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Research Article

Interpreting Mini-Mental State Examination Performance in Highly Proficient Bilingual Spanish–English and Asian Indian–English Speakers: Demographic Adjustments, Item Analyses, and Supplemental Measures

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Purpose: Performance on the Mini-Mental State Examination (MMSE), among the most widely used global screens of adult cognitive status, is affected by demographic variables including age, education, and ethnicity. This study extends prior research by examining the specific effects of bilingualism on MMSE performance.
Method: Sixty independent community-dwelling monolingual and bilingual adults were recruited from eastern and western regions of the United States in this cross-sectional group study. Independent sample *t* tests were used to compare 2 bilingual groups (Spanish–English and Asian Indian–English) with matched monolingual speakers on the MMSE, demographically adjusted MMSE scores, MMSE item scores, and a nonverbal cognitive measure. Regression analyses were also performed to determine whether language proficiency predicted MMSE performance in both groups of bilingual speakers.
Results: Group differences were evident on the MMSE, on demographically adjusted MMSE scores, and on a small subset of individual MMSE items. Scores on a standardized screen of language proficiency predicted a significant proportion of the variance in the MMSE scores of both bilingual groups.
Conclusions: Bilingual speakers demonstrated distinct performance profiles on the MMSE. Results suggest that supplementing the MMSE with a language screen, administering a nonverbal measure, and/or evaluating item-based patterns of performance may assist with test interpretation for this population.

The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), originally published in 1975 to evaluate cognitive functions in psychiatric patients, was the first broadly used standardized brief screen of mental status. It has been described as the most cited reference in the health sciences literature (70,375 citations in Google Scholar at the time of this publication) and remains the most widely used and researched quick test of cognitive status (Arevalo-Rodriguez et al., 2015; Mitchell, 2009; Nilsson, 2007; Tombaugh & McIntyre, 1992). The test is used extensively in a variety of clinical and research settings by neurologists, physicians, psychologists, and speech language pathologists to screen adults for acute and/or incipient changes in cognitive function associated with a variety of conditions, including (but not limited to) delirium, dementia, depression, multiple sclerosis, Parkinson's disease, stroke, and traumatic brain injury (Nieuwenhuis-Mark, 2010). Adaptations of the MMSE have been developed for shortened (Marshall, Mungas, Weldon, Reed, & Haan, 1997), extended (Bravo & Hébert, 1997; Teng & Chui, 1987), and telephone administration (Roccaforte, Burke, Bayer, & Wengel, 1992), as well as for special populations (Busse, Sonntag, Bischkopf, Matschinger, & Angermeyer, 2002). In addition, the MMSE has been translated into over 70 languages, including many European, Asian, and African languages (Llamas-Velasco,

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Llorente-Ayuso, Contador, & Bermejo-Pareja, 2015; Steis & Schrauf, 2009).

Psychometric studies generally report good reliability and validity in identifying moderate–severe cognitive impairment (Tombaugh & McIntyre, 1992) but weaker sensitivity/specificity in identifying mild cognitive impairment (Carnero-Pardo, 2014; Mitchell, 2009; Tombaugh & McIntyre, 1992). As with many cognitive tests, performance on the MMSE is known to be affected by demographic variables, particularly education, age, ethnicity, and language of test administration (Bravo & Hébert, 1997; Crum, Anthony, Bassett, & Folstein, 1993; Matallana & Reyes-Ortiz, 2011; Ramirez, Teresi, Holmes, Gurland, & Lantigua, 2006; Tombaugh & McIntyre, 1992). In addition, items on the MMSE have been shown to be biased toward assessment of verbal versus visuospatial and executive functions (Nieuwenhuis-Mark, 2010; Nys et al., 2005; Tombaugh & McIntyre, 1992). These properties make MMSE test interpretation challenging for individuals from minority groups, especially for those whose first language is not English. Specifically, studies have shown that individuals who differ with respect to their education and/or ethnicity consistently perform lower on the MMSE and are at greater risk for being misclassified as impaired (Marshall et al., 1997; Matallana & Reyes-Ortiz, 2011; Mungas, Marshall, Weldon, Haan, & Reed, 1996; Ramirez et al., 2006).

Several approaches have been investigated to compensate for this assessment bias. One solution, for individuals whose first language is not English, has been to translate and administer the MMSE in the person's native language (Steis & Schrauf, 2009). However, translations are available for only a handful of the world's estimated 6,000 languages (Linguistic Society of America, 2016). Furthermore, even when translations exist, normative data are often not available (Steis & Schrauf, 2009). Nonnative English speakers may also have acquired greater proficiency in English than in their first language and/or may choose to be assessed in English (Marshall et al., 1997; Matallana & Reyes-Ortiz, 2011). For these reasons, the MMSE is often administered in English to persons from minority groups, even when English is not the first language of these individuals.

To date, various alternatives for adapting the English version of the MMSE for minority groups have been explored (Arevalo-Rodriguez et al., 2015; Matallana & Reyes-Ortiz, 2011; Tombaugh & McIntyre, 1992). One approach centers on demographic adjustments. Such adjustments include modifying cutoff scores for particular populations (Escobar et al., 1986), using age- and education-based normative data to compensate for population differences (Mungas et al., 1996), and/or eliminating items that have shown differential item functioning (DIF) across groups (Marshall et al., 1997). A more recent recommendation is to interpret performance using item-based patterns of performance rather than relying on a single global score (Matallana & Reyes-Ortiz, 2011; McGrory, Doherty, Austin, Starr, & Shenkin, 2014; Nieuwenhuis-Mark, 2010; Ramirez et al., 2006). This approach is based on research showing that specific populations have difficulty on particular sets of MMSE items. For example, older adults and individuals in the early stages of Alzheimer's disease show greatest difficulty on items assessing memory, attention, and executive function whereas language items are typically less affected in these groups. In contrast, individuals from minority groups tend to have greater difficulty on items more closely tied to education, language, and other sociocultural differences. Another approach to compensate for assessment bias in minority groups has been to supplement or replace the MMSE with measures that are less influenced by verbal ability/education (Arevalo-Rodriguez et al., 2015; Carnero-Pardo, 2014; Crowe, Allman, Triebel, Sawyer, & Martin, 2010; Matallana & Reyes-Ortiz, 2011; Mitchell, 2009).

These methods have shown promising results; however, research has been limited largely to investigation of MMSE performance in Hispanic or African Americans (Busch & Chapin, 2008; Escobar et al., 1986; Hawkins, Cromer, Piotrowski, & Pearlson, 2011; Marshall et al., 1997; Matallana & Reyes-Ortiz, 2011; Mungas et al., 1996; Ramirez et al., 2006). Limited information is available to facilitate interpretation of MMSE performance in other groups, such as Asian Americans, who make up the third largest ethnic population in the United States. Moreover, in much of this literature, individuals from ethnic groups were reported as having lower levels of educational attainment than nonminority groups (e.g., see Marshall et al., 1997; Matallana & Reyes-Ortiz, 2011; Mungas et al., 1996; Ramirez et al., 2006). Thus, education and ethnicity are often confounded in the literature, making it difficult to tease apart the effects of these variables (see discussions in Gibbons et al., 2011; Hawkins et al., 2011; Matallana & Reyes-Ortiz, 2011; Ramirez et al., 2006; Tombaugh & McIntyre, 1992).

A further limitation centers on the paucity of research exploring the direct effects of bilingualism on MMSE performance. Specifically, it is widely recognized that variables associated with bilingualism, such as second language proficiency, age of acquisition, and frequency of usage, impact performance on a range of cognitive measures (Birdsong, Gertken, & Amengual, 2012; Mindt et al., 2008). Although, an estimated 25% of the U.S. population and 50% of the world population classify themselves as bilingual (O'Brien, Curtin, & Naqvi, 2014), few studies have directly addressed the effects of bilingualism on MMSE performance. The existing literature, focusing on classification of Alzheimer's disease in older (mean = 75 years of age) bilingual adults, has generated mixed results. Two studies (Anderson, Saleemi, & Bialystok, 2017; Bialystok, Craik, Binns, Ossher, & Freedman, 2014) that compared a heterogeneous (multiple first languages) bilingual group with a monolingual group found no significant group difference in MMSE performance. A third study (Spering et al., 2012), however, that compared performance across multiple homogenous (one first language) groups of bilingual speakers found significant differences in MMSE performance across groups.

Current Study

The broad purpose of this study was to explore the effects of bilingualism on MMSE performance in two highly proficient bilingual groups: (a) Spanish–English bilinguals and (b) Asian Indian–English bilinguals. Both groups represent a sizeable portion of the population as well as distinct linguistic/sociocultural communities. Moreover, demographic characteristics of these two groups make it possible to match bilingual speakers with monolingual speakers and hence control for key demographic variables (such as age and education) that are often confounded in the literature. In addition, focusing initially on Spanish–English bilinguals makes it possible to draw on an existing and closely related literature examining effects of Hispanic ethnicity on MMSE performance. Including a second group of Asian Indian–English allows us to evaluate the generalizability of any potential findings to a linguistically and socioculturally distinct bilingual group.

Our first objective was to test whether procedures used to correct for assessment bias in ethnically diverse groups could be extended to two highly proficient bilingual groups: Spanish–English bilinguals and Asian Indian–English bilinguals. Specifically, we tested whether (a) an age- and education-based demographic adjustment ($\text{MMSE}_{\text{AdjAE}}$; Mungas et al., 1996), (b) a shortened 15-item version of the MMSE adapted for minority groups ($\text{MMSE}_{\text{IAdjItems}}$; Marshall et al., 1997), and/or (c) a supplementary nonverbal cognitive measure (Raven's Colored Progressive Matrices [RCPM]; Raven & Court, 1998) mitigated performance differences between the two bilingual groups and two demographically matched monolingual groups. Our second objective was to evaluate whether the same pattern of DIF observed for minority groups was also evident in these two bilingual groups. Last, we evaluated whether English language proficiency predicted MMSE performance for the two bilingual groups. Ultimately, greater understanding of the effects of bilingualism on cognitive measures, such as the MMSE, could reduce health disparities in minority communities by improving diagnostic accuracy and increasing the likelihood that appropriate intervention is provided.

Method

Participant Recruitment

Sixty independent community-dwelling adults between 18 and 95 years of age were recruited through staff and/or written advertisement at regional University and community centers in Maryland and Utah. Recruited participants included two groups of bilingual speakers and two groups of demographically matched monolingual speakers: bilingual Spanish–English speakers from Utah (BSE), demographically matched monolingual native English speakers from Utah (MU), bilingual Asian Indian–English speakers from Maryland (BAIE), and demographically matched monolingual native English speakers from Maryland (MM). Monolingual speakers were matched to bilingual speakers with respect to geographic region, age, education, and gender. All bilingual participants spoke English as their second language, had a minimum of intermediate level proficiency in both languages (American Council on the Teaching of Foreign Languages, 2012), reported speaking both languages regularly, and indicated that they were comfortable conversing and being evaluated in English. In order to represent the diversity of the two bilingual groups in the population, no restrictions were placed on the dialect of Spanish spoken by the BSE participants or the Indian language spoken by BAIE participants. More detailed information about the demographic characteristics (including first and second language status) of the final study sample who met these basic inclusionary/exclusionary criteria is provided in the results section.

After providing informed consent following procedures approved by institutional review boards at Utah State University and the University of Maryland, a detailed demographic interview was conducted to assess health and cognitive-communicative status. Participants reported having no prior history of substance abuse, cognitive impairment, or neurological disorder and indicated that they were not currently taking any medications known to affect cognitive status. In addition, all participants passed a depression (Geriatric Depression Scale; Yesavage et al., 1983), hearing (500, 1000, and 2000 Hz at 40 dB SPL), vision (completion of demographic form), and language (Bilingual Language Profile Questionnaire, Birdsong et al., 2012; clinical interview in both languages using the AphasiaBank discourse protocol, MacWhinney, Fromm, Forbes, & Holland, 2011, interpreted using proficiency guidelines of the American Council on the Teaching of Foreign Languages, 2012) screening.

Five participants were excluded following screening due to scheduling/travel (two participants), prior history of language/learning disability (two participants), or proficiency in additional languages not included in this study (one participant). This resulted in a final sample of 60 participants.

Testing Procedures

Testing (screening and assessment of cognitive status and language proficiency) was administered by a clinician in a quiet clinical suite within a single 2-hr session. Tests were selected because of their widespread use, availability of normative data, and relatively quick/easy administration procedures.

Tests and Measures

Measures of cognitive status included the MMSE (Folstein et al., 1975) and RCPM (Raven & Court, 1998). Measures of language proficiency included the Western Aphasia Battery–Revised (WAB-R; Kertesz, 2007), Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001), and Controlled Oral Word Association Test (COWAT; Ruff, Light, Parker, & Levin, 1996).

The MMSE is a 15-min 22-item verbal screen of cognitive status that assesses orientation, registration, attention, memory, language, and visuospatial function. We administered the standardized MMSE (Molloy, Alemayehu, & Roberts, 1991) and computed two adjusted scores. The first derived score applied Mungas et al.'s (1996) regression formula to adjust for age and education differences in minority groups: $MMSE_{AdjAE}$ = Raw MMSE − (0.471 × [Education-12]) + (0.131 × [Age − 70]). The second derived score (Marshall et al., 1997) was computed by deleting MMSE items previously shown to have DIF for minority groups and then summing the remaining 15 MMSE items (Items 1, 4–9, 11b, 12–13, 15, 19, 20b, 20c, and 22). Both derived scores were developed using data from large ($n >$ 500 persons) mixed ethnicity community samples (Marshall et al., 1997; Mungas et al., 1996).

The RCPM is a 15-min 36-item test designed to assess nonverbal reasoning/executive function (design completion) in a wide range of individuals, including those who do not speak English as their first language.

The WAB-R Standard Form Part 1 (30-min administration time in neurologically healthy adults) provides a general language score as well as subscores for information content, fluency, auditory comprehension, repetition, and naming.

The BNT (35-min administration time in neurologically healthy adults) is a 60-item measure of picture naming ability that is widely used to predict overall language ability. Both full (60-item) and short (15-item) form scores were computed after administering the full test.

The COWAT is a quick three-item (1-min/item) measure of verbal reasoning and executive function (generate words beginning with "F," "A," or "S").

Analyses

All analyses were conducted using SPSS version 23.0 (IBM Corp., 2015). Two independent parallel sets of analyses were conducted to compare (a) BSE participants with demographically matched MU participants and (b) BAIE participants with demographically matched MM participants. To address the first research question, independent samples *t* tests (equal variance not assumed) were used to compare the effect of group (monolingual vs. bilingual) on (a) MMSE raw score (Molloy et al., 1991), (b) $MMSE_{AdjAE}$ (Mungas et al., 1996) score, (c) $MMSE_{AdjItems}$ (Marshall et al., 1997) score, and (d) RCPM (Raven & Court, 1998) score. For the second question, Mann–Whitney *U* tests were done to evaluate the statistical significance of group differences on individual MMSE items that most differentiated the performance of monolingual and bilingual speakers (≥ 20% difference in group performance). Last, a linear regression analysis was conducted to examine whether a brief screen of English language proficiency (BNT short form) predicted MMSE performance.

Results I: BSE and MU Speakers

Participants

Demographic information for the BSE group (n = 16) and demographically matched MU group (n = 16) Utah is summarized in Table 1. The 32 participants (18 women and 14 men) had a mean age of 53.0 years (SD = 16.0, range: 18–82 years) and a mean educational attainment of 14.9 years (SD = 4.2, range: 6–23 years). Bilingual (n = 16) and monolingual (n = 16) groups did not differ significantly with respect to age (t = 1.47, p = .15), education (t = 0.15, p = .88), or gender (χ^2 = 0.0, p = 1.00). BSE participants spoke a variety of Spanish dialects that are representative of the U.S. population, including dialects local to Mexico (n = 6), Chile (n = 2), Argentina (n = 1), Colombia (n = 1), El Salvador (n = 1), and Guatemala (n = 1). Based on Bilingual Language Profile Questionnaire data (BLPQ; Birdsong et al., 2012), on average, BSE participants used English (vs. their native language) to communicate 47.6% (SD = 23.2, range: 6%–90%) of the time, began learning English at 15.2 (SD = 4.9, range: 3–20) years of age, and rated their English proficiency (speaking, understanding, reading, and writing) as a "4.7" (SD = 1.1, range: 2–6) on a 6-point scale (0 = *not well at all,* 6 = *very well*). BSE participants received lower scores than MU participants on all four language measures. These differences were statistically significant for the WAB-R Aphasia Quotient (t = 4.4, p < .001), BNT full form (t = 6.8, p < .001), and BNT short form (t = 4.7, p < .001), but not for the COWAT (t = 1.8; p = .09).

RQ 1: Was There a Difference in the Performance of Bilingual Spanish–English and Matched Monolingual Speakers on the MMSE, $MMSE_{AdjAE}$, $MMSE_{AdjItems}$, and RCPM?

Three of the 32 participants (all bilingual) fell below the normal range (cutoff score < 24) and five (one monolingual and four bilingual) fell within the borderline to normal range (24–26) on the MMSE. Significant group differences were found for the MMSE (t = 2.82, p = .01) and the $MMSE_{AdjAE}$ (t = 3.55, p < .01), but not for the $MMSE_{AdjItems}$ (t = 1.88, p = .08) or the RCPM (t = 1.30, p = .20).

RQ 2: Was There a Difference in the Performance of Bilingual Spanish–English and Matched Monolingual Speakers on Individual MMSE Items?

As shown in Figure 1, monolingual (solid black line) and bilingual (dashed black line) participants performed similarly on most MMSE items (see Figure 1). Of the 22 MMSE items, 20 were answered correctly by 80% or more of participants. Items that most differentiated the performance of BSE and matched MU participants (≥ 20% difference between groups) included in order of greatest difference: Item 18 (phrase repetition; group difference = 69%), Item 20 (auditory comprehension of multistep command; group difference = 33%), and Item 7 (identifying

Table 1. Participant characteristics.

Demographic variables	Utah (*n* = 32)		Maryland (*n* = 28)	
	Bilingual Spanish–English speakers (*n* = 16)	Monolingual English speakers from Utah (*n* = 16)	Bilingual Asian Indian–English speakers (*n* = 14)	Monolingual English speakers from Maryland (*n* = 14)
Age, *M* (*SD*)	49.0 (17.6)	57.3 (13.5)	58.4 (17.6)	61.5 (15.5)
Education, *M* (*SD*)	14.8 (5.1)	15.0 (3.0)	19.8 (4.7)	18.2 (2.6)
Gender (female/male)	9/7	9/7	6/8	10/4
Bilingual status, *M* (*SD*)				
Percentage of time using English	47.6 (23.2)	—	65.6 (28.9)	—
Age of English acquisition (years)	15.2 (4.9)	—	5.8 (1.5)	—
Proficiency self-rating (1–6)	4.7 (1.1)	—	6.0 (0.0)	—
Language measures, *M* (*SD*)				
WAB-R	90.5 (7.7)***	99.0 (0.7)	95.0 (4.6)**	99.3 (0.8)
BNT full form	32.3 (13.4)***	55.8 (3.0)	40.4 (8.5)***	55.4 (4.3)
BNT short form	9.1 (4.0)***	14.0 (1.0)	11.0 (2.3)**	14.2 (1.6)
COWAT	26.8 (10.1)	34.8 (14.4)	32.6 (11.3)	38.3 (10.3)
General cognitive measures, *M* (*SD*)				
MMSE	25.4 (4.5)*	28.7 (1.5)	28.8 (1.7)	29.5 (0. 7)
$MMSE_{AdjAE}$	21.1 (4.1)**	25.6 (2.7)	23.0 (1.6)*	25.5 (1.9)
$MMSE_{AdjItems}$	16.6 (3.1)	18.2 (1.1)	18.5 (1.3)	18.9 (0.4)
RCPM	29.3 (4.0)	31.1 (3.9)	28.7 (8.3)	32.5 (2.4)

Note. Statistical comparisons are with respect to matched monolingual English speakers from the same geographic region. WAB-R = Western Aphasia Battery–Revised; BNT = Boston Naming Test; COWAT = Controlled Word Association Test; MMSE = Mini-Mental State Examination; $MMSE_{AdjAE}$ = MMSE adjusted for age and education (Mungas et al., 1996); $MMSE_{AdjItems}$ = MMSE adjusted for items (Marshall et al., 1997); RCPM = Raven's Colored Progressive Matrices.

*$p < .05$. **$p < .01$. ***$p < .001$.

the county; group difference = 25%). These differences were statistically significant for all three items: Item 18 ($U = 40.0$, $p < .001$), Item 20 ($U = 53.0$, $p < .01$), and Item 7 ($U = 96.0$, $p < .05$).

RQ 3: Does Language Ability Predict MMSE Performance for Bilingual Spanish–English Speakers?

The relation between language ability (as measured by the BNT short form) and MMSE score for all bilingual participants is plotted in Figure 2. As suggested by the correlation data presented in Figure 2, scores on the BNT short form and MMSE were significantly correlated for BSE participants, $r(14) = .82$, $p < .001$. Results of the regression analysis indicated that the BNT short form predicted MMSE performance in BSE participants, $\beta = .92$, $t\,(14) = 5.31$, $p < .001$. BNT test scores also predicted a significant proportion of the variance in MMSE scores for this group, $R^2 = .67$, $F(1, 14) = 28.2$, $p < .001$.

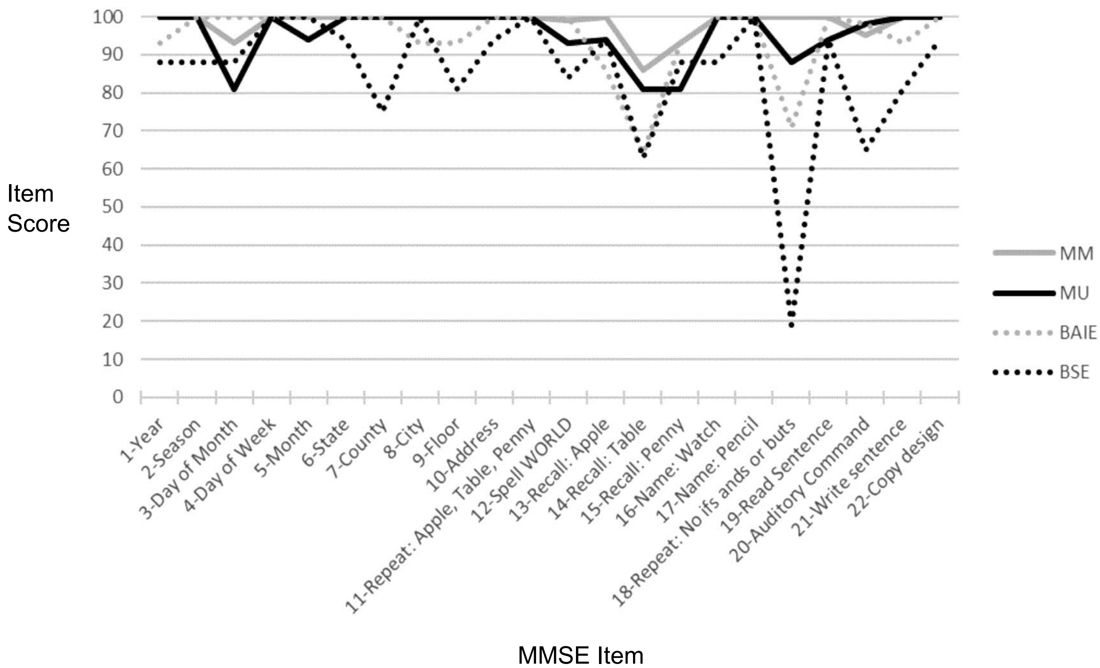
Results II: BAIE and MM Speakers

Participants

Demographic information for the BAIE group ($n = 14$) and demographically matched MM group ($n = 14$) from Maryland is summarized in Table 1. The 28 participants (16 women and 12 men) had a mean age of 60.0 years ($SD = 16.3$, range: 22–87 years) and a mean educational attainment of 18.8 years ($SD = 3.5$, range: 12–25 years). Bilingual ($n = 14$) and monolingual ($n = 14$) groups did not differ significantly with respect to age ($t = 0.49$, $p = .63$), education ($t = 0.86$, $p = .41$), or gender ($\chi^2 = 2.3$, $p = .13$). BAIE participants spoke a variety of Asian Indian languages that are representative of the U.S. population, including Hindi ($n = 10$), Marathi ($n = 1$), Kanares ($n = 1$), Tamil ($n = 1$), and Urdu ($n = 1$). Based on BLPQ data, on average, BAIE participants used English (vs. their native language) to communicate 65.6% ($SD = 28.9$, range: 22%–98%) of the time, began learning English at 5.8 ($SD = 1.5$, range: 4–8) years of age, and rated their English proficiency (speaking, understanding, reading, and writing) as a "6.0" ($SD = 0.07$, range: 5.8–6) on a 6-point scale (0 = *not well at all,* 6 = *very well*). BAIE participants performed similarly to the BSE group with respect to the four language measures. Specifically, BAIE participants received lower scores than demographically matched MU participants on all four language measures with significant differences evident on the WAB-R Aphasia Quotient ($t = 3.4$, $p < .01$), BNT full form ($t = 5.4$, $p < .001$), and BNT short form ($t = 3.9$, $p < .01$), but not on the COWAT ($t = 1.3$, $p = .22$).

The two bilingual groups (BSE and BAIE) did not differ significantly with respect to age ($t = 1.43$, $p = .17$), gender distribution ($\chi^2 = 0.54$, $p = .46$), or percentage of time using English ($t = 1.27$, $p = .25$). Notably, however, in comparison to the BSE group, the BAIE group had a significantly higher level of education attainment ($t = 2.36$, $p < .05$), acquired English at a younger age ($t = 6.59$,

Figure 1. Mini-Mental State Examination (MMSE) item scores (percentage of respondents who answered item correctly) for monolingual speakers from Maryland (MM), monolingual speakers from Utah (MU), bilingual Asian Indian–English speakers from Maryland (BAIE), and bilingual Spanish–English speakers from Utah (BSE).



$p < .001$), and reported a higher level of overall English language proficiency ($t = 4.82$, $p < .001$).

RQ 1: Was There a Difference in the Performance of Bilingual Asian Indian–English and Matched Monolingual Speakers on the MMSE, MMSE$_{AdjAE}$, MMSE$_{AdjItems}$, and RCPM?

One bilingual participant (MMSE score = 24) fell in the borderline to normal range on the MMSE. The remaining 27 participants performed within the normal range on the MMSE (see Table 1). With respect to group differences, bilinguals scored significantly lower than monolinguals on the MMSE$_{\text{AdjAE}}$ ($t = 3.25$, $p < .01$). Group differences were not significant, however, for the MMSE ($t = 1.49$, $p = .16$), the MMSE$_{\text{AdjItems}}$ ($t = 0.96$, $p = .35$), or the RCPM ($t = 1.46$, $p = .17$).

RQ 2: Was There a Difference in the Performance of Bilingual Asian Indian–English and Matched Monolingual Speakers on Individual MMSE Items?

As shown in Figure 1, the performance of monolingual (solid gray line) and bilingual (dashed gray line) groups was at or near ceiling on most MMSE items. Of the 22 MMSE items, 20 were answered correctly by 90% or more of participants. Items that most differentiated the performance of BAIE and matched MM participants (≥ 20% difference between groups) included, in order of greatest difference, the following: Item 18 (phrase repetition; group difference = 29%) and Item 14 (delayed recall of "table"; group difference = 21%). These differences were statistically significant for Item 18 ($U = 70.0$, $p < .05$), but not for Item 14 ($U = 77.0$, $p = .20$).

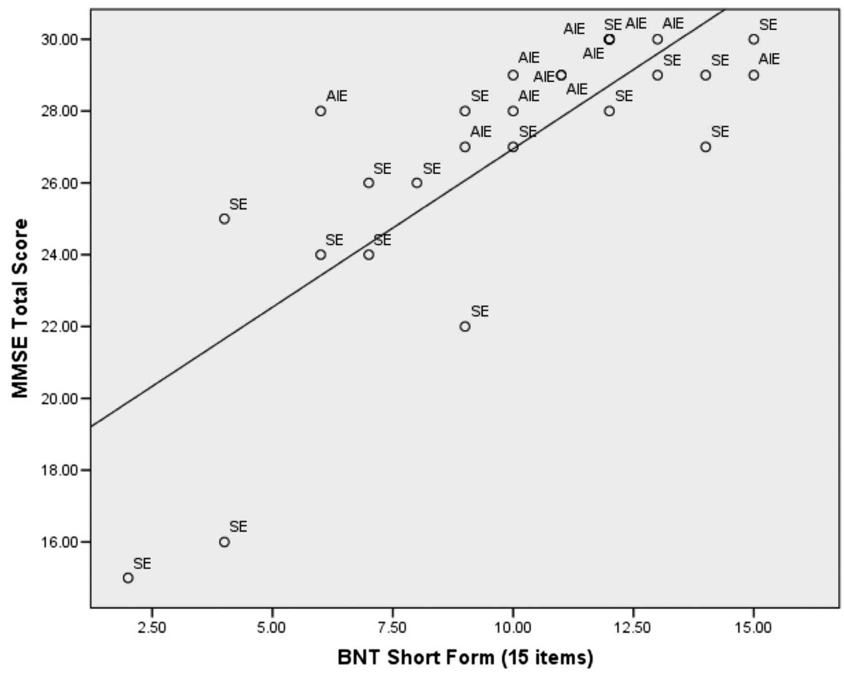
RQ 3: Does Language Ability Predict MMSE Performance for Bilingual Asian Indian–English Speakers?

As suggested by the correlation data presented in Figure 2, BNT short form and MMSE scores were significantly correlated for BAIE participants, $r(9) = .65$, $p < .05$. Results of the regression analysis indicated that the BNT short form predicted MMSE performance in BAIE participants, $\beta = 0.28$, $t(9) = 2.5$, $p < .05$. BNT test scores also predicted a significant proportion of variance in MMSE scores for this group, $R^2 = .42$, $F(1, 9) = 6.4$, $p < .05$.

General Discussion

This preliminary study explored the effects of bilingualism on MMSE performance in two bilingual groups: BSE and BAIE. Although the influence of age, education, and ethnicity on the MMSE is well documented, much less is known about the specific effects of bilingualism on test

Figure 2. Relationship between language proficiency (Boston Naming Test [BNT] short form) and Mini-Mental State Examination (MMSE) total score for bilingual Spanish–English (SE) participants and Asian Indian–English (AIE) participants. Pearson's $r_{SE} = .82$, $p < .001$; Pearson's $r_{AIE} = .65$, $p < .05$.



performance. Related research, however, has shown that bilingualism significantly impacts performance on a wide range of cognitive measures (Mindt et al., 2008). This study adds to the existing research by (a) including both subjective (Bilingual Language Profile Questionnaire and interview in both languages) and objective (standardized language testing) measures of bilingual language status, (b) comparing performance on the MMSE and standardized adjustments of the MMSE, and (c) evaluating both global and item scores on the MMSE.

The bilingual groups in this study were similar in that both groups included neurologically healthy, independent, community-dwelling, highly educated, highly proficient English speakers, who were comfortable being assessed in their nonnative language. They were also similar with respect to age, gender distribution, reported frequency of English language usage, and performance on standardized language measures. Notably, however, in addition to linguistic and sociocultural differences between the two groups, the BAIE group reported a higher level of education attainment (five more years of college education), English acquisition at a younger age (6 years of age compared to 15 years of age), and a higher level of English language proficiency (6 compared to 4.7 on a 6-point scale). As discussed in greater detail below, these demographic characteristics likely contributed to the observed differences in research outcomes for the two groups.

Our first research question investigated whether the performance of the two bilingual groups differed from matched monolingual groups on the MMSE, a demographically (age and education) adjusted MMSE ($MMSE_{AdjAE}$) and an item adjusted MMSE ($MMSE_{AdjItems}$), and a nonverbal cognitive measure (RCPM). For both analyses, bilingual participants (BSE and BAIE groups) were more likely to be classified in the borderline/impaired range than matched monolingual individuals. In addition, bilingual groups had significantly lower scores than matched monolingual groups on the $MMSE_{AdjAE}$ (BSE and BAIE groups) and the MMSE (BSE group only). However, no significant differences were found between bilingual (BSE and BAIE) and monolingual groups on the $MMSE_{AdjItems}$ or the RCPM.

In general, the performance differences observed on the MMSE are in line with prior research demonstrating that bilingual groups perform differently than monolingual groups on a wide range of cognitive measures (Anderson et al., 2017; Birdsong et al., 2012; Mindt et al., 2008; Mungas, Widaman, Reed & Tomaszewski Farias, 2011). Results are also consistent with a growing body of research indicating that MMSE score adjustments based solely on age and education are not sufficient, in and of themselves, to fully correct for performance differences across diverse ethnic groups (Mindt et al., 2008; Padilla, Mendez, Jimenez, & Teng, 2016; Pedraza et al., 2012; Spering et al., 2012). Moreover, these results add further support to the hypotheses that item-based (Matallana & Reyes-Ortiz, 2011; McGrory et al., 2014; Ramirez et al., 2006) and nonverbal measures (Arevalo-Rodriguez et al., 2015; Crowe et al., 2010; Mitchell, 2009) may provide less biased estimates of function for linguistically and culturally diverse groups.

Our second question addressed performance differences on individual MMSE items. Statistically significant differences were found between bilingual and matched monolingual groups on Items 18 (both BSE and BAIE groups), 20 (BSE group) and 7 (BSE group). These items represent a subset of MMSE questions previously identified as showing DIF for culturally diverse groups (Marshall et al., 1997; Matallana & Reyes-Ortiz, 2011; Millsap, 2006; Ramirez et al., 2006). Consistent with prior research evaluating bilingual speakers on similar measures (Luo, Craik, Moreno, & Bialystok, 2013), bilingual participants in this study scored lower than monolingual participants on items assessing culturally specific verbal knowledge (Item 18, repeating an idiomatic expression; Item 7, naming the county) and items assessing verbal working memory (e.g., Item 14, delayed word recall; Item 20, auditory comprehension). Notably, performance did not differ on items that have been more closely associated with education, aging, and/or dementia: items assessing orientation to time (Item 2, season; Item 3, day of month), attention (Item 12, WORLD backward), more basic language tasks (Item 16, naming high-frequency vocabulary; Item 19, sentence-level reading comprehension), and visuospatial processing (Item 22, design copy). In fact, related research has sometimes shown a bilingual cognitive advantage on similar attention/executive function tasks (Bialystok, 2011). Taken together, these findings add further support for the clinical recommendation (Matallana & Reyes-Ortiz, 2011) of interpreting MMSE results in culturally diverse groups using item-based patterns of performance rather than relying on a single global score.

Our final objective was to evaluate whether language proficiency (as measured by the BNT short form) predicted MMSE performance in the two groups. Results of the correlation and regression analyses for both bilingual groups indicated that there was a close relation between MMSE performance and language proficiency, as measured by standardized language testing. Specifically, language proficiency accounted for 67% of the variability in MMSE scores for the BSE group and 42% of the variability in MMSE scores for the BAIE group. The close relation observed between language proficiency and MMSE performance is in line with prior reports indicating that the MMSE is biased toward assessment of verbal versus other cognitive functions (Tombaugh & McIntyre, 1992) and that language ability impacts MMSE performance in other groups (such as persons with aphasia) who also differ with respect to their communicative function (Osher, Wicklund, Rademaker, Johnson, & Weintraub, 2008). This finding also has immediate clinical relevance because it suggests that even a brief language screening (as compared to extensive language testing) may help clinicians gage bilingual language status and its potential impact on MMSE test performance.

Although there was considerable overlap in the outcomes for the two bilingual groups across the three research questions, it is also important to emphasize that performance of the two bilingual groups differed (relative to matched controls) on the raw unadjusted MMSE score, DIF of specific MMSE items, and the magnitude of the relation between language proficiency and MMSE score. As already suggested, these differences were likely due to variability in the demographic characteristics of the two groups (particularly differences in first and second language status and years of higher education). The observed differences between the two bilingual groups in this study are consistent with related research that has shown similar variability in MMSE performance across diverse sociocultural communities (Spering et al., 2012).

The primary limitation of this study was the small sample size. In this initial research, we administered a relatively comprehensive language battery to a relatively small number of participants in order to more fully characterize the language proficiency of bilingual participants. As already stated, our initial results suggest that even a brief language screen may provide useful information that can be used to estimate language proficiency in bilingual speakers. Future research should replicate this finding in a larger sample. A related point is that the sample was limited to neurologically healthy/high functioning, highly educated, and highly proficient bilingual speakers. Thus, findings may not generalize to bilingual persons with cognitive impairment and/or lower levels of education. In spite of these limitations, results of this study closely paralleled those reported for related research examining MMSE performance in minority groups (Carnero-Pardo, 2014; McGrory et al., 2014; Ramirez et al., 2006) and/or performance of bilingual speakers on other cognitive measures (Luo et al., 2013; Mindt et al., 2008).

Summary and Conclusions

Findings from this study suggest that even neurologically healthy, highly proficient bilingual speakers may perform differently than monolingual speakers on raw and demographically adjusted MMSE scores. Item analyses indicated that these differences were largely associated with a relatively small set of items assessing culturally specific verbal knowledge and verbal working memory. Furthermore, language proficiency, as measured by a standardized naming test, accounted for a significant portion of variability in the performance of both bilingual groups on the MMSE. Collectively, these results support the use of supplemental nonverbal measures, item-based analyses, and/or language screening to assist with MMSE interpretation for highly proficient bilingual individuals. Moreover, these results highlight the clinical importance of identifying and characterizing linguistic and cultural diversity, even when assessing highly educated and proficient bilingual speakers with initial cognitive-communicative screening measures.

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