Assessing the working memory capacity of L2 young learners – A historical overview

Avaliando a capacidade de memória processual de crianças aprendizes de L2 – Uma breve revisão histórica

Evaluación de la capacidad de la memoria de trabajo de niños que aprenden una L2 – Una visión histórica

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Melissa Bettoni
ORCID: https://orcid.org/0000-0002-2522-1083
Instituto Federal de Santa Catarina, Brasil
E-mail: mebettoni@gmail.com.br
Taisa Tarso
ORCID: https://orcid.org/0000-0003-1122-3157
Instituto Federal de Santa Catarina, Brasil
E-mail: tarsotaisa@unochapeco.edu.br

Abstract

This study aimed at identifying data gathering instruments used for assessing the Working Memory Capacity (WMC) of L2 young learners and providing a historical overview of them and their administration in published studies. Studies found in search engines using a combination of the terms ‘L2 acquisition’, ‘young learners’, ‘working memory’, and ‘assessment’ had their abstracts examined to identify whether the maximum age of the participants was 12 years old. Twelve studies were selected and along with seminal work on working memory acquisition are described and discussed. Some commonalities were found among the studies. Regarding language of participants, the commonest L2 is English and the commonest L1 is Spanish. When verbal measures of WM are used, they usually occur in both L1 and L2 or only in the L1. Studies have found that WM affects L2 acquisition and L2 acquisition affects L2 acquisition of young learners. Research is still scarce and important works deserve replication considering other language combinations and controlling other variables. Assessing young L2 learners’ WMC can be based on, but must be different from assessing adult learners’ WMC. Also, care has to be taken to ensure that the instruments assess WMC and not language proficiency.

Keywords: Working memory; Second language acquisition; Young learners; Assessment.

Resumo

Este estudo teve como objetivo identificar instrumentos de coleta de dados usados para avaliar a Capacidade de Memória Processual (CMP) em L2 jovens alunos e fornecer uma visão histórica deles e de sua administração em estudos publicados. Estudos encontrados em mecanismos de busca usando uma combinação dos termos ‘aquisição L2’, ‘crianças aprendizes’, ‘memória processual’ e ‘testagem’ tiveram seus resumos examinados para identificar se a idade máxima dos participantes era de 12 anos. Doze estudos foram selecionados e junto com o trabalho seminal sobre aquisição de memória de trabalho são descritos e discutidos. Alguns pontos em comum foram encontrados entre os estudos. Com relação ao idioma dos participantes, o L2 mais comum é o inglês e o L1 mais comum é o espanhol. Quando medidas verbais de MP são usadas, elas geralmente ocorrem tanto em L1 quanto em L2 ou somente em L1. Estudos descobriram que a MP afeta a aquisição L2 e a aquisição L2 afeta a aquisição L2 de jovens aprendizes. As pesquisas ainda são escassas e trabalhos importantes merecem ser replicados considerando outras combinações linguísticas e controlando outras variáveis. A avaliação do CMP de jovens alunos L2 pode ser baseada, mas deve ser diferente da avaliação do CMP de alunos adultos. Além disso, é preciso ter cuidado para assegurar que os instrumentos avaliem o CMP e não a proficiência linguística.

Palavras-chave: Memória processual; Aquisição de segunda língua; Crianças aprendizes; Testagem.

Resumen

El objetivo de este estudio es identificar los instrumentos de recogida de datos utilizados para evaluar la capacidad de la memoria de trabajo (CMT) en jóvenes estudiantes de L2 y proporcionar una visión histórica de los mismos y de su administración en los estudios publicados. Se examinaron los resúmenes de los estudios encontrados en los motores de búsqueda utilizando una combinación de los términos ‘L2 acquisition’, ‘young learners’, ‘working memory’ y ‘assessment’ para identificar si la edad máxima de los participantes era de 12 años. Se seleccionaron doce estudios y se

describen y discuten, junto con los trabajos fundamentales sobre la adquisición de la memoria de trabajo. Se encontraron algunos puntos en común entre los estudios. En cuanto al idioma de los participantes, la L2 más común es el inglés y la L1 más común es el español. Cuando se utilizan medidas verbales de la memoria de trabajo, éstas suelen darse tanto en la L1 como en la L2 o sólo en la L1. Los estudios han encontrado que la MT afecta a la adquisición de la L2 y la adquisición de la L2 afecta a la adquisición de la L2 de los jóvenes estudiantes. La investigación es todavía escasa y los trabajos importantes merecen ser replicados considerando otras combinaciones lingüísticas y controlando otras variables. La evaluación del CMT de los jóvenes estudiantes de L2 puede basarse en la evaluación del CMT de los estudiantes adultos, pero debe ser diferente. Además, hay que tener cuidado de que los instrumentos evalúen el CMT y no el dominio de la lengua.
Palabras clave: Memoria de trabajo; Adquisición de una segunda lengua; Niños que aprenden; Evaluación.

1. Introduction

Learning a second language (L2) involves a diversity of cognitive and social skills. Such complexity has triggered research on the role of individual differences on L2 acquisition speed and ultimate attainment. Variables such as age, executive functions (cognitive flexibility, inhibitory control, and working memory), and attention have been shown to explain differences in development rate and help in the pedagogical decision making in schools. Not only do cognitive skills affect L2 learning, but they are also affected by it. Bialystok (2010), for instance, states that early bilinguals have a stronger inhibitory control because they are forced at an early age to make fast decisions when switching between languages. A lot of what is known about L2 acquisition has changed in the last years, though, due to neuroimaging techniques that have helped us understand what actually happens in our brains before, during, and after any type of learning or task performance. However, neuropsychological pencil and paper as well as computerized testing remain as important data gathering instruments for their accessibility, low costs, and specificities which make them complementary and irreplaceable in a thorough evaluation.

Working memory (WM) has been extensively researched with L2 learners and is, probably, one of the cognitive constructs which has most often correlated with measures of attainment and speed in early stages of acquisition. In order to understand the concept of WM, it is necessary to have in mind that “memory is the means by which we retain and draw on our past experiences to use that information in the present” (Sternberg & Sternberg, 2012, p.187). Memory is responsible for encoding, storage and retrieval of information; thus, it is responsible for learning. WM is the type of memory responsible for holding data in our minds for a short period and manipulating them (Baddeley, 2020). For instance, how we hold prices at the supermarket in our minds and add them up to guarantee we are going to be able to pay for the goods. Also, WM has to do with retrieving the price we paid for something the week before, holding it in our minds, and comparing it with the price we have just seen. Initially investigating the role of short-term memory (a temporary memory store) on cognition, Baddeley and Hitch (1974) found difficulties on dealing with links to long-term memory. Then, Baddeley and Hitch (1974) proposed a model for WM which has been updated during the years by Baddeley (1974, 1981, 1992, 2000).

In the updated model of WM, four main components are identified: a Phonological Loop, a Central Executive, a Visuospatial Sketchpad and an Episodic Buffer. Each component has a specific and multi-task function. The Central Executive corresponds to the control center of the system with a limited processing capacity (Baddeley, 1981). It is also plausible to say that the Executive control “is responsible for binding information from a number of sources into coherent episodes. Such episodes are assumed to be retrievable consciously” (Baddeley, 2000, p.421). While the subsidiary systems, the Phonological Loop and the Visuospatial Sketchpad, serve the Executive Control. The Phonological Loop is a temporary phonological store in which the very-fast decaying auditory memory can be rehearsed for revival and the Visuospatial Sketchpad is able to store visual and spatial information (Baddeley, 2000). The additional component, the Episodic Buffer, is then responsible for the integration of information from different sources (Baddeley, 2000). It also brings perception to the model by incorporating sensory stimuli.

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Studies have indicated that people vary in how much information they can hold and manipulate in their WM system and named this amount of information WM Capacity (WMC) (Logie, Camos & Cowan, 2021). A fruitful area of research on WMC concerns controlling the age variable. In order to do this, it is necessary to have data on both early and late learners. Carrying out research with children is challenging, though. The present study aimed at understanding how children's working memory has been assessed when the focus is on L2 acquisition. Two research questions (RQ) were proposed:

RQ1: What instruments have been used to assess the working memory capacity (WMC) of L2 young learners?

RQ2: What are the difficulties encountered by researchers when aiming at assessing L2 young learners' WMC?

In the next sessions, explanation of the working memory construct and the method of the present study are going to be presented. Then, we are going to review some studies that assessed young learners' working memory in order to identify the instruments used to assess it.

2. Method

The present study is a literature review of research on L2 young learners and WMC and follows the method used by Oliver and Azkarai (2017). Oliver and Azkarai (2017) emphasize the need for literature review studies on children L2 acquisition. The present study aimed at understanding how children's working memory has been assessed when the focus is on L2 acquisition. In order to reach this goal, we present a historical overview of how L2 young learners' WMC has been assessed throughout the years, including the most common instruments and their limitations. A combination of the terms 'L2 acquisition', 'young learners', 'working memory', 'children', 'listeners', and 'assessment' were used as filters in search engines such as Google Scholar and Portal Capes Periódicos without setting a time period. Articles were selected after reading their abstracts and seminal works on the area served to provide a background review on the construct of WM. The research articles, for the purposes of the present study, were filtered for 12 years old to be the maximum age of the participants.

3. Analysis and Discussion of the Results

For matters of organization, a brief discussion of the relationship between WMC and language acquisition is presented. Then, common instruments to assess WMC are introduced. Finally, focusing on WMC assessment, we briefly describe twelve studies from 1995 to 2020 which dealt with 12 and under L2 learners.

3.1 Working memory capacity and language acquisition

People learn most of their vocabulary during childhood. In childhood, there is a stronger relationship between the Phonological Loop and language acquisition can be identified (Baddeley, Gathercole & Papagno, 1998). Studies have shown that the Phonological Loop serves as a "temporary storage of unfamiliar phonological forms while more permanent memory representations are being constructed" (Baddeley, Gathercole & Papagno, 1998, p. 165). This way, the Phonological Loop mediates the language learning process. In fact, the Phonological Loop, also known as the articulatory loop, is one of the most studied components of the WM model. According to Baddeley, Gathercole and Papagno (1998), "The loop is specialized for the retention of verbal information over short periods of time; it comprises both a phonological store, which holds information in phonological form, and a rehearsal process, which serves to maintain decaying representations in the phonological store" (p. 164).

In order to investigate some aspects of first language acquisition, Baddeley and Gathercole (1989) tested a group of kids aged around 8 years old who had a specific language impairment (SLI). The kids were asked to answer some verbal memory tests. Later, the SLI kids were compared to another group of typical and younger children. The SLI group performance was worse than the group of typical younger children's performance leading Baddeley and Gathercole to conclude that "[…] there is a stable association between vocabulary knowledge and repetition performance which cannot be attributed to the more general cognitive factors of intelligence or chronological age." (Baddeley, Gathercole & Papagno, 1989, p. 211). Baddeley, Gathercole and Papagno (1989) continued to test children over time and assumed that a good phonological memory may facilitate vocabulary acquisition and that there is a strong correlation between WMC and long-term memory since over time children with good phonological memory acquire new vocabulary with ease (Baddeley, 2003).

The Visuospatial Sketchpad has the important role to connect visual and spatial information for later manipulation (Baddeley, 2003). Another study conducted by Baddeley (2003) tested people with Willians Syndrome and other two control groups, one with typical people and the other with people with mild general learning disability. Grammatical forms of gradually increasing complexity were presented to the test group. The Willians Sydrome group performed approximately equally, but a little lower, especially on the tasks which involved spatial terms, such as above and below. This result may indicate that "cognitive capacities and the ability to maintain and manipulate information of a visuospatial nature is likely to play an important role in language comprehension" (Baddeley, 2003, p. 201).

The relationship between WM and language development in children with specific language impairment was also object of Adams and Gathercole (2000) in a study that investigated whether short-term memory deficit was associated to differences in language acquisition in children. More specifically, the study examined whether the language/memory relationship extended across processing domains to the visuo-spatial component of working memory (Adams & Gathercole, 2000). The results suggested that there is an advantage for children with better phonological memory for vocabulary repertoire, and for longer and more syntactically complex utterances.

When we discuss language acquisition considering children, first language (L1) acquisition studies are seminal. Based on such L1 studies, research interest for L2 acquisition has been very productive. Bialystok (2010) mentions that bilingualism has the potential "to modify cognitive processes and brain structure" (p. 559). Thus, research has been carried in the relationship between cognitive processes and variables of second language acquisition to understand how, to what extent and the consequences of these changes. Having seen that WM influences language acquisition, the relationship between WMC and L2 acquisition has been thoroughly studied (Mitchell, O' Malley & Konstantinova, 2015).

3.2 Assessment of working memory capacity

The first instruments used to assess memory were memory span tasks which date back to 1884. The span tasks were used to assess short-term memory (only storage) and consisted of a series of stimuli with immediate reproduction (Humpstone, 1919). In the memory span tasks, the stimuli can vary from digits to syllables to words, and they can be presented: "auditorily, visually, articulatory, graphically or in combination of two or more" (Humpstone, 1919, p.196). Based on the memory span tasks, instruments for assessing WMC focus on both storage and processing of information, and can be presented as "listening span, reading span, digit span, speaking span, counting span and operation span tasks" (Mitchell et al., 2015, p. 273).

The Reading Span Tasks (RST) have been used in many studies because reading is a complex skill related to many cognitive processes. The RST was designed to reach both storage and processing functions (Harrington & Sawyer, 1992) and was designed by Daneman and Carpenter (1980). The RST is a word span task with a secondary task, in this case, reading comprehension of sentences. Participants read sets of sentences, with varying numbers of sentences per set, and manipulate them in some way; for instance, verifying the accuracy of the sentences while focusing on remembering the final words of each sentence (Conway et al., 2005). There are different ways of applying an RST, for instance: "[...] a subject is required to read successive sentences in a set while simultaneously remembering the final word of each sentence. At the end of each set, the subject attempts to recall all the final words in the sentences in the set". (Harrington & Sawyer, 1992, p. 27). The number of words to be remembered increase during the test and the WMC of an individual is believed to be directly related to the number of remembered words. Later, Daneman and Carpenter (1980) introduced new elements, such as true or false, that could be associated to many knowledge areas, and participants were asked to judge the information.

Based on the RST, Turner and Engle (1989) associated the reading skill to mathematics operations and developed the Operation Span Task (O-span task). Their aim was to investigate whether the nature of the secondary task, using an arithmetic based task instead of a reading based on, would provide different results. They believed it was necessary to use very demanding processing tasks to notice individual's difference in performance.

> The operation span task requires the subject to solve simple mathematics operations while remembering words for later recall. The subject is presented with an operation word pair and they are required to read the operation, say yes or no whether the given answer is correct or incorrect, and say the to-be-remembered word aloud. After a series of operation word pairs the subject is presented with a recall cue and instructed to recall all the words in correct serial order. (Conway, Kane & Engle, 2003, p.549)

By changing the modality of the stimulus from visual to auditory, the RST can become a Listening Span Task (LSP). The variation was also developed by Daneman and Carpenter. Another variant of span tasks is the Speaking Span Test (SST) which was developed initially by Daneman and Green (1986). On the SST, "subjects silently read a set of words displayed individually on a computer video screen for one second each, and then, at the end of the set, they used each word to generate aloud a sentence containing that word." (Daneman & Green, 1986, p.11). The SPT, the LSP, the RST, and the O-span task require individuals to remember words of a specific language which end up linking WMC to proficiency in a specific language. A different way to assess someone's WMC is by using a Counting Span task. It requires subjects to count shapes and remember the total (Conway et al., 2005). As Conway and colleagues (2005) explain "[…] subjects orally counted (and pointed their finger at) the green dots presented against a white background. Yellow dots, interleaved with the green dots, disrupted the visual patterns of the green dots" and added "The task presented three items of each size from one to five, in ascending order." (p. 773).

The span tasks can be administered in order to assess the WMC of an individual of any age. According to Vaupel (2001) Cohen in 1997 developed a more specific scale to assess learning and memory functions on children aged from 5 to 16 years old. The Children's Memory scale (CMS) involves three main domains: Auditory/Verbal, Visual/Nonverbal, and Attention/Concentration (working memory). Among the objectives of the CMS is providing tasks that allow screening of learning and memory disorders, evaluate the relationship between memory and intelligence, and provide an instrument which could accurately evaluate development. However, assessing WMC on bilinguals is different from assessing WMC on monolinguals. Mitchell and colleagues (2015) state that we must be careful when choosing the tests in order to avoid measuring L2 abilities instead of WMC. If we administer an RST, for instance, we don't know whether we are measuring the WMC or the reading skills/proficiency in L2.

Adults' WM differ from children and adolescents' WM (Gathercole et al., 2004). For instance, Gathercole and colleagues (2004) explain that "before 7 years of age, spontaneous rehearsal does not reliably occur" (p.177), but phonological memory can be assessed by simple span tasks in three-year-old children (Gathercole & Adams, 1993). Gathercole and colleagues (2004) studied WM of children of different ages, and they suggested that at the ages of 5 and 8 "[…] the phonological loop and the visuospatial sketchpad were independent of one another" (Gathercole et al., 2004, p. 178) and by the ages of 6 and 7 "[…] central executive and the phonological loop were separable but moderately associated with one another

[…]" (Gathercole et al., 2004, p. 178). Furthermore, assessing young learner's WMC requires specific tasks and criteria for participants' selection (Gathercole et al., 2004). We are going to review, in the chronological order of their publications, the twelve studies with under twelve-year-old participants we were able to select in which WMC of young L2 learners was assessed. The L1 and L2s, the age range of the participants, and instruments used for WMC assessment are displayed in Table 1.

Fontoura and Siegel (1995) tested 37 bilingual children living in Canada who were instructed mainly in English at school and spoke Portuguese at home. The participants were aged 9 to 12 years old. Aiming at examining the relationship between reading in both languages, among other instruments, they applied two WMC tasks, one in Portuguese and one in English. Both tests were reading span tasks and consisted of a series of sentences missing a final word presented orally to children. The task was first used by Siegel and Ryan (1989). The children were expected to complete the sentence and repeat all the missing words in order at the end of a set of sentences with set size varying from two to 5 sentences. The same sentences were used in Portuguese and in English. Some of them were very intuitive, while others not that much. An example was: '*Na primavera, o fazendeiro planta*_____' and 'In the spring, the farmer plants_____'. There was a correlation between results in the English and in the Portuguese WMC task.

Table 1 – Studies assessing WMC in young L2 learners.

Study	Participants		Instruments for assessing WMC
	Languages	age	
Fontoura & Siegel (1995)	L1 Portuguese; L2 English	9 to 12 years old	Reading Span Tasks
Gutierrez-Cellen, Calderón & Weismer (2004)	L1 Spanish; L2 English	7 and 8 years old	Competing Language Processing task (CLPT) and the Dual Processing Comprehension Task (DPCT)
Swanson et al. (2011)	L1 Spanish; L2 English	6 to 9 years old	Forward and Backward Digit Span, a Word Span, a Pseudoword (nonwords) Span, a Conceptual Span task, an LST, and a Rhyming Span Task
Gorman (2012)	L1 Spanish; L2 English	5 to 6 years old	A Complex Span Task (listening)
Morales, Calvo & Bialystok (2013)	Various L1s; L2 English	5 years old	The Simon Task
Nicolay & Poncelet (2013)	L1 French; L2 English	5 years old	a French complex nonword repetition task
Chrysochoou et al. (2013)	L1 Greek; L2 English	5.5 to 9.5 years old	Short-term memory task was assessed through a word, a digit and a nonword recall list and a word list matching. WM was assessed by a listening, a counting, and a backward digit recall.
Ebert (2014)	L1 Spanish; L2 English	5 to 11 years old	a recall task and a tonal pattern matching task
Verhagen & Leseman (2016)	L1 Turkish; L2 Dutch	5 years old	a word span task, a Dutch-Unlike nonword recall task, a Dutch-like nonword recall task, a backward digit recall task, and a listening recall task in Dutch
Efstathiad (2016)	L1 Greek; L2 English	6 to 8 years old	Listening Span Task and Backward digit span task
Janus & Bialystok (2018)	Various L1s; L2 English	8 to 11 years old	Emotional Face N-Back Task
White (2020)	Various L1s; L2 English	5 to 6 years old	Two phonological WM tasks with nonwords and a complex non-verbal visuospatial WM task (odd-one-out).

Source: Authors.

Gutierrez-Cellen, Calderón and Weismer (2004) aimed at investigating cross-linguistic differences in verbal WM between bilinguals (L1 Spanish and L2 English) and children with limited proficiency in an L2. The authors tested 26 boys and 18 girls aged 7 and 8 years old who lived in the region of Southern California. Twenty-two were equally proficient in both

English and Spanish, eleven were more proficient in English than in Spanish, and the other eleven were more proficient in Spanish than in English. Verbal WM is a unitary view of the WM and it presents both attentional (central executive) and rehearsal (phonological loop) functions. The tests administered included the Competing Language Processing task (CLPT) and the Dual Processing Comprehension Task (DPCT) in English and in Spanish.

The CLPT consisted of 42 English sentences, three words in length each. The sentences were presented in groups of two to six sentences and children had to answer "true" or "false" and recall the last word of each sentence in the end of each row. Differently from the previous study carried out by Fontoura and Siegel (1995), in this study by Gutiérrez-Cellen, Calderón and Weismer (2004), when the sentences were translated into Spanish, the syntactically well-formed sentences were kept. Spanish requires articles before nouns changing the length from English to Spanish. Even though, the researcher changed the length to 4 words each sentence, the integrity of languages was preserved. The DPCT consisted of 20 commands with 8 to 9 words with 9 to 10 syllables in English and with 8 to 10 words with 15 to 18 syllables in the Spanish version. The commands were to manipulate tokens (circles and squares) or objects (toy house, truck, shoe, star, and boat). The commands were audio-recorded by bilingual adults and headphones were used by the children. The dual processing corresponds to children either listening to two different sentences simultaneously (competing condition) or only one sentence (noncompeting condition) through their headphones. The results revealed no significant differences on language processing between proficient bilinguals and monolinguals. Also, the results revealed no significant differences attributed to proficiency among bilinguals' cross-language performances. The findings showed no significant differences across languages corroborating the idea that Verbal WM performances is not based on language specificities. (Gutiérrez-Cellen, Calderón & Weismer, 2004).

Also, considering L1 Spanish and L2 English bilingual children in California, Swanson and colleagues (2011) investigated the relation of WM and children L2 reading and acquisition. Participants were 472 students from grades 1, 2 and 3, from 6 to 9 years old, mean age of 95.85 months. Among several tasks, three were administered to assess the Phonological loop: a Forward and Backward Digit Span, a Word Span, and a Pseudoword (nonwords) Span. All digit spans increased in number starting from 2 words/digits to 8 words/digits. The Forward and Backward Digit Span required participants to recall a sequence of auditorily presented digits and in the Word Span tasks the stimuli were sets of common, but unrelated words. After each row, they should recall them in the correct order. In the Pseudoword Span task, participants listened to nonwords. Three other tests were administered for assessing the Central Executive component of WM: a Conceptual Span task, an LST, and a Rhyming Span Task. All of them were administered in English and in Spanish.

The Conceptual Span task required participants to form categories with the words they listened. That is, after listening to the words, they should say the words which fit in the same category. The LST consisted of a series of sentences in which participants should remember the last word of each sentence in the row. Finally, in the Rhyming Span test, participants listened to sets of words that rhymed. "Students were first told a word set, such as 'lip-slip-clip,' after which they were asked whether 'ship or lip' had been presented. They were then asked to recall the previously presented words '*lip-slip-clip'* in order" (Swanson et al., 2011, p. 843). The number of words in each set increased progressively reaching 14 monosyllables. Finally, to assess the Visual Sketchpad, two tests were administered, a Visual Matrix, and a Mapping and Directions. For the Visual Matrix, participants were shown a series of dots in a matrix. Five seconds later, they were asked questions, in English and in Spanish, for instance: "Are there any dots in the first column?" (Swanson et al., 2011, p.843). For the Mapping and Directions test, children were presented to a city map filled with a bicycle route and stop lights. Ten seconds were allowed for participants to memorize the map. After that, they were asked where the stop lights were and what the city route was. Participants should draw them in a blank matrix. All tests were administered in English and in Spanish and data gathering was either carried out individually or in small groups. Results indicated that WMC growth can predict L2 reading comprehension growth and there is a cognitive advantage for bilingual children.

Gorman (2012) carried out another study involving participants speakers of L1 Spanish and L2 English. Gorman investigated the relationships between vocabulary size, verbal WM and Phonological Awareness. Participants were 35 kindergarten children, aged 60 to72 months, in Texas and Midwest, all were better speakers of Spanish than English and this was important to investigate the effects of vocabulary on Phonological Awareness. A Complex Span Task was developed to assess WMC. Sentences were read to children who had to say whether they were true or false. After a set of sentences, participants should repeat the last word of each sentence. Gorman (2012) found that young L1 Spanish children had difficulties in understanding linguistic aspects, such as color, shapes, size and sequence, for instance, as in the sentence "what was the *last* word of each sentence?" (Gorman, 2012, p. 113). Vocabulary related to food and family members were more familiar to then. So, Gorman (2012) adapted the tests. Children had to say yes or no to confirm trustfulness of sentences and repeat, by the end, the foods that could be eaten. Results indicated that there are significant interrelationships between, vocabulary size, WM, and phonological awareness.

In the following year, Morales, Calvo and Bialystok (2013) published an article reporting two studies that investigated performances of bilingual and monolingual children. In the first study, the participants were 56 five-year-old children, bilinguals and monolinguals, the bilinguals were from 14 different native languages and the language spoken in school was English. Parents were questioned about how long and how often children had contact to the language and parents' social background. The tests included two background measures and a Simon-type task for assessing WM. The Simon Task required participants to hold in mind a group of either two or four response rules that demand minimal or complex Executive control. The test was composed of a series of 2 and later 4 stimuli in which children were supposed to hold the information and manipulate it. The authors explain that a purple flower and a red heart were presented one at a time in the center of the screen and participants had to press a specific key according to the stimulus shown. This part of the test was called Center-2. The next step of the test was called Conflict-2 and consisted of the same condition, but the stimuli appeared either on the right or on the left of the screen creating congruent and incongruent trials. Finally, the last step of the test was the Center-4 which consisted of 4 pictures stimuli instead of just 2 as in the Center-2. The stimuli were a blue cloud, a green tree, a yellow smiley, and a pink star. Results pointed to differences in performing the 2-center stimuli and 4-center stimuli, which can be related to the ability to hold information. Most of the participants performed better on non-conflicting tests and were better at congruent trials.

In the second study, a visuospatial span task was used in order to minimize the language differences between monolingual and bilingual participants, since there was an age difference among them – 5 years old and 7 years old. The same group of 56 five-year-old children from the first part of the study and an additional group of 69 seven-year-old children, bilinguals and monolinguals, were the participants. Age differences interfered on the ability to perform certain kind of tasks, "5-year-old are not yet capable of carrying out complex working memory tasks that involve manipulation of information, whereas 7-year-old have developed this skill" (Morales, Calvo & Bialystok, 2013, p. 195). Whereas in the first study, there was simple memory recall, in the second study, older children were required to recall more complex information. For the test, children were shown a 3x3 matrix with each of the 9 cells representing ponds. Frogs appeared either in groups or individually. Participants had to recall the ponds where frogs appeared and/or the order they appeared. Stickers were giving to children at the end of participation as a reward. Results indicated that bilinguals outperformed monolinguals in the WM tasks.

Nicolay and Poncelet (2013) carried out a four-wave longitudinal study with kindergartens aiming at investigating the relationship of cognitive skills and L1-French, L2-English five-year-old children. Language assessment occurred once a year for three years and WMC along with other cognitive skills were tested in the first session only. The authors assessed the children vocabulary knowledge, their speech perception, and their WMC. They referred to WM as phonological short-term memory, but as they used a complex span task, they assessed not only storage, but processing as well. For the French complex nonword repetition task, participants should repeat back five three-nonword series with increasing number of syllables from two to six. Results indicated that L2 vocabulary development is related to WMC and speech perception.

Chrysochoou and colleagues (2013) investigated 216 Greek learners of English. Participants' age varied between 5.5 and 9.5 years old. The study aimed at investigating the contributions of verbal short-term memory and WM to vocabulary development in early stages of acquisition. Children were grouped according to their ages and results were compared. Language knowledge was assessed by a receptive vocabulary task. Short-term memory task was assessed through a word, a digit and a nonword recall list and a word list matching. WM was assessed by a listening, a counting, and a backward digit recall. All short-term memory and WM tasks were part of the WM Test Battery for Children (WMTB-C) translated and adapted to Greek. They consisted of blocks of six trials each and increasing spans. Results showed that both short-term memory and WM correlate with L2 vocabulary acquisition.

Ebert (2014) investigated auditory non-verbal WM and sentence repetition performance in bilingual children with language impairment qualified for special education. Participants were 47 L2 English and L1 Spanish speakers aged from 5 to 11 years old. They all spoke Spanish at home and had English as the main language of instruction at school. There were two data-gathering instruments, a recall task and a tonal pattern matching task. The recall task was administered in both languages. Children were asked to recall sentences ranging from 6 to 19 words. As in Morales, Calvo, Bialystok (2013), the age was taken into consideration and the number of items in sentence repetition varied according to the age. For the tonal pattern matching task, children listened to a pair of tone sentences and had to tell whether they were the same or different. Storing the first sentence while processing the second was required. Results indicated that auditory non-verbal WM predicts variance in sentence repetition.

Two years later, a study by Verhagen and Leseman (2016) investigated whereas verbal WM is related to L2 grammar learning in the classroom and in a naturalistic setting and whether L1 learning differs from L2 learning in this sense. Another variable considered is type of grammar content. The participants were five-year-old children, 63 Turkish who learned Dutch as an L2 and 45 Dutch monolinguals. The instruments administered were a word span task, a Dutch-Unlike nonword recall task, a Dutch-like nonword recall task, a backward digit recall task, and a listening recall task in Dutch. There were also vocabulary and grammar tasks which could tire the children, so tests were split into two weeks (one day per week) and breaks were given between sessions. Also, as in the previous study, children were given stickers by the end in order to motivate and praise them. Results indicated Verbal short-term memory (storage only) was a strong predictor of vocabulary and grammar learning and VWM was a significant predictor for grammar. Also, when learning L2 grammar and vocabulary naturalistically, children employ the same memory mechanisms of L1.

Efstathiad (2016) investigated the cognitive impact of Early Foreign Language learning on Phonological short-term memory and verbal WM. Participants were 98 Greek children, aged from 6 to 8 years old from two schools in Greece. 49 participants were assigned to the experimental group and had the early instruction in English (two years before the Greek standard). Phonological short-term memory was assessed by a simple repetition task and verbal WM was assessed by a listening span task based on Daneman and Carpenter (1980) and by the backward digit span test. The LST requires recall of semantically and phonologically unrelated words with progressive increasing difficulty involving both the central executive and the phonological loop. The LST was administered in Greek. An English vocabulary test assessed language knowledge. Results indicated that the early foreign language program had positive effects on the WMC and that there is a strong correlation between WM components and early foreign language vocabulary performance.

A more recent study, Janus and Bialystok (2018) investigated WM with emotional distractions for bilingual and monolingual children. Participants were 93 children, aged from 8 to 11, 48 of them were monolinguals and 45 were bilingual speakers of various languages. School instructions were in English for all children. Something new from studies reviewed until now is that only caregivers were questioned about language use at home. The objective was to investigate if bilingualism-related advantages in Executive Functions could be found on emotional settings. Instructions for the test were given in the classroom, a relevant aspect which was not taken into consideration on other studies. This way, children could feel safer being in a familiar environment. The main task was the Emotional Face N-Back Task, initially developed by Ladouceur and colleagues (2009), that was designed to examine the interference of emotions while performing a WM task. "The task consisted of two memory conditions (1-back and 2-back), with blocked emotional (angry, happy) and neutral conditions, for each level of difficulty" (Janus & Bialystok, 2018, p. 5). Letters appeared in the middle of the screen and children were asked whether it was equal the previous letter whereas two faces appeared simultaneously every time. "In the 2-back condition, participants decided whether the current letter matched the trial that was presented two trials previously (target) or not (non-target)" (Janus & Bialystok, 2018, p. 5). Results indicated that children performed better on easier levels. Janus and Bialystok (2018) stated that bilingual children demonstrated better cognitive performance than monolingual on both WM conditions. The results showed that bilingual children scores were 6% to 9% higher. By the end of the N-Back test, children got a certificate to be thanked on the participation.

Finally, White (2020), in a three-wave longitudinal study, investigated the relationship between WMC and language performance in English L2 learners over one year. Participants were 27 English L2 learners aged between 5 and 6 who were enrolled in the first grade in a mid-low socioeconomic status school in South Africa. Along the year, three testing sessions (beginning, middle, and end of the school year) were carried out. Breaks were given during the sessions when children showed signs of fatigue. In each session, the same English proficiency and WM tasks were administered. The English proficiency tasks were a vocabulary task and a language assessment battery. The WM tasks were two phonological WM tasks with nonwords and a complex non-verbal visuospatial WM task (odd-one-out). One of the phonological WM tasks involved repetition of nonwords which followed English phonotactics and the other was identical except that instead of English phonotactics, it followed the most common phonotactics across languages. The simple tasks were gamified with a computer software. The complex task was the odd-one-out task which assessed the central executive component testing both storage and processing. By using a non-verbal task, the researchers avoided low proficiency interference in the results. Three stimuli, simple black and white drawings, were presented on a screen and children had to point to the different shape. Participants were also asked to remember the position of the odd item. The task progressively increases in difficulty by asking the children to remember up to six positions. WM was shown to be implicated in the acquisition of L2 syntax, semantics, pragmatics, and vocabulary.

4. Final Considerations

Research with L2 young learners involving WM is still scarce. Assessing young learner's WMC requires following careful procedures, in that depending on the way you administer a specific task, it can either assess the learner's L2 abilities or the learner's WMC (Mitchell et al., 2015). Some of the more recent studies reviewed managed to reward children for their participation and take measures to prevent overtiring them and demotivating them. Eleven out of the twelve studies reviewed had English as the L2 and the commonest L1 was Spanish (four out of 11). A few studies considering WMC were carried out with very young children, but considering L2 learners, five years old was the youngest age we could identify.

A few limitations can be identified when aiming at investigating WMC of L2 young learners. One of them is that the age differences among participants of the same study may be problematic considering that some participants could be literate and others illiterate. In this case, using a Reading Span Task, for instance, is neither possible nor reliable. Gathercole and colleagues (2004) mentions that each age has its specificity which must be taken into consideration when assessing WMC. It is important to understand that literacy is not the only difference across ages – children's cognition is under fast development and WMC can vary a lot. Besides age, participants' variables such as proficiency levels, learning contexts, cultural and socioeconomic backgrounds need to be controlled. Most of the studies analyzed opted for delivering a questionnaire to parents and teachers and considered the caregiver's context in order to have a more accurate diagnosis of language level and context of learning of the participants.

Since the first multicomponent WM model proposed by Baddeley and Hitch (1974), WM has been extensively researched and the methods have evolved as the hypothesis have been either refuted or corroborated. Over the years, different methods have been improved in order to confirm hypothesis or even to refute some. Among the most used tasks to assess young learners' WMC are the Digit Span and the Visuospatial Span tasks. In addition, when children are literate, Reading Span Tasks are quite popular. Besides literacy and brain developmental stages, emotion also interferes with data gathering more frequently with children than adults, perhaps due to their inability to properly use their inhibitory control. In order to overcome the shortcomings which may be imposed considering emotions and, more specifically, motivation during data gathering sessions, researchers have implemented protocols like schoolteachers to constantly praise and encourage them avoiding interfering with the results.

The studies reviewed in the present study point to a lack of consistency in terms of how WMC is assessed. Studies reviewed here should be replicated changing and controlling variables with different L1 and L2 combinations. Also, the field of Psycholinguistics has a lot to offer in terms of pedagogical implications. As another suggestion for further research, a systematic review could be carried out about how teachers and psychologists have dealt with individual differences such as WMC, attentional control, inhibitory control and higher order cognitive functions such as planning in the classroom setting.

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