years, no diploma/no GED)	−0.55
GED	−0.02
Graduated from high school	0
1–2 years of college, no degree yet	0.25
3 or more years of college, no degree yet	0.50
Graduated from 2-year college, vocational school, or Associate's Degree	0.36
Graduated from 4- or 5-year college, or Bachelor's Degree	0.65
Some graduate school	0.63
Master's degree	0.75
Ph.D., Ed.D., MD, DDS, LLB, LLD, JD, or other professional degree	0.76

Table A2. Regression Coefficients for Equation (3) (Gender)

Gender	*b*
Male	0
Female	0.10

Table A3. Regression Coefficients for Equation (4) (Occupation)

Occupation	*b*
Operator, laborer, and military	0
Service occupation	0.12
Precision production, crafts, and repair	0.16
Farming, forestry, and fishing	0.23
Sales occupation	0.31
Administrative support, including clerical	0.45
Technician and related support	0.58
Executive, administrative, and managerial	0.67
Professional specialty	0.82

Table A4. Regression Coefficients for Equation (5) (Age + Education)

Education	*b*
No school—junior high school (0–8 years)	−0.76
Some high school (9–12 years, no diploma/no GED)	−0.44
GED	−0.12
Graduated from high school	0
1–2 years of college, no degree yet	0.19
3 or more years of college, no degree yet	0.36
Graduated from 2-year college, vocational school, or Associate's Degree	0.24
Graduated from 4- or 5-year college, or Bachelor's degree	0.52
Some graduate school	0.57
Master's Degree	0.65
Ph.D., Ed.D., MD, DDS, LLB, LLD, JD, or other professional degree	0.67

Table A5. Regression Coefficients for Equation (6) (Age + Occupation)

Occupation	*b*
Operator, laborer, and military	0
Service occupation	0.08
Precision production, crafts, and repair	0.11
Sales occupation	0.31
Farming, forestry, and fishing	0.31
Administrative support, including clerical	0.42
Technician and related support	0.47
Executive, administrative, and managerial	0.58
Professional specialty	0.74

Table A6. Regression Coefficients for Equation (7) (Education + Occupation)

Education	*b*
No School—junior high school (0–8 years)	−0.83
Some high school (9–12 years, no diploma/no GED)	−0.48
GED	−0.02
Graduated from high school	0
1–2 years of college, no degree yet	0.20
3 or more years of college, no degree yet	0.43
Graduated from 2-year college, vocational school, or Associate's Degree	0.29
Graduated from 4- or 5-year college, or Bachelor's degree	0.53
Some graduate school	0.50
Master's degree	0.61
Ph.D., Ed.D., MD, DDS, LLB, LLD, JD, or other professional degree	0.62
Occupation	*b*
Operator, laborer, and military	0
Service occupation	0.02
Farming, forestry, and fishing	0.03
Precision production, crafts, and repair	0.08
Sales occupation	0.12
Administrative support, including clerical	0.27
Technician and related support	0.29
Executive, administrative, and managerial	0.32
Professional specialty	0.32

Table A7. Regression Coefficients for Equation (8) (Age + Education + Occupation)

Education	*b*
No school—junior high school (0–8 years)	−0.69
Some high school (9–12 years, no diploma/no GED)	−0.38
GED	−0.12
Graduated from high school	0
1–2 years of college, no degree yet	0.14
3 or more years of college, no degree yet	0.28
Graduated from 2-year college, vocational school, or Associate's degree	0.18
Graduated from 4- or 5-year college, or Bachelor's degree	0.39
Some graduate school	0.45
Master's degree	0.51
Ph.D., Ed.D., MD, DDS, LLB, LLD, JD, or other professional degree	0.53
Occupation	*b*
Operator, laborer, and military	0
Service occupation	0.01
Precision production, crafts, and repair	0.05
Farming, forestry, and fishing	0.15
Sales occupation	0.17
Technician and related support	0.26
Administrative support, including clerical	0.28
Executive, administrative, and managerial	0.30
Professional specialty	0.34

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