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Research Letter: Performance of the Brief Test of Adult Cognition by Telephone in a National Sample

Christina A. DiBlasio, MA; Adam Sima, PhD; Raj G. Kumar, PhD, MPH; Richard E. Kennedy, MD, PhD; Reuben Retnam, BS; Margie E. Lachman, PhD; Thomas A. Novack, PhD; Kristen Dams-O'Connor, PhD

Objective: To create a larger, more representative community comparison sample of the Brief Test of Adult Cognition by Telephone (BTACT) data to facilitate assessment of cognitive function in research studies. **Setting:** National US community-based survey. **Participants:** In total, 6747 healthy adults aged 23 to 84 years (53% female; mean age = 55 years, SD = 13). **Design:** Secondary data analysis of BTACT data collected from the National Survey of Midlife Development in the United States (MIDUS) II and MIDUS Refresher cohorts. **Main Measures:** The BTACT, a brief (15-20 minute) measure of global cognitive function validated for telephone administration. **Results:** This article provides BTACT community comparison sample data based on age, sex, and education from a national sample. Similar to other cognitive measures, BTACT scores decreased with age and increased with education. **Conclusions:** The BTACT community comparison sample will facilitate investigation of cognitive functioning in large-scale traumatic brain injury research studies and will support secondary analysis of existing BTACT data gathered through the MIDUS study. **Key words:** *adult*, *traumatic brain injury*, *cognition*, *data analysis*, *neuropsychology*, *rehabilitation*, *telephone*

ASSESSMENT of cognitive abilities is essential in research tracking recovery following moderate-severe traumatic brain injury (TBI). Traditional neuropsychological testing is time- and labor-intensive and typically must be administered in person, which may be impractical in some research situations. Telephone-based cognitive assessment has the advantages of lower cost and greater feasibility, although it cannot completely replace traditional testing.

The Brief Test of Adult Cognition by Telephone (BTACT)[1] is a short in-person or telephone-administered battery of tests that assesses key aspects of cognitive functioning (ie, episodic verbal memory, working memory, verbal fluency, inductive reasoning, and processing speed). It was designed for use in the National Survey of Midlife Development in the United States (MIDUS) by adapting established neuropsychological tests and supplementing with new subtests.[2,3] It has been shown to be a valid measure of cognition for healthy adults across a wide range of ages and ability levels.[1,4] In the context of TBI, the BTACT was shown to be a feasible and efficient measure of cognition for individuals who sustained moderate-severe TBI.[5] In addition, the BTACT composite scores of overall cognition, verbal memory, and executive function were found to be valid measures in a TBI inpatient population. ("Convergent Validity of In-Person Assessment of Inpatients with Traumatic Brain Injury Using the Brief Test of Adult Cognition by Telephone (BTACT)" submitted as companion paper to this issue of the *Journal of Head Trauma Rehabilitation*)

Author Affiliations: *Department of Psychology, College of Arts and Sciences (Ms DiBlasio), Division of Gerontology, Geriatrics, and Palliative Care, Department of Medicine (Dr Kennedy), and Department of Physical Medicine and Rehabilitation, School of Medicine (Dr Novack), University of Alabama at Birmingham, Birmingham, Alabama; Department of Biostatistics, School of Medicine, Virginia Commonwealth University, Richmond, Virginia (Dr Sima and Mr Retnam); Departments of Rehabilitation and Human Performance (Drs Kumar and Dams-O'Connor) and Neurology (Dr Dams-O'Connor), Icahn School of Medicine at Mount Sinai, New York City, New York; and Department of Psychology, Brandeis University, Waltham, Massachusetts (Dr Lachman).*

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Corresponding Author: *Christina A. DiBlasio, MA, Department of Psychology, College of Arts and Sciences, University of Alabama at Birmingham, 933 19th St S, Birmingham, AL 35294 (diblasio@uab.edu).*

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Given that the BTACT is brief (15-20 minutes) and validated for telephone administration in TBI, it has the potential to be a useful measure of cognitive function for longitudinal research focusing on recovery after TBI.[5] The BTACT has been adopted for use in several TBI studies, including the TBI Model Systems program, Translating Research and Clinical Knowledge in TBI, and the Chronic Effects of Neurotrauma Consortium. It is therefore important to ensure that an appropriate community comparison sample is available to establish the baseline distribution of the reference population and facilitate calculation of standardized scores. Ideally, to accurately interpret performance of a research sample, community reference data should be collected from a large sample whose demographic characteristics are representative of individuals whose performance will be measured with the test. It is further important to establish standardized scoring methods for the BTACT so that scores can be compared across cohorts and studies. Previous work has compared BTACT data from different MIDUS cohorts, but no study has combined the cohorts to create a sample with an expanded age range that includes younger adults younger than 32 years (MIDUS Refresher) and older adults older than 76 years (MIDUS II).[6] Accordingly, this article details methods used to pool BTACT data collected from the MIDUS II and MIDUS Refresher cohorts to create a larger, more representative community comparison sample for research use, while also illustrating standardized scoring practices for use across studies.

METHODS

Study sample

Available community data for the BTACT come from the MIDUS II study cohort and the MIDUS Refresher cohort. The MIDUS study is a national, longitudinal study of health and well-being during adulthood in a probability sample of Americans.[2] The first wave of the MIDUS study (MIDUS I)[7] collected survey data by telephone on 7108 participants in 1995-1996 based on random digit dialing of phone numbers, with oversampling of urban dwellers, older adults, and men.[8,9] Eligible participants were noninstitutionalized, English-speaking adults, aged 25 to 75 years, living in the continental United States. Further details about MIDUS study design are provided elsewhere (http://midus.wisc.edu).

The MIDUS II study,[10] conducted between 2004 and 2006, followed the original MIDUS I sample for an average of 9 years after initial contact, incorporating the BTACT for the first time. Of the original sample, 4512 participants, aged 32 to 84 years, completed the MIDUS II interview and the BTACT via telephone.[3,8] MIDUS II BTACT summary data were published by Lachman et al.[4]

The MIDUS Refresher study,[11] conducted between 2011 and 2016, supplemented the original MIDUS I sample to address attrition and permit cohort comparisons and resulted in a wider age range. The study recruited a national simple random sample of 3577 adults aged 23 to 76 years,[6,11] of which 2763 participants completed the BTACT.[12]

Measures

Brief Test of Adult Cognition by Telephone

The BTACT consists of 6 primary subtests, presented in the following text in order of administration. The Stop and Go Switch Task[1] was not included in this study. Subtest scores were compiled to create 3 composite scores: overall cognition, episodic verbal memory, and executive function.

Word List Immediate Recall measures immediate recall of a 15-word list derived from the Rey Auditory Verbal Learning Test (RAVLT).[13] The list is read aloud to participants, who then must immediately recall the words. The score represents the total number of words recalled correctly.

Digits Backward measures working memory with Digit Span Backward from the Wechsler Adult Intelligence Scale-III.[14] A string of 2 to 8 numbers is read aloud and participants are asked to repeat the numbers in reverse order. The score ranges from 0 to 8, based on the longest set of digits correctly repeated backwards.

Category Fluency involves naming as many animals as possible in 60 seconds as a measure of executive functioning. The score is the total number of different animals named.

Number Series measures inductive reasoning by asking for a sixth number in a series of 5 presented numbers. Participants must identify the pattern in the sequence and apply that pattern to successfully determine the sixth number. The score ranges from 0 to 5 depending on the total number of sequences completed correctly.

Backward Counting, a measure of processing speed, requires participants to quickly generate a nonautomatic sequence of familiar items by counting backwards from 100 aloud as quickly and accurately as possible for a span of 30 seconds. The score is the total number of digits correctly produced.[6]

Word List Delayed Recall, a measure of memory retrieval, involves recall of the RAVLT word list presented approximately 15 minutes earlier. The score ranges from 0 to 15, based on the total number of words recalled correctly.

Procedures

The MIDUS II and Refresher raw BTACT and demographic (age, sex, and education) data were obtained from the Inter-University Consortium for Political and Social Research data archive (retrieved May 14, 2019, from https://www.icpsr.umich.edu/icpsrweb/ICPSR/series/203). Age and years of education were categorized into variables with 5 (20-30s, 40s, 50s, 60s, and 70-80s) and 2 levels (less than bachelor's degree vs bachelor's degree or higher), respectively. Means and standard deviations (SDs) were computed for each BTACT subtest by age decade, sex, and education level. Subtests were used to create 3 composite scores: BTACT Composite, Episodic Verbal Memory Composite, and Executive Function Composite. First, *z*-scores were derived for each of the 6 subtests by age, sex, and education based on the stratified mean and SD of the respective MIDUS II or Refresher sample. Composites were created by averaging *z*-scores for the respective subtests and then restandardizing (mean = 0, SD = 1) the average to generate a composite *z*-score. The overall BTACT Composite was created from all 6 subtests; the Episodic Verbal Memory Composite from Word List Immediate Recall and Word List Delayed Recall; and the Executive Function Composite from Digits Backward, Category Fluency, Number Series, and Backward Counting. Means and SDs were computed for each BTACT composite by age decade, sex, and education level. Composites were only computed for cases with complete data on all required constituent subtests.

Data analysis

We derived weighted means and SDs from the MIDUS II and MIDUS Refresher cognitive data by age decade, sex, and education level (see Supplemental Digital Content 1, available at: http://links.lww.com/JHTR/A422, for full description of weighted statistics calculations). Weights were proportional to the sample size in each strata derived from the MIDUS II and Refresher data. There were

TABLE 1 *Sample characteristics*

	MIDUS II Sample ($N = 4200$)		MIDUS Refresher Sample ($N = 2547$)		Combined Sample ($N = 6747$)	
	M	**SD**	***M***	**SD**	***M***	**SD**
Age, y	56.0	12.3	52.58	14.2	54.7	13.2
	n	**%**	***n***	**%**	***n***	**%**
Sex						
Male	1925	45.8	1219	47.9	3144	46.6
Female	2275	54.2	1328	52.1	3603	53.4
Race						
White	3741	89.1	2054	80.6	5795	85.9
Black/African American	126	3.0	134	5.3	260	3.9
Asian	21	0.5	34	1.3	55	0.8
American Indian/Alaska Native	30	0.7	18	0.7	48	0.7
Native Hawaiian/Other Pacific Islander	4	0.1	4	0.2	8	0.1
Multiracial	164	3.9	138	5.4	302	4.5
Other	97	2.3	155	6.1	252	3.7
Unknown	13	0.3	7	0.3	20	0.3
Refused	4	0.1	3	0.1	7	0.1
Ethnicity						
Hispanic or Latino	124	2.8	107	4.2	231	3.4
Not Hispanic or Latino	4064	96.8	2435	95.6	6499	96.3
Unknown	10	0.2	2	0.1	12	0.2
Refused	2	0.0	3	0.1	5	0.1
Education						
Less than high school	243	5.8	108	4.2	351	5.2
High school/GED	1114	26.5	441	17.3	1555	23.0
Some college	921	21.9	458	18.0	1379	20.4
Associate's degree	325	7.7	290	11.4	615	9.1
Bachelor's degree or greater	1597	38.0	1250	49.1	2847	42.3

Abbreviation: MIDUS, Midlife Development in the United States.

TABLE 2 *Community comparison sample data for the BTACT subtests: Means and standard deviations based on age decade, sex, and education level*[a]

			Age decade													
			20-30s			40s			50s			60s			70-80s		
Measure	**Sex**	**Education**	***M***	**SD**	***N***	***M***	**SD**	***N***	***M***	**SD**	***N***	***M***	**SD**	***N***	***M***	**SD**	***N***
Word List Immediate Recall	Male	Less than BA	7.00	1.91	201	6.46	2.01	372	6.05	2.01	413	5.64	1.97	387	4.57	1.89	284
		BA or higher	7.68	2.01	233	7.47	1.92	342	7.09	1.97	360	6.39	1.87	335	5.60	2.21	205
	Female	Less than BA	7.59	2.36	259	7.43	2.16	452	7.26	2.20	563	6.97	2.25	519	5.61	2.15	433
		BA or higher	8.37	2.24	247	8.13	2.07	371	8.08	2.14	342	7.78	2.30	280	6.63	2.62	125
Word List Delayed Recall	Male	Less than BA	4.63	2.26	195	4.13	2.19	360	3.53	2.12	388	3.21	2.30	367	2.27	2.07	263
		BA or higher	5.46	2.27	218	5.07	2.35	331	4.48	2.24	355	3.75	2.18	327	3.17	2.46	195
	Female	Less than BA	5.70	2.72	245	5.47	2.50	427	4.97	2.61	539	4.59	2.61	497	3.11	2.45	402
		BA or higher	6.44	2.66	235	5.99	2.24	358	5.72	2.54	327	5.29	2.67	267	4.42	2.69	115
Digits Backward	Male	Less than BA	5.15	1.54	203	4.92	1.47	372	4.56	1.50	411	4.66	1.35	388	4.25	1.34	287
		BA or higher	5.88	1.45	233	5.53	1.41	342	5.28	1.49	362	5.21	1.43	332	4.79	1.60	205
	Female	Less than BA	5.09	1.53	256	5.06	1.48	450	4.94	1.50	563	4.92	1.43	519	4.51	1.66	433
		BA or higher	5.69	1.32	247	5.35	1.40	371	5.35	1.39	342	5.38	1.56	280	5.05	1.50	126
Category Fluency	Male	Less than BA	20.11	6.56	202	19.23	5.65	372	18.36	5.67	411	17.62	5.79	388	15.41	5.04	287
		BA or higher	24.71	6.18	232	22.90	5.88	342	21.90	5.84	363	20.63	6.13	334	17.22	5.79	205
	Female	Less than BA	19.84	5.80	258	18.89	5.76	450	18.10	5.65	563	16.64	5.40	519	14.61	5.27	434
		BA or higher	23.19	5.95	246	22.81	5.97	369	21.69	6.06	341	20.51	5.69	278	18.58	5.77	125
Number Series	Male	Less than BA	2.76	1.52	201	2.25	1.51	370	2.05	1.45	408	1.84	1.35	382	1.42	1.20	281
		BA or higher	3.66	1.19	230	3.38	1.35	342	3.37	1.30	362	2.99	1.40	334	2.46	1.49	204
	Female	Less than BA	2.17	1.43	256	2.06	1.48	446	1.85	1.42	553	1.60	1.31	510	1.24	1.18	419
		BA or higher	3.16	1.37	246	3.13	1.37	370	2.91	1.35	338	2.67	1.44	275	2.21	1.39	122
Backward Counting	Male	Less than BA	43.90	12.32	200	40.89	11.43	369	37.09	10.83	408	34.57	9.62	386	29.76	8.62	285
		BA or higher	49.83	11.41	229	46.46	11.17	340	44.48	11.23	360	39.06	9.59	334	34.47	10.06	204
	Female	Less than BA	40.86	11.45	257	37.89	11.05	446	35.10	10.00	560	31.58	8.39	516	27.57	8.55	431
		BA or higher	46.03	10.93	245	43.64	9.57	369	40.00	9.34	338	36.34	9.51	277	31.38	8.27	125

Abbreviations: BA, bachelor's degree; BTACT, Brief Test of Adult Cognition by Telephone; MIDUS, Midlife Development in the United States; *N*, combined (MIDUS II and Refresher) sample size for the corresponding level.

[a]The community comparison sample was derived by combining the MIDUS II and MIDUS Refresher cohorts, although ages 20-30 years are primarily from the MIDUS Refresher cohort and 70-80 years are primarily from the MIDUS II cohort.

TABLE 3 *Community comparison sample data for the BTACT composites: Means and standard deviations based on age decade, sex, and education level*

			Age decade													
			20-30s			40s			50s			60s			70-80s		
Measure	**Sex**	**Education**	***M***	**SD**	***N***	***M***	**SD**	***N***	***M***	**SD**	***N***	***M***	**SD**	***N***	***M***	**SD**	***N***
Episodic	Male	Less than BA	0.01	0.93	195	0.02	0.92	360	0.02	0.91	388	0.01	0.93	367	0.02	0.93	263
Verbal		BA or higher	0.02	0.94	218	0.004	0.93	331	−0.001	0.92	355	0.01	0.92	327	0.02	0.95	195
Memory	Female	Less than BA	0.01	0.95	245	0.002	0.94	427	−0.001	0.93	539	0.01	0.94	497	0.03	0.92	402
Composite[a]		BA or higher	0.004	0.96	234	0.01	0.92	358	0.01	0.93	327	0.01	0.92	267	−0.004	0.94	115
Executive	Male	Less than BA	0.003	0.67	200	0.004	0.72	369	0.01	0.69	406	0.02	0.70	381	0.004	0.66	281
Function		BA or higher	0.001	0.65	229	0.003	0.66	340	0.01	0.66	359	0.00	0.69	332	0.005	0.63	203
Composite[b]	Female	Less than BA	−0.002	0.65	251	0.01	0.69	445	0.01	0.66	552	0.001	0.67	507	0.02	0.66	417
		BA or higher	0.01	0.66	244	−0.001	0.67	369	0.002	0.65	338	0.02	0.63	275	0.02	0.60	122
BTACT	Male	Less than BA	0.01	0.66	194	0.01	0.67	359	0.03	0.64	384	0.02	0.65	363	0.02	0.62	260
Composite[c]		BA or higher	0.01	0.60	218	0.002	0.60	330	−0.003	0.61	353	0.001	0.61	326	0.02	0.61	193
	Female	Less than BA	0.01	0.60	238	0.02	0.63	425	0.01	0.62	533	0.01	0.63	489	0.04	0.64	391
		BA or higher	0.01	0.63	234	0.002	0.60	357	0.01	0.60	327	0.03	0.58	265	0.03	0.54	112

Abbreviations: BA, bachelor's degree; BTACT, Brief Test of Adult Cognition by Telephone.

[a]The Episodic Verbal Memory Composite is the average of the *z*-scores for Word List Immediate Recall and Word List Delayed Recall, standardized to a z-score ($M = 0$, SD = 1).

[b]The Executive Function Composite is the average of the *z*-scores scores for Digits Backward, Category Fluency, Number Series, and Backward Counting, then standardized to a *z*-score (does not include the Stop and Go Switch Task).

[c]The BTACT Composite is the average of the *z*-scores for all 6 subtests, standardized to a *z*-score. Composites were calculated only for cases with scores on all constituent subtests.

few individuals younger than 30 years and older than 79 years in the MIDUS II project and the MIDUS Refresher project. To adjust for the small sample sizes in these age strata, all participant information for those younger than 30 years or older than 79 years were combined with those aged between 30-39 and 70-79 years, respectively.

Differences in BTACT performance by age decade were tested using one-way analysis of variance and the Jonckheere-Terpstra test to determine trends of lower median scores with older age decades. Differences in BTACT performance by education level were tested using the independent-samples *t* test.

RESULTS

This study included 4200 participants from the MIDUS II study after excluding 312 individuals with missing education data. As documented by Lachman et al,[4] the sample predominantly comprised non-Hispanic white females who were well-educated and aged 28 to 84 years (see Table 1). From the MIDUS Refresher study, we included 2547 after excluding 216 individuals with missing education data. The majority of this sample comprised non-Hispanic white individuals aged 23 to 76 years with a bachelor's degree or higher (see Table 1). Overall, the final community comparison sample included 6747 English-speaking adults between the ages of 23 and 84 years (see Table 1).

We present the means and SDs for the MIDUS II and MIDUS Refresher combined sample based on age decade, sex, and education level for each of the BTACT subtests (see Table 2) and composites (see Table 3). Higher scores indicate better performance. The scores decreased with age and increased with greater education (see Supplemental Digital Content 2, available at: http://links.lww.com/JHTR/A423). An example of standardized scoring procedures is provided (see Supplemental Digital Content 3, available at: http://links.lww.com/JHTR/A424), and an online application for scoring and standardizing raw BTACT data may be accessed at https://hub.tbindsc.org/tbimsdatadictionary/Home.

DISCUSSION

This article provides BTACT community comparison sample data based on age, sex, and education from a national sample of 6747 healthy adults to facilitate assessment of cognitive function in research studies. Scores decreased with age and increased with education, which is consistent with published neuropsychological norms and supports the face validity of the MIDUS community comparison sample. Reference BTACT data were standardized by age, sex, and education to allow for performance-based comparisons between a TBI sample and the MIDUS community comparison sample, adjusting for demographics. Thus, standardized BTACT scores can provide a benchmark of how the cognitive status of an individual who sustained a TBI compares with a sample of cognitively intact individuals of the same age, sex, and education. Composite scores were restandardized to facilitate interpretation on a common metric.

The BTACT is a well-validated telephone-administered cognitive test battery, making it valuable for large-scale longitudinal research initiatives examining the trajectory of cognition over time following TBI.[5] Telephone administration may be preferred in large epidemiological studies whereby in-person visits may introduce selection bias. As demonstrated here, BTACT reference data are available from a large sample drawn from across the United States with a wide age range, which supports the stability of score estimates and their representativeness of the general population. Existing MIDUS and BTACT data may be requested for use at https://www.icpsr.umich.edu/web/NACDA/studies/25281 and https://www.icpsr.umich.edu/web/NACDA/studies/37081.

Some limitations remain; for example, there are fewer subjects in the lowest and highest age decades of the community comparison sample, so scores may be less accurate for adults in these age groups. It should be noted that the community comparison sample is predominantly White, and caution is warranted when comparing the community comparison sample with diverse populations. Finally, the BTACT is a brief cognitive assessment tool and has not been validated for clinical use or diagnosis.

Overall, our characterization of the combined BTACT community comparison sample will facilitate investigation of cognitive functioning in large-scale TBI research studies and will support secondary analysis of existing BTACT data gathered through the MIDUS study.

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