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Bilingual advantages of working memory revisited: A latent variable examination☆

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ABSTRACT

This study examined the organizational structure of working memory (WM) and latent mean differences in WM components in Arabic–English bilinguals and carefully matched monolinguals. Twelve WM tests, assessing four WM components, were administered to 615 8–12-year-old children, of whom 309 were monolinguals (155 girls and 154 boys) and 306 were bilinguals (152 girls and 154 boys). The multi-group confirmatory factor analysis of nested models was used to test measurement invariance and mean structures in four WM factors across the two language groups. The results showed that the four WM component model is supported in both mono- and bilingual children. Moreover, the WM construct measure was similar in both mono- and bilinguals, and there were significant differences in the latent factor means that favored the bilinguals in the four WM components. These findings have theoretical and methodological implications with respect to the multi-component model of WM and emphasize the structure of WM in Arabic–English bilinguals.

1. Introduction

The majority of bilingualism research in the last two decades has focused on the extent to which bilingual children acquire and process two languages and the possible underlying cognitive mechanisms of bilingualism. There is crucial evidence that the two languages in bilinguals are simultaneously active in the brain in both language comprehension and production (Blumenfeld & Marian, 2007; Marian & Spivey, 2003). The brain monitors and switches attention to the target language during reciprocal activation of the second language (Desmet & Duyck, 2007).

Several studies have examined the individual differences between both mono- and bilinguals in cognitive processes such as working memory, inhibition and shifting (Abu-Rabia & Siegel, 2002; Ardila, 2003; Arêas Da Luz Fontes & Schwartz, 2011; Morales, Calvo, & Bialystok, 2013; Namazi & Thordardottir, 2010; Pascale & de Abreu, 2011). Bilingual differences in cognitive abilities have been attributed to individual variations in the executive control system, which includes inhibition, attentional focus and task switching (Bialystok, 1999). In one accepted explanation of executive functions (Miyake et al., 2000), there are three basic components involved in inhibition, shifting and updating. These components are similar to the functions of the central executive component of working memory (WM) in the most widely accepted model of WM (Baddeley & Hitch, 1974).

According to this model, WM is a limited capacity system that temporarily preserves and manipulates information from different modalities to perform complex cognitive tasks (Baddeley & Logie, 1999). This system comprises three distinct but interrelated components, with one master and two subsystems. One subcomponent is the phonological loop that is dedicated to temporarily storing and manipulating verbal materials. A typical measure of the storage capacity of the phonological loop is tasks that require serial recall of digits and words (Baddeley, Gathercole, & Papagno, 1998; Gathercole, Pickering, Ambridge, & Wearing, 2004), which are frequently used in studies examining WM components (Alloway, Gathercole, Willis, & Adams, 2004; Baddeley et al., 1998; Gathercole & Pickering, 2000; Gathercole et al., 2004).

A second subcomponent is the visuospatial sketchpad, which is dedicated to maintaining and processing visual and spatial information (Gathercole, 2008). The storage capacity of the visuospatial sketchpad component of WM is assessed using tasks that require simultaneous storage and the processing of visual and spatial materials. Several tasks have been proposed to assess the visuospatial sketchpad, but the most salient tasks for use with children are block recall, visual pattern and mazes memory (for more details on the measures of the visuospatial sketchpad, see Alloway et al. 2004; Gathercole et al. 2004). The two subsystems work integrally under the supervision and control of a third component, the central executive, which integrates the two systems with other components of the cognitive system. A well-established measure of the central executive of WM uses a complex memory paradigm that requires concurrent storage and processing of information (Alloway et al., 2004).

However, the model has limitations in explaining how information from different modalities (phonological and visuospatial) is combined

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while maintaining their interchangeable basic coding systems as well as in clarifying the interface of WM and long-term memory (Allen, Hitch, & Baddeley, 2009). Therefore, Baddeley (2000) incorporated a fourth component called the episodic buffer, which is devoted to binding verbal and visuospatial information and connecting them to long-term memory under the supervision of the central executive (Baddeley, 2000; Baddeley, Allen, & Hitch, 2011). Typical measures of the episodic buffer require temporary storage activities that integrate information from a variety of sources. This is based on combining semantic and linguistic long-term information into an articulated unit with other related activated semantic and linguistic information from the different modalities of the other two WM subsystems, such as the phonological loop and the visuospatial sketchpad. In line with this observation, three tasks were used in this study: memory for stories, paired recall and category fluency.

Baddeley and Hitch's model is supported by a massive number of empirical studies on different samples, including children (Alloway, Gathercole, & Elliott, 2010; Alloway, Gathercole, Kirkwood, & Elliott, 2009; Gathercole, Alloway, et al., 2008;Gathercole, Alloway, Willis, & Adams, 2006; Gathercole, Briscoe, Thorn, Tiffany, & Team, 2008), adults (Baddeley, Jarrold, & Vargha-Khadem, 2011; Logie, 2011; Parra, Sala, Logie, & Abrahams, 2009; Tam, Jarrold, Baddeley, & Sabatos-DeVito, 2010) and neuropsychological patients (Gathercole & Baddeley, 1990; Spooner, Gathercole, & Baddeley, 2006), as well as neuroimaging studies (Schneiders, Opitz, Krick, & Mecklinger, 2011; Yan, Zhang, Gong, & Weng, 2011).

Several studies have suggested that bilinguals outperform monolinguals in a wide range of WM-related processes, including executive functions (Adi-Japha, Berberich-Artzi, & Libnawi, 2010); verbal tasks, auditory digit span tasks and nonword repetition measuring short-term memory in the prediction of learning a second language (Ganschow, Sparks, Javrosky, Pohlman, & Bishop-Mabury, 1991); general WM capacity (Hyon, 2008); and the acquisition of second-language vocabularies (Arecco & Ransdell, 2002). There is also evidence that executive function control (e.g., shifting and switching) develops earlier in bilingual children relative to their monolingual counterparts (Bialystok, 2010; Yang, Yang, & Lust, 2011). Even in adulthood, bilinguals surpass monolinguals in tasks evaluating executive functions (Bialystok, 2011; Penn, Frankel, Watermeyer, & Russell, 2010).

Research on WM in monolingual children has suggested that during development, considerable changes occur in performance on all tasks that evaluate WM components, particularly the three basic components. According to the Baddeley and Hitch's model, Gathercole et al. (2004) examined the factor structure of WM in 4- to 15-year-old monolingual children using a comprehensive test battery, which evaluated the three basic components of working memory. Their findings revealed that the factor structure of the three components exists in children from the age of six, that the relationships between the WM components do not change with age and that the correlation between the phonological loop and central executive modules increases with age.

Bialystok (2001) argued that bilingual children are not the same as their monolingual counterparts, suggesting that bilingual children live different lives compared with their age-matched counterparts. Moreover, bilinguals might have different family arrangements, spend more time in formal schooling, attend more classes for their home languages, travel more and contact more diverse cultures when visiting their relatives. Therefore, it cannot be guaranteed that both mono- and bilingual children conceptualize measured constructs similarly nor that the constructs can be measured in the same way in both language groups.

The literature pertaining to differences in WM among mono- and bilinguals depicts four joint concerns. First, in a series of studies, Bialystok and colleagues (Bialystok & Feng, 2009; Bialystok & Viswanathan, 2009; Emmorey, Luk, Pyers, & Bialystok, 2008; Greenberg, Bellana, & Bialystok, 2013; Luo, Luk, & Bialystok, 2010) demonstrated bilingual advantages in different aspects of executive control, particularly in inhibitory control and task switching. Bilingual individuals have more experience in resisting cross-linguistic interference and switching between two languages than monolinguals, and such daily experiences should transfer to other executive control situations. In this context, Bialystok and colleagues have argued that bilinguals have a more limited vocabulary and weaker lexical representations than monolinguals (even in the more dominant language). From this observation, it could be argued that bilinguals do not perform as well on verbal short-term memory or WM tasks as monolinguals do, although their executive advantage may lead to better performance than monolinguals in nonverbal aspects of WM. This suggests that monolingual and bilingual children differ in their WM components and factor structure in specific ways.

A second concern was that almost all of the previous studies have focused on the differences between mono- and bilinguals at the level of manifested variables rather than latent variables, which implies a neglect of measurement errors and measurement equivalence. Therefore, interpreting differences based on observed variables will not be accurate because measurement errors and possible differences in a given construct can result in less true variance in one group than the other. This suggests that measurement invariance is more precise, as it considers the errors in items and latent factors, unlike comparing the observed score means, which consider that both groups exhibit similar degrees of error.

Based on the consensus that measurement invariance is a prerequisite of judging mean differences between groups, one advantage of this study compared with previous studies was the examination of a high level of measurement invariance (configural, metric, scalar and strict) that – if confirmed – implies that both mono- and bilingual children conceptualized the constructs similarly and that the examination of the latent mean differences will be possible and will indicate real mean differences in WM constructs between mono- and bilingual children.

A third concern was that the literature on WM and the related cognitive resources, particularly studies focusing on the phonological component and the central executive in mono- and bilingual children, has neglected to examine the similarities and differences with respect to bilingualism using a comprehensive battery of WM tasks that evaluate WM components. Additionally, none of the previous studies examined the role of the episodic buffer (the fourth WM component) in bilinguals, despite its role in combining information from different modalities (verbal and visuospatial) and connecting them semantically to long-term memory. Despite evidence of differences in performance between bilingual children and monolingual children in nearly every aspect of WM tasks, no studies have investigated the organizational structure of WM in a large sample of either mono- or bilingual children using the M-WM model.

A fourth concern was that bilingualism among Arabic–English bilinguals is not well understood, considering the complete absence of lexical resemblance to Western languages and the complexity of Arabic syntax. As such, native English speakers face difficulties in learning Arabic. Arabic is difficult to learn because of sentence structure (VSO), pronunciation and grammar. Moreover, Arabic has various dialects with which foreign learners need to familiarize themselves. Most of the Arabic letters have four forms, which depend on the place they occupy within a word. Additionally, vowels are not included in written Arabic, although the vowel sounds are included (Al-Hamouri et al., 2005). An Arabic-speaking student learning a Western language (e.g., English, French, Italian or German) will encounter many common words, unlike English-speaking Arabic learners (http://mylanguages.org/difficult_languages.php). Such difficult and complicated languages could impose more demands on the cognitive resources involved in first- and second-language switching and, consequently, on the subsystems involved in storing and manipulating information from different modalities.

The main objectives of the current study were (i) to examine the existence of the four-factor model in mono- and bilingual children in