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Artigo Científico

Working memory capacity and L2 writing performance

Capacidade da memória de trabalho e desempenho da escrita na L2

Joara Martin Bergsleithner✐

Departamento de Letras e Artes, Universidade Estadual de Santa Cruz, Ilhéus, Bahia, Brasil

Abstract

This article surveys an experimental research on working memory capacity and second language (L2) writing performance. It attempts to tap on a principled account on whether individual differences in working memory capacity are related to L2 writing performance and whether such performance could be affected by working memory capacity. The experiment consists of a memory test – *The operation-word span test* (the *OSPAN test*), and the performance of a written task in the L2 (a sequencing narrative story board), as measured by accuracy and complexity. The results revealed evidence that there is statistically significant relationship between working memory (WM) capacity and L2 writing performance. In the concluding part, these issues are discussed and directions for further research are suggested. © Cien. Cogn. 2010; Vol. 15 (2): 002-020.

Keywords: working memory capacity; L2 writing performance; accuracy; complexity.

Resumo

Este artigo investiga uma pesquisa experimental sobre capacidade da memória de trabalho e desempenho da escrita na segunda língua (L2). Ele examina se as diferenças individuais na memória de trabalho estão relacionadas ao desempenho da escrita na L2 e se tal desempenho poderia ser afetado pela capacidade da memória de trabalho. O experimento consiste em um teste de memória – "The operation-word span test" ("the OSPAN test"), e no desempenho de uma tarefa escrita na L2 (uma narrativa em quadrinhos), como medida de precisão e complexidade. Os resultados mostraram evidência que existe uma relação estatisticamente significativa entre a capacidade de memória de trabalho e o desempenho da escrita na L2. Na conclusão, estes tópicos são discutidos e direções para futuras pesquisas são sugeridas. © Cien. Cogn. 2010; Vol. 15 (2): 002-020.

Palavras-chaves*: capacidade da memória de trabalho; desempenho da escrita na L2; precisão; complexidade.*

1. Introduction

One of the most complex cognitive tasks that humans have to achieve in their second (L2) or foreign language performance is writing. This complex language skill entails cognitive attentional recourses and processes such as working memory (hence forward WM)

✐ - *E-mail* para correspondência: joaramb@hotmail.com.

capacity, as well as the involvement of other cognitive mental representation processes such as semantic and syntactic processes, which are cognitively required when individuals want to express their ideas and propositions to communicate with others (Olive, 2003).

Several researchers have claimed that individual differences in WM capacity play an essential role in various cognitive tasks, such as in language performance with regard to language comprehension and production (Daneman and Carpenter, 1980, 1983; Daneman and Green, 1986; Just and Carpenter, 1992; Miyake and Friedman, 1998; Miyake *et al.*, 1994; Shah and Miyake, 1996, 1999). However, there are just a few studies that examined the relationship between individuals' WM capacity and writing performance (e.g. Abu-Rabia, 2003; Hayes, 1996; Hayes and Flower, 1980; Hayes and Grawdol-Nash, 1996; Kellogg, 1996; 2001b; McCutchen, 1996, 2000; Olive, 2003; Olive *et al.*, 2001). Therefore, the current study particularly investigates this issue.

Based on the assumptions above, the primary research question addressed for this study concerns the investigation on whether there is a relationship between WM capacity and L2 writing performance. The second question is extent to whether L2 writing performance may be affected by WM capacity. These questions are based on the hypotheses that there will be a statistically significant relationship between WM capacity and L2 writing performance, and that L2 writing performance might be constrained by WM capacity.

Before such questions and hypotheses can be addressed in the method section, it is useful to review theoretical discussions on this issue in the literature segment. Finally, the results and conclusions are analyzed and discussed on the relationship between WM capacity and L2 writing performance.

2. Review of literature

2.1. Working memory

Working memory (WM) is the human cognitive system that refers to the storage and processing of information during complex cognitive tasks (Baddeley and Hitch, 1974; Daneman and Carpenter, 1980, 1983; Harrington and Sawyer, 1992; Shah and Miyake, 1996), as for example during language tasks performance such as language production (e.g. writing), among others. Further definitions of WM were proposed in the literature to claim that "working memory is a system consisting of those long-term memory traces active above threshold, the procedures and skills necessary to achieve and maintain that activation, and limited-capacity, controlled attention" (Engle *et al.*, 1999: 102).

Several researchers have claimed that humans have individual differences among themselves especially when dealing with a complex cognitive task, such as when performing an L2 (Cowan, 1988; Daneman and Carpenter, 1980, 1983; Daneman and Green, 1986; Engle *et al.*, 1999; Harrington and Sawyer, 1992; Just and Carpenter, 1992; Miyake and Friedman, 1998; Robinson, 2001a, 2001b, 2002a, 2002b; Skehan, 1998). Their findings have shown that WM capacity (the limited capacity one has in storing and processing information) may potentially affect individuals' language comprehension and performance.

In recent years, many studies (Bergsleithner, 2007; Daneman and Carpenter, 1980, 1983; Daneman and Green, 1986; Fortkamp, 1999, 2000; Fortkamp and Bergsleithner, 2007; Harrington and Sawyer, 1992; Mota, 2003; Tomitch, 1996) have investigated the crucial role of WM capacity and its limitation either in first language (L1) or in L2 performance as regards language comprehension and/or language production. Nevertheless, just a few studies (e.g. Kellogg, 1996; McCutchen, 1996; Penningroth and Rosenberg, 1995; Piolat and

Fruttero; 1998; Olive, 2003; Olive and Kellogg, 2002) have explored the issue of WM capacity as regards its relationship with writing performance, either in L1 or in L2.

However, this does not imply that this language skill is not relevant to be investigated or debated in the field of WM. This lack of literature may be related to the fact that writing is a very complex cognitive task that involves language production, and that the implication of WM capacity in writing is not enough depicted (Olive, 2003). If compared to other language skills such as reading and speaking, for example, writing skill has its specific characteristics and genres. Differently from other language abilities, writing provides its performers with more time to reflect on the task while doing it (Skehan, 1996, 1998; Skehan and Foster, 1997, 2001).

2.2. Writing

Writing is a powerfully complex task that integrates not only how the cognitive processes trigger writing performance but "how their activation is orchestrated in the cognitive system" (Olive, 2003: 2). The broad concern on this issue is to understand how these mental processes deal with on-line (re)organization and control L2 processing and production (Kellogg, 1996).

Some researchers (Abu-Rabia, 2003; Hayes and Grawdol-Nash, 1996; McCutchen, 1996; Olive, 2003) have claimed that writing certainly engages many cognitive mechanisms that manage different levels of representation. During the writing process, for example, writers usually have time to plan and think about some issues before the act of writing. Although they have time to reflect, this reflection implies that working memory capacity manages several simultaneous processes. Thus, some planning processes involve the ideas a writer constructs in the pre-verbal message when she/he wants to communicate before going on into the real message. That is, one needs to access the linguistic knowledge to transform planning into a verbal message (Olive, 2003). Such knowledge involves grammatical encoding and the access of the mental lexicon by retrieving syntactic and morphological word categories (Olive, 2003, based on Bock and Levelt, 1994).

Thus, individuals have to organize and reorganize ideas to write on a given issue, especially if the writing performance is in L2. In other words, they have to retrieve the necessary lexical and semantic information and the previous knowledge about the issue from their long-term memory (LTM) in order to perform writing in L2 (Kellogg, 1996, 2001a; Olive, 2003). Generally, when one has previous knowledge about a topic, a lower cognitive effort in writing performance is demanded (Kellogg, 2001a). Furthermore, skilled writers require less effort to manage the attentional resources that activate linguistic (syntactic and semantic) information necessary for writing performance (Kellogg, 2001c). In contrast, poor writers need a more demanding cognitive effort to produce a text (Abu-Rabia, 2003, McCutchen, 1996).

2.3. Models of writing and models of WM

Over the last decades, two theoretical models of writing have been particularly investigated according to their historical context. First, Hayes and Flower's (1980) model originally examines the description of the three phases of writing: planning, translating and revising processes. After a first proposal in association with Flower (Hayes and Flower, 1980), Hayes (1996) proposed a modified model, in which he attributed an essential role for WM and also for sources of knowledge in LTM (McCutchen, 2000).

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Secondly, Kellogg's (1996) model scrutinizes the management of the writing processes and writing cognitive functioning, such as the role of WM (especially the slave systems of WM) in writing performance and the individual differences in the development of writing expertise. Based on Baddeley and Hitch's (1974), and on Baddeley and Logie's (1999) multi-component model of WM, Kellogg (1996) focused on the limitation of WM for the demanding cognitive resources that the writing processes required from the central executive. He also considered how the phonological loop and the visual-spatial sketch pad (the code-specific components of WM) are engaged by the writing processes. More recently, Kellogg (2001b, 2001c, 2006) suggested that writing involves multiple representations and processes, and the development of the writing skill may be constrained by WM capacity.

Kellogg's (1996) model is in line with Levelt's (1989) model. Each system in Kellogg's model is related to each component in Levelt's (1989) model (conceptualizing, formulation, and articulation). Although Levelt's (1989) model was designed for L1 speech production accounts, and later on adapted to L2 by De Bot (1992), it is available for theories of writing (Hayes and Flower, 1980; Kellogg, 1996, as cited in Ellis, 2005). According to Ellis (2005), Kellogg (1996) proposed similar processes to the ones suggested by Levelt (1989), and they can be accepted in both L1 and L2 writing. As reviewed in Ellis (2005), Kellogg's (1996) model presents three different systems drawn in written text production: formulation, execution, and monitoring. Each system involves two processes.

First, the *formulation* involves (a) planning (the writer's goals and ideas, and organization of ideas), and (b) translating (the writer's lexical and syntactic choice to encode ideas). Second, the *execution* entails: (c) programming (the writer's output translation is transformed into production for the motor systems – handwriting or typing – to take place, and (d) executing (the writer's real language production). Last but not least, the *monitoring* involves (e) reading (the writer's reading of his own text), and (f) editing (the writer's attention to micro (linguistic errors) and macro (text organization) language aspects (Ellis, 2005).

In the vein of Levelt (1989), Kellogg (1996) highlights that writers activate the three systems (formulation, execution, and monitoring) at the same time, and that such activation relies on WM. The main issue of Kellogg's (1996) model is that the central executive has limited capacity. Moreover, when a writer has to write under pressure (time constraints), he may have to quickly make decisions to prioritize one writing process before the other. This fact may reflect in a trade off of attention, thus the formulation process might be affected (Ellis, 2005).

Other researchers (Berninger and Swanson, 1994; McCutchen, 1996) adopted a correlational approach to examine the writing skill and its performance. As for example, McCutchen (1996) reviews Just and Carpenter's (1992) Capacity Theory of Comprehension to report individual differences in writing development and performance. This theory proposes that the total amount of activation of individuals' attentional resources vary among individuals, and thus Just and Carpenter (1992) distinguish them in capacity of storage and processing information. Based on this theory, McCutchen (1996) scrutinizes experimental and correlational studies in order to see the efficiency of the writing processes. This researcher found that the more fluent and efficient the writing processes work, the less cognitive demanding they are, thus, implicating in a more enhanced performance in writing.

Various WM models have been adopted to investigate how individuals maintain information for a short period of time, efficiently process that information and maintain it to retrieve it in further recall (Cowan, 1988; Engle *et al*., 1999). This study adopted Engle et al.'s (1999) model of WM, since the model includes features such as domain free, limited capacity controlled attention; domain-specific codes and maintenance (as for example phonological loop and visual-spatial sketchpad); individual differences in L1 and L2, although, individual differences in capacity to control attention and process are general (Engle *et al*., 1999: 102).

Engle and colleagues (1999) argue that WM capacity controls attention. They do not see capacity as the entire system but the limited capacity to control attention, what Baddeley and Hitch (1974), and Baddeley and Loggie (1999) called central executive. In addition, Engle *et al*. (1999) suggest that individual differences in WM capacity mirror the individual capacity for controlled processing in situations in which controlled attention is required.

As regards performance in WM capacity measurements, Engle (2002) assumes that performance in such measures "predicts performance on a wide range of real-world cognitive tasks" (p. 19). In other words, this researcher argues that individual differences in WM capacity reflect performance in higher order (complex) cognitive tasks. However, he states that WM capacity is not related to the number of items or chunks individuals can store but to their differences in the capacity to control attention and in the ability to maintain such information for further recall. Moreover, he claims that WM capacity is more related to attention rather than to memory *per se*. "It is about using attention to maintain or suppress information" (Engle, 2002: 20). In all, he suggests that higher spans have more ability to control attention in order to maintain or suppress information and to avoid distraction (Engle, 2002).

3. Method

3.1. Participants

A group of 32 Brazilian learners (16 male and 16 female) of English as an L2 participated in this study in all testing occasions. They are all from an undergraduate foreign language course, from a University in the Northeast of Brazil. First, the participants came from two different groups, although all of them were enrolled in the same English course offered on the 6th semester. They were adult males and females aged between 20 and 40. Before selecting the actual group for this study, all participants' level of proficiency in English as an L2 was controlled. The First Certificate in English (FCE) Cambridge test was applied to make sure the group chosen for the study was relatively homogeneous in terms of L2 proficiency, in order to avoid confounds of proficiency in the results of the writing task performance. Departed from a pool of 52 participants, 18 were excluded for further participation since their scores in the FCE were below 6.0, the average to indicate English proficiency in the test. After this exclusion criterion, a group of 34 participants with a mean performance level in English proficiency of 85.15 out of 100 was obtained for this study. With the application of the WM test, 2 more participants were also excluded from this study since they could not accurately solve the mathematical equations in the operation-word span (OSPAN) test. These equations were used as a marker of whether the participant was putting forth a good effort in processing, thus, anyone below 85% accuracy on the OSPAN test was eliminated from this study, following Engle *et al*. (1999) (see details on the OSPAN, as follows). Finally, a more homogeneous group of 32 participants carried out this study.

3.2. Instruments: material, equipment and procedure

3.2.1. Assessment and measure of working memory capacity

A memory test - *The operation-word span test* (OSPAN) - was administered and recorded individually to each participant in a silent room. The original test in English was proposed by Turner and Engle (1989). However, the present researcher applied Prebianca's (2009) OSPAN test version in Portuguese (participants' L1) to avoid confounds with participants' proficiency in L2 (see Appendix A for the OSPAN list of operation-word strings). The test consists of 42 operation strings on the left, which come with two-syllable words to the right side of it, in a total of 42 Portuguese words. From the 42 trials, 19 strings present correct responses in the mathematical operation string while 23 strings present incorrect responses. The operations and words are presented once at a time in the middle of the computer screen, as the one set example as follows:

(9 ÷ 3) - 2 = 2 ? (yes or no) LÁBIO
(8 ÷ 4) - 1 = 1 ? (yes or no) FICHA
??

Thus, each participant was required to read aloud a series of operation-word strings such as test block of three sets each (with sets from 2 to 6 varied in each block) of arithmetic operations plus Portuguese words on the right side. Immediately after the presentation of the series in sequence, participants were required to verbally answer the results to the operation string and to retain the word added to it for succeeding recall until a blank screen indicates that a set had finished. Afterward, the participant was required to recall the words in the same form and order in which they were presented on the computer screen. The question marks indicated the number of words they had to recall. Before doing the actual test, all participants were guided on how to do the test and also had opportunity to practice the trials to feel themselves comfortable to do the task (see Appendix A for the OSPAN practice session). Each participant's performance in the OSPAN test was operationalized with the total number of words (the maximum 42 words) properly recalled, being one (1) point to each correct recalled word in its correct serial position.

In sum, this study employed the OSPAN test to verify the hypothesis that WM capacity is not task specific, but general in nature (Engle *et al*., 1999). Other researchers (Conway and Engle, 1996; Engle *et al*., 1992) reaffirmed *the General Capacity Hypothesis* to suggest that WM capacity would predict significant correlations with other complex language tasks performance.

3.2.2. Assessment of L2 writing performance

The rationale for using a narrative task to assess writing performance in this study is justified in terms of having validity of this task (here called *test*) (Tavakoli and Skehan, 2005). Narrative tasks are commonly used to assess language performance (Iwashita *et al*., 2001; Robinson, 2001b), and frequently based on a prompt sequencing set of pictures (Tavakoli and Skehan, 2005). They are usually considered more demanding cognitive tasks if compared to descriptive tasks or interactive tasks such as interviews (Ortega, 1999).

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3.2.2.1. Narrative task

Participants were individually elicited to write a narrative in L2 -- a sequencing story board, that is, a story in pictures in which they had to narrate in sequence (see Appendix B). They were given 7 minutes of time constraint to perform the task, but no planning time to do the task in order to demand a more complex cognitive task from them, and thus, distinguish higher spans from lower spans. The current researcher carried out a pilot study with 5 students to decide on the time of the task. Participants were required to do the same task of the real study the fastest they could. Three participants took 7 minutes, one took 4 minutes and another took 10 minutes to do the task. Then, it was made an average with a mean of 7 minutes as the time required for the narratives of the actual study, all of them finished the task when the time was completed (7 min).

3.2.3. Measures of L2 writing: accuracy and complexity

The current study employed measures of accuracy and complexity to assess L2 writing performance. These measures are distinguished as different aspects of language production, since they draw on different systems (Skehan, 1998). Accuracy reflects grammatical and lexical correctness and the L2 learners' effort to control attentional resources in order to avoid errors, while complexity entails more elaborated language, that is, the effect of risk taking and "restructuring" language (Ellis, 2005: 15; Foster and Skehan, 1996; Ortega, 2003; Skehan, 1998). In Skehan's (1998) cognitive model, the two language dimensions compete and cannot go together, since individuals would have limited attentional resources available, and thus accuracy or complexity could be prioritized to be allocated on a given task (Skehan, 1996, 1998; Skehan and Foster, 1997, 2001).

Some authors (e.g. Foster and Skehan, 1996; Mehnert, 1998; Skehan, 1998) originally proposed to adapt general accuracy and complexity measures for oral performance to writing performance. As this study is exploratory in nature, general measures of accuracy (since no specific linguistic forms were required to be used in this task) and complexity seem to follow a suitable procedure.

As regards the measure of accuracy, errors were analyzed in various L2 aspects such as in syntax, morphology, lexical choice and word order, including repetitions. Proportion of errors was calculated by the number of errors divided by the number of the words produced in each text, and the resulting figure was multiplied by 100 to convert it into percentage (Fortkamp, 2000; Fortkamp and Bergsleithner, 2007; Mehnert, 1998; Mota, 2003; Ortega, 1999). For the measure of complexity, the use of subordinate clauses was considered a crucial indicator of internal complexity in L2 writing performance in this study. Thus, the number of subordinate clauses made by each participant was counted per 100-word text (Foster and Skehan, 1996; Mehnert, 1998; Ortega, 1999; Skehan, 1998).

3.2.4. Procedure to collect data and data transcription procedures

The OSPAN data were collected individually. Then, each subject was recorded individually in an MP3 and later transcribed by this researcher. The narrative task was collected with all participants together in the classroom at class time. Thus, each participant was required to individually carry out two tests.

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3.2.5. Inter-rater reliability

After the current researcher judged all participants' narratives, all the texts were submitted to another rater, an MA English professor from the same university. In order to check inter-rater reliability, both raters separately judged the scores of accuracy and complexity in all narratives, by following the same criteria, established in this study (see Section 3.2.2. above). The inter-rater reliability coefficients were all above .90. Then, both raters checked all the discrepancies and resolved them by discussion.

3.3. Data analysis

This study employed Pearson product-moment Correlation Coefficient to determine the relationship between WM capacity and L2 writing performance (as regards accuracy and complexity). The correlations between WM capacity and accuracy, WM capacity and complexity, and accuracy and complexity were calculated through simple linear regression analysis.

The study focused on the following research questions and hypotheses:

<u>Research Question 1</u>: Is there a relationship between WM capacity, as measured by the OSPAN test, and L2 writing, as measured by accuracy and complexity?

<u>Research Question 2</u>: May L2 writing performance be affected by WM capacity?

<u>Hypothesis 1</u>: There will be a statistically significant relationship between WM capacity, as measured by the OSPAN test, and L2 writing performance, as regards accuracy and complexity.

<u>Hypothesis 2</u>: WM capacity may affect L2 writing performance since it might be constrained by WM capacity.

4. Results and discussion

4.1. Descriptive statistics

Table 1, as follows, reports the descriptive statistics for the variables of the study: working memory capacity, the independent variable, and accuracy and complexity, the two dependent variables to assess L2 writing performance.

	N	Minimum	Maximum	Mean	*SD*	Skewness	Kurtosis
WMC	32	16	40.0	29.25	6.21	-0.33	-0.40
Accuracy	32	72	100.0	91.23	6.21	-1.57	3.17
Complexity	32	0	5.8	2.06	1.49	0.66	0.41

Table 1 - Descriptive statistics for the variables of the study: working memory capacity (WMC), accuracy and complexity.

As can be seen in Table 1, the descriptive statistics point to the scores for the measure of WM capacity, as measured by the OSPAN test, by presenting a sizeable difference among

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32 participants' WM capacity scores with a mean of 29.25. Moreover, Table 1 reports the scores in the OSPAN test performance departed from a minimum range of 16 to a maximum range of 40 points out of 42. These scores (from 16 to 40) represent the participants' score in WM capacity (OSPAN test), which means that the highest spans (or processors) participants are, the biggest their WM capacity scores are in the results. These results may indicate that the higher spans had a better performance on the given task, since they may allocate more attentional resources on it (Cowan, 1988; Engle *et al*., 1999).

The descriptive statistics in Table 1 also indicate the average mean performance in participants' accuracy, with a mean of 91.23, and in participants' complexity, with a mean of 2.06. The scores in the measure of accuracy (grammatical and lexical correctness) departed from a minimum range of 72 to a maximum range of 100 points out of 100, which represent the participants' score in accuracy in L2 writing performance, that means that, the most accurate they were in grammar and lexicon use, the highest their scores were. Concerning complexity (risk taking), the participants' scores departed from a minimum range of 0.0 to a maximum range of 5.8. These scores (from 0.0 to 5.8) represent the number of subordinate sentences they elaborated in the task performance, that is, how complex they could be in the L2 writing task performance.

4.2. Inferential statistics

Table 2, as follows, displays the correlation findings among the measures for the variables of this study. Correlation coefficients were calculated among the measures for working memory capacity, accuracy and complexity in L2 writing performance. All measures were calculated on the two testing occasions. A two-tailed alpha decision level of $p < .05$ was set for all inferential decisions of statistical significance for the correlations.

Variables		**working memory capacity**	**Accuracy**
Accuracy	***r* (32)**	**.62****	**-**
	***p*-value**	**.000**	**-**
Complexity	***r* (32)**	**.69****	**.490****
	***p*-value**	**.000**	**.004**

Table 2 - Pearson correlation among working memory capacity, accuracy and complexity. ** Correlation is significant at the p < .01 level (2-tailed).

As can be seen in Table 2, some findings are apparent for the correlational comparisons among the variables of this study. The measures between (a) WM capacity and accuracy in writing performance (r (32) = .62, $p < .001$) and (b) WM capacity and complexity in writing performance (r (32) = .69, $p < .001$) are reasonably strong and statistically significant correlated. These correlations suggest that WM capacity may be related to the L2 writing performance of the picture narrative. Thus, these findings provide substantial support to Hypothesis 1.

As shown in Table 2, the analysis indicate a tendency for a correlation between accuracy and complexity (r (32) = .49, $p < .001$). Perhaps, since the study was narrowly sampled, the correlation is around .49, and not stronger than that. Another indication that might be related to such correlation is the participants' variability in L2 writing performance.

As follows, Figure 1, 2, and 3 depict the results reported in Tables 1 and 2, for all variables and participants. As can be seen in Figure 1 below, the higher spans better performed the texts with a lower rate of errors. The coefficient of determination (R^2 = 0.3863) indicates that 38.6% of variation in accuracy may be explained by the variation in WM capacity.

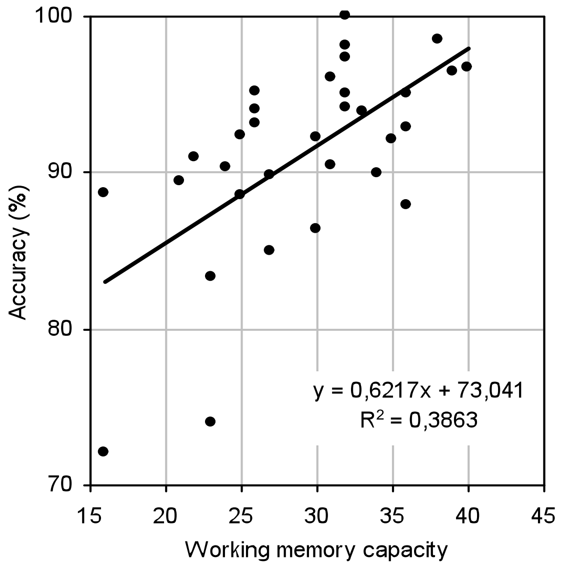

Figure 1 - Accuracy and working memory capacity.

Figure 2 displays the correlation finding between complexity and WM capacity. This result also indicates that the higher spans better performed linguistically more complex written narratives. Furthermore, complexity is slightly more strongly related to WM capacity than accuracy.

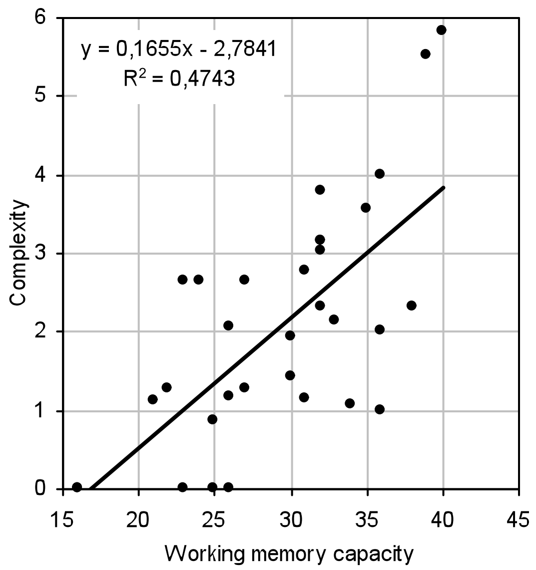

Figure 2 - Complexity and working memory capacity.

Next, Figure 3 displays the correlation finding between accuracy and complexity, the measures for the L2 writing performance. There is a relationship between the two variables, though it may not be strong (r (32) = .49, p = .004). This result might be an indication of a trade-off between accuracy and complexity during L2 writing performance (Skehan, 1996, 1998).

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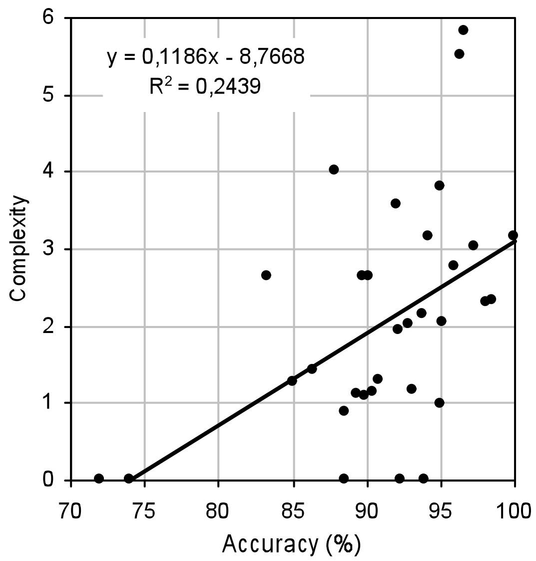

Figure 3 - Accuracy and complexity.

Despite individual variability within the group, as showed in the Figures above, the findings suggest that the variability within participants may be inherent to individual differences (Cowan, 1988; Daneman and Carpenter, 1980, 1983; Daneman and Green, 1986; Engle *et al*., 1999; Harrington and Sawyer, 1992; Just and Carpenter, 1992; McCutchen, 1996; Miyake and Friedman, 1998; Robinson, 2002a, 2002b). Some participants' variability in L2 writing performance (in terms of accuracy and complexity) may be related to their WM capacity. These results might be taken as evidence that individuals with a larger WM capacity are more prone to perform more accurate and complex written texts in L2.

In response to the main question of whether WM capacity seems to be related to L2 writing performance on the only writing testing occasion, the correlation suggests that there is indeed a statistically significant relationship between the variables of this study. More specifically, there seems to have a relationship between WM capacity and L2 writing performance when this was measured by accuracy and complexity. This result might indicate that individuals with a larger WM capacity were more prone to producing accurate and complex narratives (Fortkamp, 1999, 2000; Mota, 2003; Skehan, 1996, 1998).

The analysis further indicates a tendency for an interaction between accuracy and complexity, although there seems to be a trade-off effect between these two language aspects (Skehan, 1998). This finding suggests that gains in one aspect resulted in losses in the other (e.g. gains in complexity resulted in losses in accuracy and vice-versa). The results are in line with results obtained by Foster and Skehan (1996), Mehnert (1998), and Ortega (1999).

Thus, based on these findings, Hypothesis 1 was supported with the claim that most of the higher spans generally demonstrated to be more accurate and complex in L2 writing performance, which means that individual differences in WM capacity reflect differences in controlled processing that demands controlled attention during a complex task (Engle *et al*., 1999). Therefore, the higher spans allocated more attentional resources to pay more attention to the given task performance (Engle, 2002; Engle *et al*., 1999). In other words, they dispensed more attention to form and meaning, and thus could better access syntactic (grammatical encoding) and morphological word categories (mental lexicon) during task performance (Olive, 2003, based on Bock and Levelt, 1994).

Moving on to the second research question of whether L2 writing performance might be affected by WM capacity, the correlation suggests that, generally, limitations in WM

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capacity may have constrained individuals' controlled attention to perform the task (Cowan, 1988; Engle *et al*., 1999; Kellogg, 1996, 2001a, 2001b, 2006). Thus, the higher spans probably could better administrate the written task performance if compared to the lower spans. These results supported the second hypothesis that WM capacity could affect L2 writing, since the lower spans could not have the same L2 writing performance because of limitations in controlled attention of their WM capacity, while the higher spans demonstrated better language performance (Abu-Rabia, 2003; Kellogg, 1996, 2001b, 2006; McCutchen, 1996, 2000; Olive, 2003).

Therefore, what is important to address is the notion that it is the controlled attention that leads the higher spans to process more accurate and complex grammatical and lexical cognitive processing during language performance (Engle, 2002; Engle *et al*., 1999). Even though all participants showed to have good proficiency in English as an L2, the lower spans could not perform accurate and complex narratives as the higher spans could do. Limitations are due to their attentional resources in time constrains and task type (Ellis, 2005; Kellogg, 1996). This implies that the lower spans could not control the same amount of attention in the task performance. Thus, their performance was poorer than the higher spans, whose the controlled attention component of WM presented higher order cognitive ability (Engle, 2002; Engle *et al*., 1999). There has been some kind of trade-off of attention on the task (also because of time constraints), and maybe the formulator process (the first writing process) was spoiled to administrate accuracy and complexity in L2 writing performance, reflecting thus in the other two systems, execution and monitoring during written production (Kellogg, 1996; Ellis, 2005).

In accordance with above discussion, the findings showed statistically significant correlation between WM capacity and L2 writing performance. There is evidence that greater attention was paid to form in both accuracy and complexity by higher spans. These findings suggest that manipulating task features seems to be able to allocate learners' attention to task performance.

In view of that, the results support Skehan's (1998) claims on his Limited Attentional Capacity Model. In fact, the findings are in line with Skehan's (1998) and Skehan and Foster's (2001) predictions that L2 learners have a limited processing capacity when dealing with a complex cognitive task. Thus, the trade-offs between accuracy and complexity dimensions are likely to occur. These researchers sustain a limited capacity view of attention and claim that these two distinct language dimensions cannot go together, since there is competition in promoting selective attention to the performance of a complex cognitive demanding task (Skehan, 1998).

In addition, the trade-off effect between accuracy and complexity is also in line with the trade-off view of WM theories (when a demanded task exceeds WM capacity (Mota, 2003)) and with Kellogg's (1996) model (involving the writing processes), which suggests that, the central executive (what Engle *et al*. (1999) and the present researcher call WM capacity or controlled attention) has limited capacity and this may reflect in writing performance especially when a writer has to produce a text quickly, under pressure (Ellis, 2005).

5. Conclusion

Given these results in the present study, the strength of conclusions above seem to indicate the crucial role of WM capacity as the higher controlled attention ability that differentiates humans among themselves (Engle, 2002; Engle *et al*., 1999). In the same words, individual differences in WM capacity reflect the individual capacity for controlled processing when controlled attention is required (Engle *et al*., 1999; McCutchen, 1996, 2000; Piolat and Fruttero, 1998; Olive and Kellogg, 2002). These findings suggest that individuals allocate different amount of attention in complex tasks performance according to their WM capacity (Engle *et al*., 1999; Engle, 2002). In all, this conclusion might contribute to the previous studies on WM and L2 performance in complex cognitive tasks, given the relevance of WM capacity as a cognitive system responsible for the controlled attention during L2 writing performance (Kellogg, 1996; Olive, 2003).

The current study examined the correlation between WM capacity and L2 writing performance. Researchers have been looking at WM capacity and its relationships with other variables such as reading and speaking, for example, to investigate such relationships. However, to date, there are very few studies investigating the relationship between WM capacity and writing. Thus, more studies on how WM capacity may correlate with writing performance (either in L1 or in L2) as well as affect output performance can be a promising area for further research in the fields of Second Language Acquisition (SLA) and Psycholinguistics in Applied Linguistics. Moreover, future research should also investigate individual variation in L2 writing performance.

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APPENDIX A

OSPAN – list of operation-word strings (Prebianca, 2009)
Testing Session

Mathematical Operations	**Words**
Block 1	
(10 ÷ 2) – 3 = 2 ?	carta
(10 ÷ 10) – 1 = 2 ?	lençol
(7 ÷ 1) + 2 = 7 ?	terra
(3 ÷ 1) - 2 = 3 ?	papel
(2 x 1) - 1 = 1 ?	avó
(10 ÷ 1) + 3 = 13 ?	tinta
(9 x 2) + 1 = 18 ?	guerra
(9 ÷ 1) - 7 = 4 ?	chuva
(8 x 4) - 2 = 32 ?	fila
(9 x 3) - 3 = 24 ?	água
(4 ÷ 1) + 1 = 4 ?	maçã
(10 ÷ 1) - 1 = 9 ?	ferro
(8 x 4) + 2 = 34 ?	jornal

Block 2	
(6 x 3) + 2 = 17 ?	feira
(6 ÷ 3) + 2 = 5 ?	lago
(6 x 2) - 3 = 10 ?	fogão
(8 ÷ 2) + 4 = 2 ?	lixo
(8 ÷ 2) - 1 = 3 ?	dedo
(9 ÷ 1) - 5 = 4 ?	balde
(6 ÷ 2) - 2 = 2 ?	ladrão
(7 x 2) - 1 = 14 ?	rocha
(6 x 2) - 2 = 10 ?	padre
(2 x 2) + 1 = 4 ?	jardim
(7 x 1) + 6 = 13 ?	leite
(3 ÷ 1) + 3 = 6 ?	braço
(10 ÷ 1) + 1 = 10 ?	cobra
(4 x 4) + 1 = 17 ?	fita
(3 x 3) - 1 = 8 ?	irmão

Block 3	
(3 x 1) + 2 = 2 ?	telha
(4 ÷ 2) + 1 = 6 ?	vinho
(5 ÷ 5) + 1 = 2 ?	foto
(2 x 3) + 1 = 4 ?	mala
(9 ÷ 3) - 2 = 1 ?	bruxa
(10 ÷ 2) - 4 = 3 ?	álbum
(5 ÷ 1) + 4 = 9 ?	dente
(10 x 2) + 3 = 23 ?	vidro
(7 ÷ 1) + 6 = 12 ?	trilha
(3 x 2) + 1 = 6 ?	feijão
(6 x 4) + 1 = 25 ?	nuvem
(9 ÷ 3) - 1 = 2 ?	calça
(8 ÷ 1) - 6 = 4 ?	pato
(9 x 1) + 9 = 1 ?	festa

Practice Session

Mathematical Operations	Block 1
(9 ÷ 3) -2 = 2 ?	Lábio
(8 ÷ 4) -1 = 1 ?	Ficha
(6 ÷ 2) + 1 = 4 ?	Jóia
(6 x 3) -2 = 11 ?	Grito
(4 x 2) +1 = 9 ?	Saia
(10 ÷ 2) + 4 = 9 ?	Cofre
(2 + 3) + 3 = 8 ?	Lenda
(7 + 3) - 2 = 8 ?	Pilha
(3 - 1) + 1 = 1 ?	Noite
(9 - 1) ÷ 2 = 4 ?	Perna
(3 x 5) - 2 = 12 ?	Classe
(4 x 3) - 3 = 10 ?	Granja
(2 + 7) + 4 = 12 ?	Loja
(10 – 4) ÷ 2 = 4?	Carne

APPENDIX B

Task 1 : Look at the picture you have in front of you.
Narrate a story according to the sequencing story board.
Use your own imagination to write a good text. Be creative!
No time for planning.
You have 7 minutes to write a story.