



Reading comprehension: contribution to verbal working memory in single-sex Primary Education
Comprensión lectora: contribución de la memoria de trabajo verbal en Educación Primaria diferenciada

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Abstract

The results of the international tests indicate the need to improve reading comprehension in Mexican students. Verbal working memory is a cognitive process involved in reading comprehension. The aim of this research is to study the possible correlations between verbal working memory and reading comprehension that students of single sex education have during the first year of primary education. The sample consist of 105 students aged between 6 and 9 years old ($M=7.35$, $SD=1$) from a single sex school of Jalisco (México). The instruments used are the text comprehension test (PROLEC-R) to assess reading comprehension and letters and numbers (WISC-IV) to evaluate verbal working memory. Results of the linear regression indicate that verbal working memory predicts reading comprehension. Educational implications are proposed to enhance reading comprehension during acquisition courses in single sex education.

Resumen

Los resultados de las pruebas internacionales indican la necesidad de mejorar la comprensión lectora en los estudiantes mexicanos. La memoria de trabajo verbal constituye un proceso cognitivo implicado en la comprensión lectora. El estudio analiza la relación entre la memoria de trabajo verbal y el nivel de comprensión lectora que tienen las alumnas de educación diferenciada durante los primeros cursos de educación primaria. La muestra está formada por 105 alumnas con edades entre 6 y 9 años ($M=7.35$, $DT=1$) de un colegio de educación diferenciada de Jalisco (México). Los instrumentos utilizados son la prueba comprensión de textos del PROLEC-R y la prueba Letras y números (WISC-IV) para evaluar memoria de trabajo verbal. Los resultados de la regresión lineal indican que la memoria de trabajo verbal predice la comprensión lectora. Se proponen las implicaciones educativas para potenciar la comprensión lectora durante los cursos de adquisición en educación primaria diferenciada.

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Introduction

The development of reading skills is one of the most relevant issues in today's educational landscape, both due to its involvement in learning acquisition and to the development of competences that allow students develop their social and cultural skills successfully.

According to the results obtained in the last international report on education (Organisation for Economic Cooperation and Development [OECD], 2016), Mexico ranks 58 out of a total of 70 participating countries, and Mexican students scored an average of 423 points in reading performance, below the average of 493 points, 42% of the students being below Level 2, the level considered as the level of proficiency that enables students to show skills of productive and effective participation in today's society (OECD, 2016). The results of these international assessment studies show that the educational system needs to be improved in terms of reading skills, according to Schleider (2007) "excellence is an attainable goal that can be achieved at a reasonable cost" (p. 6). Such improvement will both be in the interest of those students with suitable reading literacy to enable them to attain full capabilities, and also in the interest of those students with poor performance to enable them to attain a minimum level that allow them to develop themselves both educationally and personally.

Students need robust reading competence to allow them understand, use and reflect on written texts from various languages, as it is the key to their personal, social and professional development. Although there are many processes involved in reading comprehension, recent studies (Gómez-Veiga, Vila, García-Madruga, Contreras & Elosúa, 2013; McVay & Kane, 2012) show the importance of verbal working memory, a good predictor of future readers. For this reason, this situation leads us to explore which factors may have a positive impact on reading comprehension to boost them both in the school and in the family environment. This

research is conducted in this context, analysing the role played by verbal working memory in reading comprehension in the early grades, when reading comprehension is acquired.

Current status

Do learning and reading competence development during primary education require verbal working memory, among other factors?

From a traditional point of view, in education reading comprehension has always been seen as an activity that focuses on decoding signs to build a meaning, under which a passive role is given to the reader in this process (Bahamondes & Rozas, 2004). Nowadays, this concept is contextualised within a wider paradigm, where reading comprehension is the result of the existing interaction between the text and the reader, who also extracts information from the text, interprets it and reflects thereon, acting as an active actor (Gómez-Veiga *et al.*, 2013).

OECD (2013) conceptualises reading comprehension "as the capacity to understand, to assess, to use and to get involved in written texts, to participate in society, to attain proposed goals and to develop the greatest possible knowledge and potential" (p. 1); years later, in this same line OECD (2016) defines reading competence as "understanding, using and reflecting on written texts to attain personal goals, to develop one's own potential and participate in society" (p. 49). Both definitions explicitly reflect the importance of reading competence as a requisite for the successful students' evolution in the future.

In order to reach an adequate level as regards reading comprehension, the student has to be able to understand the overall meaning of the text, to extract information from it, to interpret it and to reflect on it. To that end, the interactive models (Kintsch, 1998; Kintsch & Van-Dijk, 1978) conceive reading comprehension as a result of the existing interaction between the text and the reader, and although several models were developed in the last decade, the

most representative model was developed by Kintsch & Van-Dijk (1978), which was subsequently updated by Van-Dijk & Kintsch (1983) and by the Kintsch's construction-integration model (1998). This model (Kintsch, 1998) shows that, in order to get a mental representation of the text, the reader goes through a series of representation levels: in the first level, meaning units are analysed, a literal copy of what is being read; in the second level, the macrostructure is built, which is an overall representation of what is being read, combining a network of ideas called microstructure on the one hand, and the link between propositions that generated more abstract, non-explicit ideas from the text, called macropropositions; in the third level, a situation model is created, in which inferential processes are triggered, linking the information from the text and the reader's background knowledge. Therefore, reading comprehension enables to understand the text's implicit and explicit data and to create a situational model that is consistent with the reader's background knowledge and the ideas outlined in the text (Van-Den-Broek *et al.*, 2005; Van-Dijk & Kintsch, 1983). Several studies (Van-Den-Broek, Mouw & Kraal, 2016) show that background knowledge make it easier to generate the situational model of the text that is being read.

According to Sánchez & García-Rodicio (2014), different types of representations or types of comprehension can be obtained:

- Superficial understanding: the reader understands the text based on the information thereof using minimal background knowledge. In this level, tasks related to the extraction of ideas, decoding, issue identification, generation of summary ideas and linear integration thereof are performed.
- Deep understanding: the reader integrates the information provided by the text and his/her background information, creating a situational model. In this level, background knowledge is triggered and inferences are made.
- Critical understanding: the reader reflects on the text, creating goals and plans, assessing

the text-context- link, identifying and resolving any potential incoherence.

Nowadays, neuroimaging techniques reveal that different brain areas are activated when reading comprehension activities are performed (Marmolejo-Ramos, 2007), which shows that the medial prefrontal cortex is involved in the selection and management of information; that the lateral prefrontal cortex of the side of the brain is involved in the idea management process; that the temporoparietal junction is involved in the production and comprehension of text, and also linked to inferential processes that enable the allocation of states of mind; that the anterior temporal lobe is in charge of linking sentences and prepositions and of supporting the construction of states of mind; and that the posterior cingulate cortex is in the association of new information to background knowledge, by modulating emotions when ideas are retrieved. The information collected thanks to neuroimaging provides scientific robustness to the behavioural data obtained from tasks inherent to reading comprehension.

Reading comprehension is a complex activity where several factors related to the type of text, the reader's goals, the socio-cultural context, the background knowledge and cognitive processes are involved (Cain, Oakhill & Bryant, 2004; Kintsch, 1998). This work focuses on working memory, a specific cognitive process of the reader that is necessary to process reading comprehension (Van-Dijk & Kintsch, 1983).

Working memory is one component of the executive function, which enables to keep information actively for a certain amount of time to perform a task. According to Baddeley (2012), it is an active memory system responsible for storing and processing the information needed to perform complex cognitive tasks simultaneously. The working memory model with a greater amount of empirical evidence is that of Baddeley & Hitch (1974), reformulated subsequently, based on a simultaneous processing in which several subsystems are interrelated (Baddeley,

2012): the central executive subsystem, responsible for planning and coordinating the activities, a phonological loop or bond that stores, which keeps linguistic information active and manipulates it, a visuospatial sketchpad that processes visual and spatial information, an episodic buffer that integrates information of a different nature and also facilitates linkage with long-term memory. More specifically, this study focuses on the phonological loop, which makes up verbal working memory. This subsystem processes information of a linguistic nature and is made up of two elements: a phonological store where verbal information is kept for a short period of time and a subvocal articulatory review process that allows for keeping information (Baddeley, 2012). The functioning and structure of this phonological loop is scientifically supported by the experimental effects under study (Baddeley, 2012), such as the word length effect, which shows that those words with more syllables require a longer-lasting pronunciation and are less remembered than those with less syllables; the articulatory suppression effect, which consists on performing a memory task while repeating irrelevant verbal material out loud at the same time, blocking articulatory review and reducing memory; the phonological similarity effect, which shows that the more phonologically similar words are, the worse the memory will be; and the irrelevant speech effect, based on inferencing a task using meaningless syllables, making reminiscence work worse. These effects are linked to the nature of the two components of working memory: on one hand, the similarity effect together with irrelevant speech and phonological store and, on the other hand, the length and articulatory suppression effect together with the articulatory review process.

The phonological loop procedure (Baddeley, 2012) is as follows: when information is presented verbally, it accesses to the phonological store directly and makes an articulatory overview or not depending on whether information is intended to be kept or not; but if information is presented visually, it needs to

be articulated subvocally in order for it to be presented phonologically and to keep information in the phonological store. Verbal working memory's functionality is linked to learning new words and to language structure itself, as well as to learning new vocabulary, phonological processing of words and reading acquisition (Vallar & Shallice, 2007). At a neurophysiological level, those studies using neuroimaging show that several anterior and posterior regions of the brain are activated when performing activities related to verbal working memory activities (Lazar, 2017). Ravizza, Delgado, Chein, Becker & Fiez (2004) found that the left supramarginal gyrus is activated when verbal information is stored on the short term; in other words, the temporal and parietal areas are activated, while Broca's area is activated during articulatory review.

Different studies (Kintsch, 1998; Unsworth & McMillan, 2013) highlight how working memory is involved in the development of reading comprehension, noting its relevance to keep the information from the text actively, to discard irrelevant information from the text and to draw attention during the reading process. Such findings have aroused interest in analysing the individual differences that could be determined by verbal working memory in the context of reading comprehension. McVay & Kane (2012) state that working memory is a significant predictor of reading comprehension. A study conducted by Cain *et al.* (2004) showed that verbal working memory and reading comprehension are very closely linked; such authors also noted that verbal memory tasks explain the differences in reading comprehension better than other predictors such as decoding or word and vocabulary recognition. Carretti, Borella, Cornoldi & De-Beni (2009) conducted a comparative study on good and bad readers to determine the impact of several working memory domains on reading comprehension, and they concluded that there is a significant difference between the tasks where the verbal component and attention control in working memory were

involved. González *et al.* (2016) assessed verbal working memory, fluency, vocabulary and reading comprehension, and determined that the level of verbal working memory affects the level of reading comprehension. Gómez-Veiga *et al.* (2013) state that working memory is involved in reading comprehension at different levels: at a word level, by retrieving and keeping the text's meaning according to the context; at a sentence level, by processing and keeping the ideas conveyed in each sentence; and at a text level, by allowing to build the text's meaning mentally.

Therefore, research has shown the link between reading comprehension and working memory at throughout different educational stages (Swanson & Alloway, 2012). On the other hand, other studies do not find any specific link between verbal working memory and reading comprehension (Canet-Juric, Burin, Andrés & Urquijo, 2013; Savage, Lavers & Pillay, 2007), and identify other neurophysiological processes, such as inhibitory control, processing speed, naming pace and reading fluency.

All the studies outlined above that analyse the link between reading comprehension and working memory are conducted among population samples that do not belong to single-sex education; in other words, such samples include both genders. Nevertheless, there are no studies analysing the link between reading comprehension and working memory in single-sex education (only male or only female students), taking into account that this type of educational establishments exist in Mexico and in most countries. For this reason, this study is presented in order to identify the existence of such link between reading comprehension and verbal working memory in single-sex education in the primary levels of Primary Education.

Objectives of the research

The objectives of this research are the following:

- 1) To assess reading comprehension and verbal working memory in female students of Primary Education.
- 2) To analyse the link between reading comprehension and verbal working memory.
- 3) To determine whether working memory forecasts the students' reading comprehension.

Methodology

Participants

The sample of this study is purposive, selected by non-probability sampling based on accessibility; therefore, the female students were free to participate therein at all times with the consent of their legal custodians.

The sample is made up of 105 girls aged between 6 and 9 ($M= 7.35$; $SD= 1.00$) studying year 1 and year 3 of primary education from a private catholic school in the city of Jalisco (Mexico), an example of single-sex education. The sample is distributed by levels as follows: 35 students of year 1, 35 students of year 2 and 35 students of year 3.

The criteria followed to include them in the sample were the following: they had to be students of the first three levels of primary education at that educational establishment, the consent of their parents/legal custodians was given, they had neither learning difficulties nor any neurological or psychological problems and they had not been applied the tools used for at least 6 months.

Measurement tools

The PROLEC-R (Cuetos, Rodríguez, Ruano & Arribas, 2014) test was used to assess their reading comprehension; such test assesses reading processes among children aged between 6 and 12. More specifically, in this study to assess reading comprehension, only the written text comprehension subtest is used. In this task,

the students read four texts and answer a few questions related to each of them. They get one point for each right answer, added together to get their final score. Interpretation is performed using the scales used for a Spanish population, and its reliability had a Cronbach alpha coefficient amounting to .79.

The Numbers and letters subtest of the Wechsler Intelligence Scale for Children (Wechsler, 2005) was used to assess verbal working memory. This overall scale to assess intelligence and cognitive processes is aimed at children aged between 6 years and 0 months and 16 years and 11 months. In the Numbers and letters subtest, a series of numbers and letters mixed with each other is read to the child, who then has to repeat them; in first place, he/she has to say the numbers correlatively and the letters in alphabetic order. The child gets one point for each right answer, added together to get his/her final score. Interpretation is performed using the scales used for a Spanish population, and its test-retest reliability amounted to .77.

Data collection procedure

In first place, the General Management and the Academic Planning Department of the establishment was contacted to introduce the study. Once it was accepted, the informed consent form was sent to the families of students of year 1 and 3 of primary education, where the goals thereof were explained. Once the informed consents were obtained, the students were invited to take the tests and were guaranteed the confidentiality of their data. The academic coordinator was responsible for scheduling the students' assessment and, in order for the study to be conducted, she was offered a well-lit, quiet classroom to avoid disruptions.

Each assessment was performed individually in the presence of the researcher in approximately 30-minute sessions, once the parents/legal custodians of the students signed the informed consent. In the same session, the

Numbers and letters test was applied in first place and the Text comprehension test was performed subsequently. The application order was the same for all respondents.

Data analysis

The data are analysed using the SPSS version 23 software. The statistical analyses performed in this study are, on one hand, descriptive analyses using statistical descriptives as a mean and a standard deviation to describe the variables' values and, on the other hand, the Pearson correlation coefficient to analyse any potential link between the two variables; additionally, a linear regression analysis was performed to determine if verbal working memory is a predictor of the students' reading comprehension.

Results

When performing the descriptive analyses of the variables under study, the mean was used to measure the central tendency and the standard deviation was used as a dispersion rate of reading comprehension ($M=10.46$, $SD=3.13$) and verbal working memory ($M=12.51$, $SD=3.49$). According to the sample's educational level, the statistical descriptives for reading comprehension are the following: year 1, $M=9.83$, $SD=3.86$; year 2, $M=11.62$, $SD=2.27$; year 3, $M=10.50$, $SD=2.09$. As far as verbal working memory is concerned, the descriptives are the following: year 1, $M=11.90$, $SD=4.04$; year 2, $M=13.50$, $SD=2.70$; year 3, $M=12.66$, $SD=3.02$. The scores obtained by the students from the various levels are within the normal range, both in terms of reading comprehension and verbal working memory.

An analysis of the differences in the means by year was performed to determine their influence on such results; it was found that there are no significant differences between the three levels both in terms of reading comprehension and verbal working memory. The results obtained in the analysis of the differences in the means for reading comprehension are: year 1/year 2, $t=$

1.69, $p = .09$; year 2/year 3, $t = 1.50$, $p = .14$; year 1/year 3, $t = 0.67$, $p = .50$. The results for verbal working memory are: year 1/year 2, $t = 1.41$, $p = .16$; year 2/year 3, $t = 0.84$, $p = .40$; year 1/year 3, $t = 0.69$, $p = .49$.

As far as the results of the Pearson correlation between reading comprehension and verbal working memory, it was found that there is a direct statistically significant correlation between reading comprehension and verbal working memory ($r = .657$; $p < .05$). This means that a moderate increase in verbal working memory directly results in a moderate increase in reading comprehension and vice versa.

Regarding the linear regression results, reading comprehension is used as the criterion variable and verbal working memory is used as the predictor. The resulting regression equation may explain 42.3% of reading comprehension through verbal working memory, which is a statistically significant model, $p < .05$.

Discussion and Final Thoughts

The objective of this study is to analyse the link between reading comprehension and verbal working memory in the context on single-sex education in the period in which reading comprehension is acquired and developed, i.e., the first levels of Primary Education. The results obtained show that there is a moderately positive significant correlation between reading comprehension and verbal working memory in single-sex education. Such finding in single-sex education is in line with the data provided on the existence of a link between reading comprehension and verbal working memory in single-sex education establishments. The results obtained in studies conducted with students from non-single-sex education establishments are used due to the lack of studies in population samples belonging to single-sex education. Therefore, the results obtained are consistent with the data obtained in prior studies (Cain & Oakhill, 2007), which identify a significant correlation between

verbal working memory and reading comprehension and verify that performance in verbal working memory tasks is a good predictor of the level of reading comprehension. Several studies (Carretti *et al.*, 2009; Swanson, Howard & Saez, 2006) even highlight the direct link generated when relevant long-term memory contents are activated and retrieved and such contents are integrated with the information from text, when irrelevant contents are refrained, when information in the memory is updated and when attention is drawn to reading activities and focus covers several mental representations or operations.

The regression analysis confirms that verbal working memory explains a significant part of the performance shown in the reading comprehension test; more specifically, it can forecast 42.3% of it. This result is in line with the findings from prior studies (Gómez-Veiga *et al.*, 2013), which show that working memory is involved in reading comprehension. Additionally, such finding shows that keeping relevant information, a task performed by verbal working memory, is directly linked to keeping and activation processes during reading comprehension activities, which verifies the results obtained in prior studies (Swanson *et al.*, 2006). According to Kintsch's construction-integration model (1998), working memory is involved when retrieving and integrating information at a word level because it keeps and retrieves the meaning according to the context provided by the text, at a sentence level because it keeps propositions from each sentence and at a text level because it facilitates the text's situational model.

In short, the data obtained in this study confirm the link between reading comprehension and verbal working memory and provide new evidence in a sample selected at a girls' single-sex educational establishment.

The educational implications that can be implied from this study suggest that reading instruction methods followed in the primary

levels of primary education should not only include training on cognitive processes of a perceptive, lexical or syntactic nature, but should also promote the optimisation of more complex processes involved in text processing and meaning construction, such as verbal working memory. These instruction programmes should teach students metacognitive strategies involved in reading comprehension and in other activities, such as organising and updating information, keeping it, verifying if the technique used is the right one, planning tasks to be performed and their sequence etc. (García-Madruga, 2006). These strategies can be implemented in the classroom through motivating gamified activities that also promote learning, such as repetition and extension exercises, following instructions, making up stories, keeping auditory information, etc. In a study conducted by García-Madruga *et al.* (2013), they obtained positive results as reading comprehension was enhanced upon implementing a working memory training programme among students of year 3 of primary education and Carretti, Borella, Elosúa, Gómez-Veiga & García-Madruga (2017) also identified improvements in terms of reading comprehension and working memory upon implementing a working memory training programme among students of year 3 of primary education. Therefore, in order for primary education students to acquire a suitable reading competence enabling them to gain knowledge in all subjects, executive activities dealing with verbal working memory should be included in daily classwork; some studies also show that individual differences in working memory may affect reading comprehension (Cowan & Alloway, 2009) and, according to Cain *et al.* (2004) and Carretti *et al.* (2009), those students having a good performance in working memory activities use suitable reading comprehension strategies.

Finally, it is worth noting that the sample's selections main limitation of this study, as defined in terms of size, gender, context and geographic area; therefore, extrapolations to

other populations should be done with caution. In future research, it would be advisable to have a broader sample size, selecting non-single-sex educational establishments, using causal design and analysing if there are significant links as those identified in this study using other executive components (planning, cognitive flexibility and inhibition) or even other working memory measurements. It would also be advisable to use another reading comprehension activity to complement it, as the one used in this study does not allow distinguishing the scores obtained in the various cognitive processes involved.

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