



Assessing working memory capacity in a non-native language

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ABSTRACT

The present studies directly test the usefulness of two English-language working memory capacity (WMC) assessments with two samples of students whose native language was not English. Participants completed two widely used complex span tasks, Reading Span (RSpan) and Operation Span (OSpan), in English. To determine whether the well-established relationship between WMC and Raven's Advanced Progressive Matrices (RAPM) would be observed when span tasks were not given in the native language of the participant, span scores were regressed against performance on the RAPM. Results indicated that while OSpan was a reliable and valid predictor of RAPM in non-native-English speakers, RSpan administered in English was not.

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Given the increasing population of individuals who speak more than one language, a topic of growing interest is the effect of bilingualism on cognition and the mechanisms that underlie effective bilingual memory and language processing. Many recent studies have explored how bilingualism affects executive functioning, flexibility and attentional control in individuals (Bialystok, 2007; Colzato et al., 2008; Ransdell, Barbier, & Nilt, 2006). Importantly, a methodological point that has not been subject to much scrutiny in previous studies on bilinguals is the language in which various cognitive tests are performed.

Specifically, little attention has been given to the linguistic background of participants in many cognitive experiments at English-speaking universities. In these settings, assessments of executive functioning and general cognitive abilities are routinely administered only in English. Although many cognitive tasks have been shown to be reliable and valid measures for native speakers, it is imperative to determine whether these same tasks are reliable and valid predictors of ability when given in a non-native language. This point seems especially relevant for tasks with a large verbal component, such as one of the most popular working memory span tasks (e.g., Reading Span). The present study directly tests the usefulness of English-language working memory

capacity assessments with a population whose native language is not English.

Working memory capacity (WMC) has emerged in the past 30+ years as a powerful predictor of performance across a myriad of tasks (Conway et al., 2005). WMC predicts performance in dichotic listening, Stroop, and anti-saccade tasks (Colflesh, & Conway, 2007; Kane et al., 2001; Kane, & Engle, 2003), as well as reading comprehension (Daneman, & Carpenter, 1980; Long, & Chong, 2001; Payne, Kalibatseva, & Jungers, 2009), metacomprehension skill (Griffin, Wiley, & Thiede, 2008), memory for baseball games (Hambrick, & Engle, 2002) and learning in science (Sanchez, & Wiley, 2006, 2009). Further, WMC also predicts reasoning, problem solving and decision making (Ash, & Wiley, 2006; Copeland, & Radvansky, 2004; Ricks, Turley-Ames & Wiley, 2007; Shamosh et al., 2008).

WMC is typically assessed using complex span tasks with two distinct components (1) a processing component, and (2) a concurrent storage component in which the participant attempts to remember unrelated information for later recall (see Conway et al., 2005 for a review). As these tasks require participants to process and store information concurrently, complex span tasks are considered measures of a domain-general cognitive ability which some have argued is essentially the ability to control attention (Kane et al., 2001), the ability to focus attention (Cowan, 2005), or the ability to resist interference (Bunting, 2006). This construct goes beyond just the basic capacity of the short-term store as assessed by simple word or digit-span tests which do not require concurrent processing (Daneman, & Merikle, 1996; Engle et al., 1999).

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The original reading span task (RSpan; Daneman, & Carpenter, 1980) required participants to read sets of 2–6 sentences out loud while also trying to remember the last word of each sentence for later recall. While this original RSpan measure was found to correlate well with measures of reading comprehension and VSAT performance (Daneman, & Carpenter, 1980), some have argued that this correlation could be a result of domain-specific skills in verbal ability supporting better memory for the sentences that were read (Baddeley, 2003; Daneman, & Merikle, 1996; Ericsson, & Kintsch, 1995). In an effort to eliminate the potential influence of verbal proficiency, newer RSpan tasks require that participants recall unrelated letters instead of the last words of the sentences.

Alternatively, several parallel measures that are less verbal, but share the same basic components as the RSpan task, have been developed including the operation span task (OSpan, Turner, & Engle, 1989). OSpan involves making mathematical judgments for number strings rather than sensibility judgments for sentences. Despite the difference in the processing component, previous research has found a high correlation between RSpan and OSpan tasks with native-English speakers ($r = .60$, Conway et al., 2005). Further, in native-English populations, both OSpan and RSpan have been shown to correlate at .30 with performance on the Raven's Advanced Progressive Matrices which is a prototypical measure of fluid intelligence (Unsworth, & Engle, 2005). While some have suggested that the constructs of fluid intelligence (G_f) and WMC are nearly synonymous (Kyllonen, & Christal, 1990), more recent research suggests instead that these constructs are indeed separate (but highly correlated) entities that share variance due to the need to control or focus attention (Unsworth, & Engle, 2005). Given the strong and well-documented correlation between WMC and G_f , a standard way to assess the validity of a WMC assessment as a measure of controlled attention is to examine the extent to which it correlates with RAPM. If the task is truly tapping the WMC construct, then it should reveal a moderate to strong correlation with RAPM.

The present studies are the first to examine the reliability and predictive validity of a set of English-language span tasks with a population whose native language is not English. The individuals in the first study are American college students who report Spanish as their native language, but have spoken English for ten or more years. To further generalize the effects, a second experiment was conducted using another sample of American college students who were non-native-English speakers, where native language was free to vary. These participants reported a variety of native languages (including Spanish).

To assess the predictive validity of these standard span tasks within these populations, the analysis of interest is whether span scores will correlate with RAPM scores. Results for these non-native-English speakers are contrasted with the results of native-English speakers from the same college population. If administration of these tasks in a non-native language fundamentally changes the nature of the construct measured by these tasks, then one might expect a divergence in the correlations between span measures and RAPM across the two linguistic groups. In the most extreme case, neither span task might predict RAPM performance in the non-native population. On the other hand, if both English-language RSpan and OSpan are reliable and valid measures of the WMC construct for native-English and non-native individuals, the usual relationship between each of these measures and RAPM across language groups should be seen.

1. Experiment 1

2. Method

A total of 134 participants were recruited from a large public Midwestern university in the United States. Half of these participants were native-English speakers, and the remaining 67 participants were

native-Spanish speakers who reported having spoken fluent English for at least 10 years ($M = 14.25$ years, $SD = 2.82$). The average age (in years) that the bilinguals began speaking English was 5.33 years old ($SD = 2.45$). All participants received course credit for their participation.

All participants completed OSpan, RSpan, and RAPM with breaks between each task. The order of the span tasks was varied across participants. At the end of the session all participants completed a Language History Questionnaire in which they reported their native language and any additional languages they spoke or read, the number of years they had spoken English fluently, and the age at which they began speaking English.

2.1. Operation Span (OSpan)

The OSpan task (Turner, & Engle, 1989) requires participants to verify simple mathematical strings while also trying to remember unrelated words. Standards of administration and proportional scoring followed the recommendations in Conway, Kane, Bunting, Hambrick, Wilhelm and Engle (2005). For each trial, participants were required to read aloud and verify the correctness of a single math problem, and then immediately read and remember the word following the equation. For example,

$$IS(8 / 2) - 1 = 1? \text{ BEAR}$$

As soon as the participant read the word, the next operation–word string was presented. The operation–word strings were presented in sets of two to five trials. At the end of each set, the participant was prompted to recall all words in the set, in the correct order. Three trials of each set size were presented, in a random order. In order to ensure that participants were attending to the processing task, an 85% accuracy criterion on the math operations was required. Reliability for the OSpan task was calculated following Unsworth, Heitz, Schrock and Engle (2005). The proportion score for the first presentation of every set size was averaged together to form a sub-score. The same procedure was followed for the second and third presentation of each set size, yielding 3 sub-scores. Cronbach's α was computed using these 3 sub-scores. As shown in Table 1, while reliability was slightly higher for native English speakers in OSpan, the reliability for bilinguals remains high and similar to previous values (Conway et al., 2005 reports that reliability estimates for span tasks are typically in the .7–.9 range).

2.2. Reading Span (RSpan)

The RSpan task (Kane et al., 2004) is identical to the OSpan task except that participants read sentences, make sensibility judgments, and then remember a set of unrelated letters, rather than verifying math equations and remembering words. Administration and scoring was identical to OSpan. Reliability estimates were computed as above, and as shown in Table 1, RSpan appears to be a highly reliable measure in both language groups.

2.3. Raven's Advanced Progressive Matrices (RAPM)

RAPM (Raven et al., 1998) is considered a measure of fluid intelligence. The test consists of 36 individual items presented in ascending order of difficulty (i.e., the easiest item is presented first). Each item consists of a matrix of geometric patterns with the bottom-right corner missing. The participant selects, from 8 alternatives, the option that correctly completes the matrix. The task was administered according to standard instructions with a 40-minute time limit. A participant's score was the total number correct. Reliability of the RAPM was determined by computing Cronbach's α from the subscores

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