THE RELATIONSHIP BETWEEN BILINGUALISM AND WORKING MEMORY: A REVIEW
A RELAÇÃO ENTRE BILINGUISMO E MEMÓRIA DE TRABALHO: UMA REVISÃO

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ABSTRACT

This paper presents a review of the literature aimed at exploring the main findings regarding studies on the issue of bilingualism and working memory. It is organized with an initial discussion on the construct of working memory and its development through time, followed by the topic of bilingualism, with general evidence of its advantages and disadvantages to the cognitive system, and finally the examination of current pieces of research addressing working memory in bilingual children and adults. The objective is to illustrate what contributions research has shown so far and what future directions might be.

KEYWORDS: bilingualism; working memory; cognition.

RESUMO

Este artigo apresenta uma revisão de literatura com o intuito de explorar as descobertas mais relevantes acerca de estudos sobre bilinguismo e memória de trabalho. Inicialmente, discute-se o construto memória de trabalho e como o mesmo tem evoluído enquanto objeto de pesquisa. Na sequência, apresenta-se a questão do bilinguismo, trazendo-se evidências gerais de estudos acerca de suas vantagens e desvantagens em termos cognitivos. Por fim, as pesquisas mais recentes acerca da relação entre memória de trabalho e bilinguismo em grupos de crianças e adultos são apresentadas. O objetivo principal é fazer um apanhado geral sobre quais contribuições estas pesquisas têm apresentado até o momento e quais as direções futuras que novas pesquisas podem vir a tomar a partir disso. Palavras-chave: bilinguismo; memória de trabalho; cognição.

PALAVRAS-CHAVE: Bilinguismo; Memória de trabalho; Conhecimento

INTRODUCTION

Due to the increasing number of people learning and speaking additional languages[1], an important endeavor in this highly connected global society (CAFFARRA ET AL., 2015), a topic that

[1] The term ‘additional language’ is being used here as just another way to refer to a language which is different from one’s first language (L1) or mother tongue; therefore, it may refer to a second language (L2), a third language (L3) and so on.

has raised researchers' attention is the impact of bilingualism on cognition and the mechanisms underlying effective language processing, among other aspects. Recent studies have been concerned with the relation between bilingualism and executive functions (EF, e.g., BIALYSTOK, 2007; COLZATO ET AL., 2008) such as inhibition (MARTIN-RHEE; BIALYSTOK, 2008; SABOURIN; VINERTE, 2015; SALVATIERRA; ROSSELLI, 2010), task switching (PRIOR; MACWHINNEY, 2010) and working memory (ARDILA, 2003; FONTES & SCHWARTZ, 2011; KEIJZER, 2013), as well as the consequences of bilingualism for the mind and brain (BIALYSTOK; CRAIK; LUK, 2012; COSTA; SEBASTIÁN-GALLÉS, 2014).

In what concerns executive functions, working memory (WM) is known to play an important role in complex cognition (MIYAKE; SHAH, 1999), in which language processing and the acquisition of a second language (L2) is inserted. Considering the consequences of bilingualism to these general cognitive functions, it seems important to acknowledge that the term 'executive function' is in fact an umbrella term which refers to higher cognitive functions, such as inhibition and working memory (NGUYEN; ASTINGTON, 2014). Working memory in this sense is part of this general executive control system. This perspective differs from that of Baddeley and Hitch (1974), for instance, in which working memory comprises a central executive component, whose functions may be similar to those of the general executive (e.g., inhibition, shifting and updating) (SOLIMAN, 2014). For Engle and colleagues (e.g., ENGLE, 2002; ROSEN; ENGLE, 1998), working memory refers to a 'central executive capacity', which is in itself an 'executive attention' mechanism. Rosen and Engle (1998) claim that "working memory capacity is simply another name for individual differences in central executive functioning" (p. 434). Being aware of these perspectives seems necessary for comprehending how research on WM and bilingualism has been conducted in the field of psycholinguistics and cognitive psychology.

Considering thus the relevant role WM plays in complex cognitive task performance as well as in L2 learning, the goal of this article is to review relevant empirical research regarding the interplay of bilingualism and working memory capacity (WMC) in order to better understand what the main findings on this relationship are. For that, this paper is organized in a way to: a) address the construct of WM and give a brief overview of its development; b) discuss the issue of bilingualism, considering some general understandings regarding its definition and also possible advantages and disadvantages to the cognitive system; c) and finally, examine the relationship between WM and bilingualism, pointing out consistent findings of research up to now and also considering possible future directions.

1. Working memory: conceptualization and scope of investigation

The term 'working memory' emerged more than 30 years ago. In the beginning, the concept used in psychology was that of a short-term memory (STM) and it concerned solely the temporary storage of small pieces or chunks of information during brief periods of time (e.g. MILLER, 1956; SIMON, 1974). It was only later (BADDELEY; HITCH, 1974) that the term evolved to become widely used in cognitive psychology as referring to both maintenance and processing endeavors (BADDELEY, 2010), even though still today no consensus has been reached in terms of its definition, operationalization and measurement (ALPKETIN; ERÇETIN, 2009). In general terms, WM can be seen as part of the human cognitive system which is responsible for the temporary and simultaneous storage and manipulation of information understood as necessary for a wide range of complex cognitive activities, such as comprehension, reasoning, and problem solving, among others (e.g. BADDELEY, 2003; DANEMAN; CARPENTER, 1980; MIYAKE; SHAH, 1999; AUTOR, 2003; 1999-2000; 1996).

Different models of WM have been proposed throughout the years, such as Baddeley and Logie's Multi-component model, Cowan's Embedded-Processes model, and Engle, Kane and Tuholski's Controlled Attention framework, among others (see MIYAKE; SHAH, 1999 for a review of these and other models). Each model attempts to tackle WM in particular ways. Cowan's model, for instance, considers levels of activation as an important aspect for understanding WM. In his embedded model, WM is, generally speaking, an activated portion of long-term memory (LTM). All pieces of information entering WM need to be activated at some level: if a piece is in the spotlight, that is, at the 'focus of attention', it is highly activated, though other pieces may also be maintained in WM with lower levels of activation, not being then on the spotlight. In Engle and colleagues' model, WM refers to a unitary and domain-free system "consisting of LTM traces active above threshold, the procedures and skills necessary to achieve and maintain that activation, and limited-capacity, controlled attention" (ENGLE; KANE; TUHOLSKI, 1999, p. 102). While Cowan and Engle consider the functions or processes as important elements of WM, Baddeley and colleagues concentrate on its structures in order to explain how the construct is organized.

Baddeley and Hitch's (1974) multi-component model is the most widely accepted model of WM. In this model, WM is a limited capacity system responsible for the temporary storage and manipulation of information in order to perform different cognitive verbal and non-verbal tasks (BADDELEY; LOGIE, 1999). Three separate though interactive components are part of the system: the executive control and two 'slave subsystems', the phonological loop and the visuospatial sketchpad. The central executive is the attentional mechanism in charge of managing the two slave subsystems and integrating them with other components of the cognitive system. The phonological loop is engaged in storing and manipulating verbal material, while the visuospatial sketchpad maintains and processes visual and spatial information. Later on, Baddeley (2000) added one more component to the model – the episodic buffer – which is dedicated to storing the sub-products of the two verbal and visuospatial subsystems and connecting them to long-term memory (LTM).

Regarding the assessment of WM, there seems to be a great deal of task type variation in the literature, probably because it is a complex construct to be operationalized. In line with other researchers in the area (e.g. BADDELEY, 2012; MIYAKE; SHAH, 1999; JUST; CARPENTER, 1992), in this study, we are considering measures of working memory capacity only those which tax both functions: storage and processing. Simple span tasks such as the word span or the digit span, only measure storage functions and are not considered appropriate to account for the complexities of working memory processes. Complex span tasks, or dual-tasks, such as the Operation Span (OSpan, TURNER; ENGLE, 1989) and the Reading Span task (RST, DANEMAN; CARPENTER, 1980), usually require subjects to recall some items while concurrently performing another activity which also demands attention; therefore, they tackle storage together with processing. In the OSpan participants are required to perform simple mathematical operations as they try to memorize words, whereas in the RST, they have to read and comprehend sentences as they try to memorize their last words for later recall. In both cases the set of words that have to be memorized and recalled increase as the test moves on. Some researchers, such as Fortkamp and Bergsleithner (2007), for example, following Daneman and Green (1986), have also used the Speaking Span Test (SST) which measures WMC in L2 oral production tasks. The SST follows the same principles of the RST, that is, it also measures 'processing' (by asking participants to produce sentences) and 'storage' (by requiring that they memorize a set of words to be later recalled, at the same time as they produce the sentences). Considering the great amount of possibilities, Foster et al., (2014) suggest the use of more than one measure or multiple indicators when investigating WMC so that more reliable results can be reached. In relation to investigations in L2, a decision that has to be made by researchers is whether the working memory task proposed is going to be in the L1, in the L2 or in both languages. According to

Linck, Osthus, Koeth, and Bunting (2013, p.12), "to the extent that the WM task performance requires L2 use, *the task will be an indicator of both WM abilities and L2 proficiency*, and therefore will not purely measure WM" (our emphasis). This means that to avoid extraneous confounds, the authors advise researchers to use working memory measures in the participants' L1; otherwise, we are not going to be able to conclude whether the results we got are due to real capacity of the system (WM limitations) or to the participants' actual proficiency (or lack of) in the L2.

WM has been shown to be a predictor of a number of higher level cognitive tasks such as reading comprehension (ALPTEKIN; ERÇETIN, 2009; AUTOR, 2003; 1999-2000, 1996; DANEMAN; CARPENTER, 1980), language comprehension, vocabulary learning, following directions, reasoning, complex learning (ROSEN; ENGLE, 1998), playing bridge and learning to write computer programs (ENGLE, 2002). However, individual differences in WM will matter most when there is some type of task interference together with the need for information to be maintained for a brief period of time, or when there is a need for control and monitoring because the task may lead to inaccurate actions, or even when performance might be enhanced by the suppression of these inaccurate actions (ROSEN; ENGLE, 1998). In addition, when designing WM tasks, an optimum level of complexity must be considered in order to avoid ceiling and floor effects, that is, so that the task is neither extremely easy (that scores for all subjects will be high) nor quite difficult (all scores being low).

2. Bilingualism: advantages and disadvantages

Early research on bilingualism in the past decades has focused on how children acquire and process two languages at the same time and what mechanisms allow it to happen (e.g., BIALYSTOK, 2001). Nowadays, evidence has piled up in the sense of confirming the parallel activation of two languages in the bilingual brain both for comprehension and production (BLUMENFELD; MARIAN, 2007; MARIAN; SPIVEY, 2003, cited in SOLIMAN, 2014). This dual language activation requires attentional control for language selection; thus, the executive system takes the responsibility for assisting with this switching, selecting, and inhibiting of one language in favor of the other (SOLIMAN, 2014, p. 168).

Defining what bilingualism entails is a difficult endeavor, as it relates to a large classification of speakers. In general terms, simultaneous bilinguals are those that acquire two languages from birth, while successive bilinguals are those that acquire a second language (L2) after they have acquired their first language (L1); of this last group, some researchers may separate those who are 'early' or 'late' bilinguals as well, considering whether they acquired the L2 before or after the age of twelve (COSTA; SEBASTIAN-GALLÉS, 2014). Despite differences in terms of age or context of acquisition, proficiency levels may also vary, and overall these aspects together may prove a methodological challenge for studies investigating bilingualism.

Despite difficulties regarding the definition of what a bilingual is, it is well accepted that the bilingual experience can affect the brain and mind, that is, it can modify the structure and functioning of the brain. As Bialystok, Craik and Luk (2012) advocate, "lifelong experience in managing attention to two languages reorganizes specific brain networks, creating a more effective basis for executive control and sustaining better cognitive performance throughout the lifespan" (p. 3). The consequences of bilingualism are then said to extend language processing: they reflect domain-general cognitive functions, and it is all possible due to brain plasticity, that is, the capacity of the brain to adapt in this context of dual language use (KROLL; DUSSIAS; BICE; PERROTTI, 2015).

There seems to be now strong evidence suggesting a bilingual advantage in executive functioning (e.g., BIALYSTOK, 2007; BIALYSTOK; CRAIK; KLEIN; VISWANATHAN, 2004; BI-

ALYSTOK; CRAIK; LUK, 2012), though some may advise caution claiming for possible publication bias (BRUIN; TRECCANI; SALA, 2015). When matched in age and other background elements, bilinguals have demonstrated to perform better at tasks requiring inhibition, task switching and even working memory. Recent evidence has also shown the association of lifelong bilingualism with a delay in the initial stages of dementia, such as Alzheimer's disease (BIALYSTOK; CRAIK; LUK, 2012). This advantage is named 'cognitive reserve' and it "refers to the resistance of certain aspects of cognition to brain damage" (COSTA; SEBASTIÁN-GALLÉS, 2014, p. 337).

Despite the positive aspects regarding bilingualism, some disadvantages have also been reported, such as the bilingual costs for verbal processing leading to decreased fluency. It seems that while better at nonverbal tasks, bilinguals show poorer performance in verbal tasks when compared to monolinguals. This is mainly due to their reduced lexical knowledge which is distributed across the languages they know (BIALYSTOK; POARCH; LUO; CRAIK, 2014). Thus, considering both the pros and cons just mentioned, it is essential to acknowledge that not much is yet known about whether bilinguals may also show advantages in terms of WM performance, and this is the topic we turn to next.

3. Working memory and bilingualism: main research findings

The relationship between WM and bilingualism seems not to be well understood yet, perhaps due to the overlap of the functional processes between EF (Executive functioning) and WM (Working memory), that is, the close relation that these concepts have in several models (LUO ET AL., 2013). Studies that have attempted to investigate such a relationship are still scarce and, considering these few pieces, results have been mixed: some bringing evidence of a bilingual advantage, some showing no such effect. Nevertheless, there seems to be a tendency for bilingual benefits to be observed: 7 out of the 11 studies [2]here described provide positive evidence regarding WM and bilingualism for both children (e.g., MORALES; CALVO; BIALYSTOK, 2013) and adults (BIALYSTOK; POARCH; LUO; CRAIK, 2014), as shall be seen in the following paragraphs.

Morales, Calvo and Bialyatok (2013) conducted two studies in order to investigate WM in monolingual (English) and bilingual (English and other languages) children using an adapted Simon task[3] that manipulated WM demands and a visuospatial span task. In the first study with 56 5 year-olds, a bilingual effect on EF was found: bilingual children were faster and more accurate in the incongruent trials compared with monolinguals. In the second study with 125 5 to 7 year olds, a bilingual advantage was also found, with bilingual children outperforming their monolingual peers in the visuospatial span task. Another study, carried out by Blom, Kunty, Messer, Verhagen and Leseman (2014), found a bilingual advantage for children (ages 5 and 6), but this time having controlled for vocabulary and socioeconomic status (SES). Here, socioeconomically disadvantaged children who were Turkish-English bilinguals (*n* =68) outperformed their monolingual peers (52 Dutch children) in verbal and visuospatial WM tasks. An adapted version of the Automated Working Memory As-

[2] The 11 articles selected for close consideration in this paper were identified in the CAPES Periodicals Portal (www.periodicos.capes.gov.br) under the general heading of Arts and Humanities, Linguistics, Neuroscience and Psychology. Of those titles initially returned by the search engine, 11 were selected as answering to the terms of increasingly more refined searches [search-strings: working memory, bilinguals, and bilingualism; working memory, bilingual (in the title); working memory, advantage (added together with bilingualism/bilingual)] and a selection process based on the perusal of the first ten pages to ensure their entire relevance to the topic in question.

[3] According to Bialystok et al (2005) the Simon task is a "nonverbal task that can be used to examine the extent to which bilinguals and monolinguals differ in inhibitory control".(p.41).

sessment (AWMA) was applied in Dutch, as well as four other tasks for measuring verbal and non-verbal WM performance: a) the Forward and the Backward Digit Recall; and b) the Dot Matrix and the Odd-One-Out tasks. The findings here that bilingual performance was mostly superior for highly demanding WM tasks, such as the Backward Digit Recall and the Dot Matrix, converges with evidence of recent studies which also found bilingualism as affecting EF. This result, as the researchers explain, corroborates other studies which have investigated low socioeconomically disadvantaged children (CARLSON; MELTZOFF, 2008; ENGEL DE ABREU ET AL., 2012; CALVO; BIALYSTOK, 2014; cited in BLOM ET AL., 2014, p. 115) and also acknowledged bilingualism as being responsible for enhancing inhibition and attentional control, effects not dependant on socioeconomical background, according to the authors.

Soliman (2014), in a study about the relationship between WM and bilingualism, investigated older children – 8 to 12 years olds. In this study, the bilingual (Arabic and English, *n* =306) and the monolingual (Arabic, *n* =309) children underwent a battery of 12 WM tests. The great number of tasks intended to measure each of Baddeley's four components: a) digit recall, word list recall, and nonword list recall (phonological loop); b) block recall, visual pattern scan and maze memory (visuospatial sketchpad); c) backward digit span, listening recall and counting recall (central executive); and d) category fluency, paired recall, and memory for stories (episodic buffer) (p.171). Overall, bilingual children outperformed the monolingual group in the four factors that represented each of the WM components.

Bialystok, Craik, Klein and Viswanathan (2004), investigating adults in an Indian context, found that bilinguals (Tamil and English) outperformed monolinguals (English) in three different tasks: the Simon task (with extra memory demands), the alpha span task and the sequencing span task. Participants were young and older adults (overall mean ages of 43 and 71, respectively). Bilinguals in both age groups performed better: they were faster in the Simon task (especially in the incongruent condition) and could handle better the higher demands of having to hold four rules instead of two in WM. This may serve as evidence that the bilingual advantage might be more salient in situations requiring higher processing demands (p. 298). Also, bilingual advantage was greater for older adults, allowing the understanding that "the lifelong experience of managing two languages attenuates age-related decline in the efficiency of inhibitory processing" (p. 301).

In a study with Dutch/English bilinguals and monolinguals, Keijzer (2013) investigated WMC, inhibitory control and the role L2 proficiency played in aging. The study was carried out with a total of 63 highly proficient bilinguals (Dutch and English), together with 54 Dutch and 56 English monolinguals. Participants were all adults who belonged to three distinct age groups: ages 40 to 50, ages 60 to 70, and age 71+. For measuring WM performance, the RST was used, and for inhibition, a Stroop task[4] was used; both tasks were applied in both L1 and L2. Overall, results showed younger adults performing better than older adults for WM in inhibition tasks (though a decline in WM efficiency was observed for the oldest group, corroborating the aging literature – p. 1273). Age here seemed to play a bigger role than proficiency, since the older bilinguals – who had higher L2 proficiency (schooling effect and more time of experience) – performed worse that the youngest ones in both the WM and inhibition tasks. On these two aspects, WM and inhibition, there seems to be a difficulty in research to separate them. As Keijzer explains, it is still not clear yet whether they tap into different or similar constructs.

[4] In the Stroop Task usually participants are asked to name colors where the name of the color might be incongruent with the ink color (McLeod, 1991). The result is called the Stroop Effect and describes the difficulties posed by the task since participants usually take longer to name colors in incongruent situations.

Luo, Craik, Moreno and Bialystok (2013) also tested younger and older bilingual (*n* =159) and monolingual (*n* =119) adults using different verbal (word span and alpha span) and spatial (Corsi blocks) WM tasks. Younger adults were between 18-35 and older adults between 60-80 years old. Monolinguals had English as their L1 and bilinguals had English as their 'dominant language' and also spoke different L2s, such as Russian, Spanish, Cantonese, Farsi, Punjabi, among others. Results have shown an advantage of bilinguals overall regarding the non-verbal domain: from both groups, the bilingual participants outperformed the monolingual ones in the WM spatial tasks. However, regarding verbal WM, monolinguals performed better than bilinguals in both age groups. This disadvantage of bilinguals regarding verbal WM corroborates previous findings (e.g., BIALYSTOK ET AL., 2008) and is explained by the fact that monolinguals had a higher vocabulary level (p.32).

Bialystok, Poarch, Luo and Craik (2014) conducted two studies in order to investigate the effects of bilingualism and aging on EF (Study 1) and WM (Study 2). Regarding the second study, 108 participants performed complex verbal (letter task) and nonverbal (figure task) WM tasks which assessed proactive interference[5] in WM. There were 36 younger monolinguals (English; mean age of 20 years) and 36 younger bilinguals (English/other languages), as well as 18 older monolinguals and 18 older bilinguals (mean age of 70 years). Results show a bilingual advantage in the nonverbal task and for older adults; also, older adults showed 'reduced interference costs' in the Simon task, considered a complex task (p. 703). Researchers explain that advantages for bilinguals tend to appear in more demanding tasks because they involve processing which is more demanding (p.703); they also explain the advantages for both children and older adult bilinguals as being due to more efficient EFs - which develop in childhood and decline with older adulthood – as well as a 'functional ceiling effect' for younger adults: they are at the peak of their EF abilities, so bilingualism effects are minimal at this stage (p.703).

Differently from the studies just mentioned, Bialystok, Craik and Luk (2008) found no bilingual benefit regarding WM. The study investigated cognitive control, WM and lexical access in a total of 96 younger (20 year-olds) and older monolingual (English) and bilingual (68 years; English/other languages) participants. Measures for assessing WM performance were the forward and backward Corsi blocks test, together with a self-ordered pointing task. Results showed that the performance of bilinguals resembled that of monolinguals in the WM tasks, though the younger bilinguals were able to recall longer strings in both forward and backward conditions if compared with younger monolinguals (p. 869). Researchers explain that WM may be in fact 'a family of related constructs rather than a unitary entity' (p. 870) and that bilingualism may affect WM tasks in different ways, so further studies are needed in order to clarify the issue.

Namazi and Thordardottir (2010) explored the relationship between verbal WM, visual WM, and controlled attention (CA) in 5-year-old bilingual (15 English/French) and monolingual (15 French and 15 English) children. A listening span, a nonword repetition, a digit span, and an adapted version of the Pattern Recall Test were used for measuring WM, as well as the Simon Task (an inhibitory control task) for measuring CA. In the study, a bilingual advantage was not found either: bilinguals and monolinguals showed equivalent performances on the WM tasks, though children with better visual WM performed better on the Simon task.

Engel de Abreu (2011) questioned the bilingual effect issue by conducting a 3-year longitudinal study with multilingual children (mean age of 6 years) from public schools in Luxembourg. The participants were 22 monolingual and 22 simultaneous bilingual children with Luxembourgish as the L1, and other languages (e.g., German, Dutch, French, Portuguese, among others) as the L2. In the

[5] According to Ashcraft (1994), proactive interference (PI) represents "any interference in which material presented at one time interferes with material presented later" (p.679).

study, children were followed from kindergarten until second grade. In the school curriculum, children start with German classes (8 hours a week) in the first grade and with French in the second grade (3 hours a week), both being official languages. Instruments for measuring WM were a counting picture recall and a backwards digit recall task (complex span tasks). The author also used two simple span measures as controls: a digit recall and a nonword repetition task. Contrary to predictions, results did not show the bilingual effect as being higher in older children due to 'prolonged L2 exposure' (p.535). Here, monolinguals performed better than bilinguals in WM tasks. Possible explanations brought by Engel de Abreu include the following: first, bilingual experience might impact more on mechanisms in charge of conflict resolution/inhibition, for instance, and tasks here did not tackle that. Besides, WM may be more associated with updating, which may not be easily connected with inhibition or switching. The last aspect mentioned by the author is that perhaps the participants were too young to rely on cognitive mechanisms – switching might be more automatic for them.

Finally, Kudo and Swanson (2014) also conducted a longitudinal study with children, in which they investigated whether bilingual proficiency (vocabulary) was related to WM performance, using Baddeley's component measures. The bilingual children - English language learners (mean age of 7 years and 10 months) from grades 1, 2 and 3, who mainly spoke Spanish at home - were compared across different groups: emerging bilingual (if scores were below 85 in both the English and the Spanish vocabulary tests), English dominant bilingual (if scores on the English vocabulary test were 85 or above), Spanish dominant bilingual (if scores on the Spanish vocabulary test were 85 or above), and additive bilingual (if scores on both the Spanish and the English vocabulary test were 85 or above) (p. 97). They were individually tested (60 minutes total) through the use of several different tasks: a conceptual span, a listening sentence span, a rhyming word span and an updating task (for the central executive), a forward and backward digit span, a phonetic memory span, and a word span (for the phonological loop), a mapping and directions span, as well as a visual matrix task (for the visuospatial sketchpad) regarding WM performance, together with a battery of tests to measure vocabulary and fluid intelligence (see p.97). Results show no evidence for bilingual advantages on WM (in any of the components) neither when bilingual children were compared to language dominant children (either in Spanish or English), nor when bilingual groups whose status had been maintained were compared (p.100). However, for children 'transiting' from the Spanish dominant to additive bilinguals, an advantage was observed in the executive control, that is, they performed better in tasks related to the executive component: Conceptual Span, Listening Span task, Rhyming and Updating; and for those transiting from English dominant an advantage on the phonological loop was found, that is, they performed better in the measures related to the phonological loop component: Forward and Backward Digit Span, Phonetic Memory Span task, and Word Span task. Researchers suggest a language development explanation: when vocabulary proficiency in both languages reaches a later developmental level, improvements in WM might be better observed. This explanation is in line with the processing efficiency view of working memory advocated by many authors (e.g. DANEMAN; CARPENTER, 1980; JUST; CARPENTER, 1992; AUTOR, 2003; 1999-2000; 1996), in which it is asserted that, during language processing, there is a trade off in terms of working memory resources that must be distributed between storage of the by-products of comprehension and manipulation of the incoming information being processed. Any deficiency concerning the knowledge that feeds the system, or in terms of the execution of the sub processes involved in language processing, may overburden working memory capacity. Vocabulary knowledge is vital in language processing since it feeds decoding (in matching the printed word with the correspondent meaning in memory), lexical access (in disambiguating meaning in the context of the sentence) and also in inferential comprehension (in using the meaning of the words in context in order to activate relevant schemata in memory and provide inferences to: integrate clauses, sentences and paragraphs;

construct the main ideas in the text; and elaborate on the textual information to connect with other 'texts' in memory). Therefore, it is plausible to think that, as vocabulary knowledge develops, working memory is somehow set free, having more resources available to execute other processes.

4. Final remarks

The goal of this article was to present the main findings of studies which have investigated the relationship between WM and bilingualism. Eleven articles were explored here, being that 7 of them reported a bilingual WM advantage and 4 reported no differences between bilinguals and monolinguals when WM performance was the focus of concern. Thus, there seems to be a tendency for observing a WM advantage due to bilingualism. However, due to the limited number of studies, the question of whether WM performance is affected by bilingualism should remain open – there is still little evidence as to whether bilingualism is related to the improvement of memory in general and of working memory in particular (BIALYSTOK, 2009, p. 6). Further studies are thus needed to clarify this relationship and allow for generalizations to be made.

Considering the diversity of instruments (especially WM tasks) and methods employed by studies, future investigations can replicate previous experiments or design new ones - longitudinal or cross-sectional, making use of behavioral together with neuroimaging techniques - taking into consideration relevant aspects such as different groups, age of acquisition, proficiency, languages used, learning context, among other factors that might influence the relationship. Furthermore, more research on the nature and underlying processes of WM is also needed, so that we can better grasp in which specific ways it might differ or relate to EF, for instance. It is only after more empirical evidence emerges that the question - of whether bilingualism impacts positively (or not) on one's WM performance - might be more appropriately answered.

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