The effect of working memory capacity on word recognition speed in Arabic second grade readers[17].

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Abstract

The current study examined the effect of working memory capacity (WMC) on word recognition speed (WRS) in Arabic second grade readers. We start from the hypothesis that WRS performance depends on WMC. Two groups of good and poor readers were tested on measures of WMC and WRS.The results show that high working memory (WM) span readers are more rapid in word recognition (WR) than low WM span readers. We found also high correlations between WMC and WRS, which means that WMC can be a good predictor of word recognition ability in Arabic orthography.

Keywords: Word recognition speed; working memory capacity; Arabic orthography.

ملخص

فحصت الدراسة الحالية تأثير قدرة الذاكرة العاملة على سرعة التعرف على الكلمات لدى أطفال عرب يتابعون دراستهم بالمستوى الثاني الابتدائي. وقد افترضنا أن سرعة التعرف على الكلمات ترتبط بقدرة الذاكرة العاملة. وقيست في هذه الدراسة قدرة الذاكرة العاملة وزمن التعرف على الكلمات لدى مجموعتين من جيدي وضعيفي القراءة. وقد أظهرت نتائج الدراسة أن القارئين الذين كانت قدرة ذاكرتهم العاملة عالية كانوا أسرع في التعرف على الكلمات من ذوي القدرة المنخفضة للذاكرة العاملة. ووجدنا أيضا ارتباطات قوية بين قدرة الذاكرة العاملة وسرعة التعرف على الكلمات، وهو ما يشير إلى أن قدرة الذاكرة العاملة يمكن أن تكون متنبئا جيدا بقابلية التعرف على الكلمات في اللغة العربية.

الكلمات المفتاحية: سرعة التعرف على الكلمات؛ قدرة الذاكرة العاملة؛ الأرطغرافيا العربية.

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Introduction

The current study is concerned particularly with the relationships between word recognition speed (WRS) and working memory capacity (WMC). Reading performance depends largely on the ability to identify words (Lyon, 1996; Share & Stanovitch, 1995a). Therefore, accurate and rapid word recognition (WR) could reflect good reading ability. Previous findings have related difficulties specifically in WR to deficits in WMC (Leather & Henry, 1994; Kail & Hall, 1994; Siegel & Ryan, 1989; Swanson, 2003; Swanson and Ashbakar, 2000; Swanson and Siegel, 2001). Significant correlations have been found between WMC and reading performance (e.g. Swanson, 2003), or adjacent skills such as phonological awareness (Cormier & Dea, 1997; Oakhill & Kyle, 2000). Additionally, dyslexic children have a deficient WM (Siegel & Ryan, 1989).

In an interesting study, Swanson (1993) found that problems experienced by poor readers stemmed from impairments in WMC that permits performing reading operations. This means that differences between poor and skilled readers on measures of reading ability are due to differences in WMC. In another study, Swanson (2003) establishes also that WM span scores of learning disabled readers are inferior to that of skilled readers, which suggest that the difficulties undergone by poor readers are generated by WM deficits.

WM is a workspace in which simultaneous storage and processing of information are carried out, as it was determined in the pioneering work of Baddeley and Hitch (1974). They specified that WM comprises two passive storage buffers (phonological loop and visuo-spatial sketchpad) and processes of attentional control (central executive). Recently, Baddeley (2000) added a third slave subcomponent, episodic buffer responsible for the integration of multi-modal information. WM is then responsible for retrieval and maintenance of information while processing operations are executed (Baddeley, 1986, 1997). So, storing information, only, as is the case in simple memory span or short term memory span tasks (word span, digit span) does not reflect the functioning of WM (La Pointe & Engle, 1990). Furthermore, WM is a limited capacity system (Baddeley, 1997); these limits concern the quantity of information that could be processed at one time (Cowan, 2001).

According to Leather and Henry (1994), complex memory span tasks (counting span, listening span) correlate highly with performance on word recognition. Their results demonstrated that individual differences in word recognition are related to WMC rather than short-term memory span. Contrary to measures of simple short term memory that predict weakly reading ability, WMC assessment is closely linked to performance in reading (Daneman & Carpenter, 1980). For example, Daneman and Carpenter (1980) confirmed that WM span tasks provide more efficient predictions of reading proficiency than do word span

tasks. They argued that simple memory tasks, like digit span, tape only the passive storage capacity, so complex memory tasks that coordinate both storage and processing functions explain efficiently individual differences in reading. Equally, Dufva, Niemi and Voetten (2001) found that phonological memory has a small and weak effect on phonological awareness (an indirect measure of word recognition) in preschool and second grade, and so it has little influence on the development of reading ability and therefore does not predict word recognition. In the same line of evidence, Swanson and Ashbakar's (2000) results indicate also that measures of working memory predict word recognition and comprehension, and that poor achievement of learning disabled readers in word recognition and comprehension reflected deficiencies in WMC.
WM span tasks that measure WMC were designed from Baddeley and Hitch's (1974) conception of WM. These tasks require a simultaneous storage and processing of information; such as reading span (Daneman & Carpenter, 1980), counting span (Case, 1985), operation span (Turner & Engle, 1989) and modified digit span (Daily, Lovett & Reder, 1999). For example, Daneman and Carpenter's (1980) reading span task requires a processing component (reading the sentences) and a storage component (simultaneously storing the last words of the presented sentences), and after a number of sentences, the final words have to be recalled in the order in which they were presented. The number of words recalled in the end of the test was considered as the reading span.
In summary, the memory tasks that the previous studies relate to reading achievement must combine simultaneous storage and processing. In other words, simple memory tasks like word span and digit span limited to storage predict less word recognition ability than complex WM tasks (e.g. reading span).
Word recognition can be direct (visual access to whole phonological forms of words), or indirect mediated by grapheme-phoneme mappings. When word recognition is holistic, the naming of the word is direct and the production of the phonological form necessitates merely associating the visual stimulus (the printed word) with its phonological correspondent in the mental lexicon. However, in the beginning of reading, visual recognition of words was not sufficiently matured; hence, word identification tends to depend on grapheme-phoneme correspondences. In this case the phonological processing must take into consideration different letters and transfer the perceptual information to the phonological processor that activate the corresponding sounds from the phonological store. The activated elements are sequenced and grouped before producing the phonological response (Seymour, 1986). Thus, the processing of the printed material range from fast visual recognition of frequent and familiar words (related to orthographic knowledge) to the application of grapheme-phoneme rules that are cognitively demanding and slow in the beginning of

learning to read. In this study, we do not deal with the type of the processes used to identify words (visual or phonological), but we examined if slowness in word recognition in Arabic orthography is linked to deficits on WMC. Also, we will not consider the accuracy factor, because participants in the experiment should have enough grapheme-phoneme knowledge and trained to phonological processing.

Arabic (Modern Standard Arabic) is a Semitic language, and like Hebrew, is written from right to left, and comprises 29 letters, all are consonants and three of them serve also as long vowels. Short vowels are represented by specific diacritics added above or below the letters, whereas long vowels are inserted in the body of the word. In the beginning of learning to read, words and texts must be vowelized which make Arabic a transparent orthography. But in higher levels, Arabic is partially vowelized, so, only long vowels remain, whilst short vowels disappeared and that changed Arabic from a transparent to a deep orthography (in contrast to Latin orthographies in which vowels are part of the alphabet and are represented by specific letters). Difficulties emanate also from the structure of the letters, because many of them have similar forms, therefore the distinction between some groups of letters is based principally on the existence, location and number of dots (e.g. ب /b/, ت /t/, ث /th/). Another source of problems is that the form of a great number of letters change depending on their position in the word (initial, medial and final), and when they are preceded by a non-connecting letter (/j/ ـج ج ـجـ جـ). These characteristics of Arabic orthography make grapheme-phoneme correspondences complex by the fact that similar graphemes can represent different phonemes, and different graphemes represent the same phoneme (Ibrahim, Eviatar & Aharon-Perez, 2002). Compared to other orthographies (e.g. English, French …), few studies have investigated the specificity of Arabic orthography and its implication for the universal theory of reading. The studies of Arabic were limited to the effect of some orthographic characteristics on reading, such as the impact of vowels and context on reading accuracy (Abu-Rabia, Siegel, 1995; Abu-Rabia, 1997, 1998), or the effect of Arabic orthography on the speed of word naming (Ibrahim, Eviatar & Aharon-Peretz, 2002).

Correlations between WMC and WR were established in alphabetic orthographies (e.g. English) (Kail & Hall, 2001), and morphemic orthographies (e.g. Chinese) (So & Siegel, 1997). Little research, as far as the author is aware, was assigned to a similar relation between WRS and WMC in Arabic orthography, although some studies have encountered relationships between WR and WM in Arabic readers (Abu-Rabia, 1995) and bilingual Arabic-English children (Abu-Rabia & Siegel, 2004), but without a clear mention to the effect of WMC on WRS.

The main purpose of this study is to investigate the effect of WMC on reading speed in Arabic, so we hypothesized that the amount of WMC affects the WRS. In other words, we presume that deficits in WMC affect the processing of the printed material in low capacity readers and produce slowness in word naming. Knowing that slowness in processing extends the time period over which information may be lost (Towse & Hitch, 1995), we suppose that low capacity readers suffer from slowness in WR because they lack sufficient WM resources that permit to store and process printed linguistic information. So, low capacity readers are slow because they need more time to process the components of the printed word and to maintain the partial products of the processing until the production of the response, which leads to an increase in the response latency. Deficits in WMC explain, then, individual differences in WRS which is compatible with previous findings (Dufva, Niemi & Voetten, 2001; Kail & Hall, 1994; Oakhill & Kyle, 2000; Siegel & Ryan, 1989; Swanson, 1993, 2003).

Summarising, the present study is concerned with the relations between WMC and WRS in Arabic orthography and specifically the effect of this cognitive capacity on speed of phonological or orthographic processing. During this study, we addressed the hypothesis that WMC can provide us with insights about the level of performance on WRS. So, we assume that high WMC readers identify words faster than low WMC readers. In particular, we assume that there are correlations between slowness in word naming of low capacity readers and difficulties in storing and processing printed words. These insufficiencies in storage and processing influence poor reader’s ability to respond to demands of maintaining linguistic information as far as the preparation of the phonological response. Finally, we expect that WMC is a good predictor of performance in WRS, which means that automatic and rapid WR depends strongly on WMC.

Method

Subjects: 64 native Arabic children took part in this study. All of them came from similar socioeconomic backgrounds. The mean age ranges from 7 to 7 ½. Half of them are good readers, while others suffer from problems in word reading speed. Subjects were selected based upon their teacher's observations, and no initial specific evaluation was administered.

Material: We have adopted to test children's performance in two tasks, one aimed at evaluating word-naming time (WR test), while the other is directed to measure WMC (Modified Digit Span).

* Word recognition test: It consists of 20 vowelized Arabic words. Words were taken from the reading book programmed for the second year in primary schools in Morocco. Participants were asked to read the words aloud. The instruction consists in telling to the reader: "We are going to give you some words. The goal of the test is to measure your reading time, so you must read

the words as rapidly as possible. But you must take care that your reading speed does not affect your reading accuracy and making you commit errors that you avoid if you read at your normal cadence".

* Modified digit span (MODS): This task was adapted from Lovett, Reder and Lebiere (1999) by the author. MODS is similar to the task designed by Oakhill, Yuill and Parkin (1986); who have replaced the sentences in the task of Daneman and Carpenter with groups of three numbers. While cognitive functioning is affected by a number of factors like strategies that can cloud differences in WMC (Turner & Engle, 1989), MODS enables assessing WMC and reducing the effect of individual differences in compensatory strategies and prior knowledge (Daily, Lovett & Reder, 2001). The task requires the subject to read sequences of letters, which end in a digit. The number of sequences varies from 3 to 5. After that, the participants were asked to repeat the final digits in correct order. The test was suspended when the participant failed in two successive trials. The number of digits recalled accurately constitutes the WM span.

Procedure: Measures of WR are taken first, and then we evaluate WMC using MODS. Children were tested individually in a separate room in their school by the same experimenter (the author). They received the same instructions at the beginning of each test, and practice trials were given in the beginning of the tests. The results taken from tests include descriptive statistics that comprise means and standard deviations. After that, we analyse correlations between the variables (WMC and WRS).

Results

Table 1: Means and standard deviations of Arabic readers in word reading recognition and working memory capacity.

	Good readers			Poor readers		
	N	Mean	SD	N	Mean	SD
Word recognition time (S)	32	52.53	6.15	32	98.87	11.89
Working memory capacity	-	3.78	.42	-	2.06	.24

Note: Word recognition time was measured in seconds (S).

Table 1 shows that high capacity readers perform better than low capacity readers in word recognition. The general pattern of results indicates striking differences between good and poor readers in WRS and WMC tasks. Good readers obtained a mean of 52.53s in reading 20 words, whereas poor readers spent a mean of 98.87s to read the same list of words. We note in WMC scores that good readers have the best mean with 3.87, while poor readers mean is limited to 2.06.

Results indicate that a significant decrease in reading time is accompanied by an increase in WMC. This means that slowness in word naming is due to deficits in WMC.

Analysis of correlations

Table 2: Correlations between word recognition time and working memory capacity.

	Good readers			Poor readers		
	N	1	2	N	1	2
1. Word recognition time (S)	32	1	-.80	32	1	-.17
2. Working memory capacity	-	-.80	1	-	-.17	1

Note. $p < .05$

Strong correlations are observed between WMC and good readers WRS ($r = -.80$, $p < .05$), while poor readers results showed a weak correlation between WMC and WRS ($r = -.17$, $p < .05$). This showed that reading time depends on WMC. Poor readers responded slowly because they have deficient working memory, while good readers produce faster responses as a cause of a normal developing WM. Then, the results of the study establish a significant relationship between word processing speed and available WM capacity.
The results of the correlation analysis confirm our hypothesis that WMC can explain individual differences in WRS.

Discussion

The main purpose of this study was to investigate the relationship between WMC and WRS. Our results were concordant with previous findings (Siegel & Ryan, 1989; Swanson, 1993, 2003) that have established a strong correlation between word recognition performance and WMC. We found that problems encountered by low capacity readers are caused by deficiencies in WMC. In this sense, WMC measures could reveal the functioning of the reading system. These correlations between WMC and WRS confirm also that WMC plays the same role in Arabic orthography like in other alphabetic and morphemic orthographies. So, poor Arabic readers are subject to the same restrictions related to WMC.
The results obtained confirm our hypothesis that slowness in word naming can be caused by deficiencies in WMC. In general, the findings follow two conclusions: First, the improvement in word naming speed depends on growing efficiency of WMC. Second, Arabic orthography like other orthographies interacts positively with performance in WM tasks. The data suggests that the weak achievement of Arabic second grade poor readers in WRS was probably caused by limited WM resources. This indicates that high WMC leads to

reduced word naming time, while low WMC potentially leads to increased word naming time. The development of a rapid and efficient WR ability, therefore, could be mediated by a normal developing WMC.

As supposed by our hypothesis, Arabic second grade readers depend on WMC in their performance of word naming. So, good WRS is related to efficient storage and processing functions. The efficient coordination of processing and storage produces a rapid response in word identification. The observed decrease in word naming speed was substantially generated by an abnormal development of WMC. The contribution of WMC in reading development can be explained by poor performance of low capacity readers. This means that reading speed depends on WMC. Moreover, the results account also for the fact that complex memory measures (like modified digit span) provide reliable information about the efficiency of the phonological or orthographic processing. So, as mentioned earlier, word identification in Arabic relies on WMC to store and process. Our results fit strongly with previous findings that establish correlations between the ability to identify words and the WMC (Kail & Hall, 2001; Leather & Henry, 1994). WMC, therefore, could play a crucial role in the process of automatizing reading operations in Arabic language. Furthermore, slowness in word processing could be explained by deficits in mechanisms related to working memory, which produce the waning of some activated information during processing and require a return to the printed word or to long term memory (LTM), which increases the time necessary for processing.

WM deficits constitute a source of problems to some children in the initial development of reading ability. Poor readers experience more difficulties because they are deprived of sufficient cognitive resources, which reflect on the word naming performance. Additionally, the results indicate that problems of poor readers are related to an impaired WMC, which prevents reducing reading times. As Cantor and Engle (1993) noted, limitations in WMC does not facilitate rapid access to information in long term memory, which explain that poor readers encounter difficulties in retrieving rapidly the necessary information from LTM. Conclusively, the study shows that problems in storing perceptual information about the word and activating the corresponding information in LTM can result from deficient WMC. Our findings support previous research, and provide further evidence concerning the correlations between WRS and WMC in reading.

Consequently, WMC can be considered as a reliable predictor of reading ability in Arabic. This establishes that complex memory measures may give us insights about the level of word identification, particularly naming speed. WMC, therefore, can predict performance in word naming in the Arabic language. So, measures of WMC could be used to identify readers with problems in word recognition speed.

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