THE ROLE OF WORKING MEMORY CAPACITY IN THE DEVELOPMENT OF L2 SPEECH PRODUCTION

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Abstract

This study addresses the question of how working memory capacity and L2 speech production covary over a period of time, during learners' L2 speech development. Participants were submitted to two data collection phases, each one consisting of a working memory test (an adaptation of Daneman's 1991 *speaking span test*) and a speech generation task, with a twelve-week interval between the two data collections. The results show that both lower and higher span individuals experienced some increase in L2 speech production scores in between phases. However, only lower span participants had a statistically significant improvement in working memory scores over trials. In addition, the speaking span test was related to the development of complexity in speakers' L2 speech.

Keywords: individual differences, working memory capacity, L2 acquisition.

1. Introduction

Working memory has been broadly defined as the human cognitive system responsible for the simultaneous and temporary processing and storage of information in the performance of cognitive tasks (Baddeley & Hitch, 1974; Daneman & Carpenter, 1980, 1983; Miyake & Shah, 1999). Research in language acquisition to date has acknowledged that limitations in individuals' working memory capacity may be seen as a possible independent constraint on the process involved in using and acquiring both a first and a second language (Daneman & Green, 1986; Daneman, 1991; Fortkamp, 1999; 2000; Fontanini, Weissheimer, Bergsleithner, Perucci & D'Ely 2005; Weissheimer & Fortkamp, 2004; Bergsleithner, 2005; Guará-Tavares, 2005; Finardi & Prebianca, 2006; Xhafaj, 2006; Finardi, 2008; Bergsleithner & Fortkamp, 2007; Finardi & Weissheimer, 2009). These studies have shown that, in general, individuals with a higher working memory capacity tend to outperform those with a lower capacity in various aspects of language performance and acquisition.

The view of working memory capacity as a source of individual differences in L1 is already indisputable (Just & Carpenter 1992; Daneman & Green, 1986, Tomitch, 2003; Turner & Engle, 1989; Conway & Engle, 1996; Engle, et al., 1999; Kane, Bleckley, Conway & Engle, 2001). There is now mounting evidence for the role of working memory capacity as a possible independent constraint on the process involved in both L2 use and acquisition (Harrington, 1992; Harrington & Sawyer, 1992; Ellis & Sinclair, 1996; Miyake & Friedman, 1998; Berquist, 1998; Fortkamp, 1999; Fortkamp, 2000; Fontanini et al., 2005; Weissheimer, 2007; Finardi, 2008; Berghsleitner & Fortkamp, 2007; Finardi & Weissheimer, 2009). Overall, these studies suggest that working memory capacity may be even more involved in the processes of using and acquiring an L2 than in those processes involved in L1.

The reasons why working memory capacity may be more required during L2 acquisition and use are, among others, the possible lack of access to UG and qualitative differences between L1 and L2 development (Harrington, 1992). Miyake and Friedman (1998) suggest that L2 acquisition may have to rely to a greater extent than L1 acquisition on general learning mechanisms and principles, such as, for example, working memory capacity. Because working memory capacity is believed to be more required during L2 use and acquisition, an extra load is imposed on the system, affecting the speed and quality of acquisition.

A look at Levelt's (1989) model of L1 speech production, which inspired models of L2 speech production, may help us understand the role that working memory plays in language production. According to Levelt (1989), the speaker has to go through a number of processes, namely *conceptualization*, *formulation* and *articulation,* up to the point when the message can be finally articulated as overt speech. Working memory stores intermediate representations of messages generated in the components of the system (Conceptualizer, Formulator and Articulator) making them available for further processing.

The distinction between controlled and automatic processing (Shiffrin & Schneider, 1977) is key in Levelt's speech production model, since these two processes, although dichotomous, coexist within the act of speaking. According to Shiffrin and Schneider (1977), automatic processes are executed without intention or conscious awareness, are usually quick, and operate on their own resources. Controlled processes, on the other hand, demand attentional resources, which are limited in working memory. Controlled processes are usually serial and, therefore, take time. Looking back at the components of Levelt's model, message generation (in the Conceptualizer) involves highly controlled processing. The other components of Levelt's model – Formulator and Articulator - are claimed to be largely automatic in L1.

When it comes to L2 speech production, it can be argued that working memory capacity may be even more important as it would play a role not only in conceptualization but also in message formulation, since grammatical encoding processes are not completely automatized in L2 (Fortkamp, 2000).

In skill acquisition, the role of working memory is also a crucial one. Decades of research in cognitive psychology have revealed general information-processing constraints on the acquisition of skilled performance (McLaughlin, 1987; McLaughlin & Heredia, 1996). The most important constraint concerns the capacity of working memory – the amount of information about the task and generated results that subjects can keep continuously accessible during task performance (Ericsson & Delaney, 1998).

In this paradigm, learning takes place along a developmental continuum in which attention and control are necessary processes, at least in the early stages of skill development. Learning occurs with the mediation of controlled and automatic processes (Shiffrin & Schneider, 1977) and practice plays a key role for it is through practice that procedures are automatized, thus freeing controlled processes to be allocated to other higher levels of processing (McLaughlin & Heredia, 1996).

According to a number of researchers (Harrington, 1992; Berquist, 1998; Harrington & Sawyer, 1992, Fortkamp, 1995; Miyake & Friedman, 1998, among others), an interesting question to be pursued is whether working memory capacity may vary in the course of L2 acquisition as a function of increased command of language and, consequently, more automatization of the linguistic system. This belief is mainly based on the low correlations researchers have found between measures of working memory capacity in L1 and L2, which have led them to suggest, as already mentioned, that working memory scores in L1 and L2 may be independently motivated to some extent. While, in L1, working memory is believed to be more closely linked to a biological trait, in L2 it is often associated to the degree of proficiency one has in that specific language (Harrington, 1992; Berquist, 1998; Harrington & Sawyer, 1992; Miyake & Friedman, 1998).

Following the rationale above, researchers have been attempting to compile evidence on the extent to which working memory capacity is related to learners' performance and development of L2 speech (Bergsleithner & Fortkamp, 2007, Finardi, 2008; Fortkamp, 1999, 2000, 2005; Fontanini et al., 2005; Weissheimer & Fortkamp, 2004; Fortkamp & Bergsleithner, 2007; Guará-Tavares, 2005; Finardi & Prebianca, 2006; Xhafaj, 2006; Weissheimer, 2007; Berghsleitner & Fortkamp, 2007; Finardi, 2007; Finardi, 2008; Finardi & Weissheimer, 2009) .

Within this research paradigm, the degree of proficiency learners show in the cognitive task being performed, in our case L2 speaking, is a problem that researchers dealing with the psychometric correlational approach seem to be avoiding (Fortkamp, 1995). In order to address this issue, it has been suggested that investigations may verify this aspect more carefully by assessing individuals' working memory capacity during various moments of their L2 acquisitional process and then observing whether working memory capacity is held constant (Harrington, 1992; Berquist, 1998; Harrington & Sawyer, 1992; Miyake & Friedman, 1998). This is a contribution this study is intended to make.

2. The Present Study

An important consideration underlying this study is whether working memory capacity, as measured by the speaking span test, changes in the course of L2 speech development. Deriving from this possibility is the question of whether a change in working memory capacity would have a different impact on higher and lower span individuals.

In order to contribute to this discussion, the present study focuses on three main hypotheses: 1) Participants' working memory capacity scores will statistically vary across testing phases; 2) Participants who experience more gains in working memory scores across testing phases will also be those who experience more gains in L2 speech production scores within tests; 3) Higher span participants will experience more gains in fluency, accuracy, complexity and lexical density over testing phases than lower span participants.

3. Method

In order to address the relationship between working memory capacity and the development of L2 speech production, a longitudinal, experimental, mainly quantitative study (Nunan, 1996) was carried out at Universidade Federal da Bahia (UFBA).

3.1 Participants

Sixty-two undergraduate students of the Letras course at Universidade Federal da Bahia (UFBA) integrated the original sample of this experiment. Based on the proficiency trial[1], seven participants were excluded from the sample, leaving fifty-five to undergo the data collection procedures. Pearson's Correlations, which were run for each of the three ratings in the proficiency trial, proved to be significant (r (52) =.59; .76; and .64, $p < .01$), showing consistency among results provided by the three different raters. Cronbach's coefficient alpha for the proficiency test was .85, attesting internal consistency and reliability to the test, and, therefore, confirming the intermediate level of proficiency of the participants involved in the study.

Additionally, proficiency mean scores of the two groups (higher and lower span) were compared and results did not yield a significant difference ($t(16) = .13$, $p = .289$), suggesting that proficiency level does not seem to have impacted the memory scores in this study.

Out of these fifty-five participants, classified as intermediate-level subjects, forty-five were randomly chosen to compose the experimental group and ten students constituted the control group. The experimental group was divided into 16 lower span subjects and 18 higher span subjects based on their working memory scores. The data of 11 subjects in the middle tertile of the range of span scores were omitted from the analysis.

The control group performed two working memory tests, one immediately after the other, in order to identify whether there would be gains in performance due to practice effects.

3.2 Instruments

Each phase of the experiment consisted of two tasks: a task aimed at measuring working memory capacity and a task aimed at eliciting speech production in the L2.

3.2.1 The Speaking Span Test (SSPAN)

In order to assess participants' working memory capacity, two L2 versions of Daneman's (1991) speaking span test were constructed and applied in each of the two phases of the experiment. Each test consisted of 60 unrelated words, organized in sets of two to six words, which were silently read by the participants. The first word was individually presented for one second on the center of a computer screen. After ten milliseconds, the next word in the set appeared in the same position on the screen as the previous word was presented. At the end of each set, participants were required to orally produce a sentence for each word presented, in the form and order the word was presented.

After each participant finished generating the sentences for a given set, the next set would appear, and this procedure was followed until all sets had been presented. A two-word set was presented first, followed by a three-word set, and so on, ending the sequence with a six-word set. The end of each set was signaled by a black screen with interrogation marks on it and a sound signal. The interrogation marks signaled the number of words that had to be recalled and the number of sentences to be produced in that specific set.

Participants were instructed to use the words in the correct form and order they appeared to generate syntactically and semantically acceptable sentences, aloud, in English. For example, for the following set of three words:

job dog ice

a participant might produce the sentences:

"I've got a job"
"The dog is big"
"Ice melts"

There were no restrictions concerning the length or complexity of the sentences produced. Participants were also instructed to start uttering their sentences as quick as possible after the sound signal and not to interrupt the testing phase, since Response Time was one of the variables taken into consideration in this study[2]. A participant's speaking span was determined by the number of correct sentences produced, the maximum being 60.

Each participant underwent a training phase consisting of the same amount of words as the working memory test, taking as much time as necessary for him/her to feel comfortable with it. The actual testing phase only took place when participants reported being comfortable and confident enough to perform the test. Half of the participants performed SSPAN 1 and the other half performed SSPAN 2 in both phases of the experiment in order to avoid order and task effects. The interval between testing phases was of twelve weeks.

3.2.2 The Speech Generation Task

The two speech generation tasks consisted of participants describing two picture-cued narratives and were administered right after participants had completed the memory tests in both phases. Participants were encouraged to narrate the stories with as many details as possible, using their own imagination, command of language and background knowledge to accomplish the task. No time limit was given to participants for performing the task and they could keep the picture in front of them during the narration. All participants took at least one minute to perform the task. In order to control for task effects and avoid differences in performance in the two moments due to task complexity, half of the participants were assigned Speech Generation Task 1, and the other half was assigned Speech Generation Task 2 in both phases of the experiment.

Participants' L2 speech samples were analyzed in terms of seven variables, namely: (a) fluency, in terms of speech rate pruned and unpruned[3], and number of silent pauses per minute; (b) accuracy, considering number of errors per hundred words and percentage of error-free clauses; (c) complexity, in terms of number of subordinate clauses per minute; and (d) weighted lexical density, consisting of the percentage of weighted lexical items present in the speech sample.

4. Results

4.1 Gains in Working Memory Scores in two phases

In order to provide an overview of learners' performance in both phases of the Speaking Span Test, Table 1 below displays the means and standard deviations in working memory capacity scores for the two groups of participants – lower and higher span. For both groups, the maximum possible span score was 60.

Table 1. Means and standard deviations for working memory scores in two moments for the lower and higher span groups

Paired Samples Statistics					
LOWER		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	WM1	18.81	16	2.344	.586
	WM2	21,94	16	5.446	1.362
HIGHER Pair 1	WM1	32.61	18	4.767	1.124
	WM2	30.61	18	6.853	1.615

The results in Table 1 point to some increase in working memory capacity within phases for the lower span group. However, a slight decrease instead of an increase in working memory scores is found among higher span individuals from phase 1 to phase 2 of the experiment.

In order to attest statistical significance to the patterns of working memory variation found in the table above, a set of Paired Samples T-tests was applied to the data. Results are displayed below.

Table 2. Paired-samples test for working memory scores in two phases for the two memory groups

Paired Samples Test							
			Paired Differences		T	df	Sig. (2-tailed)
			Mean	Std. Deviation			
WM_GRUPO							
Lower	Pair 1	WM1 – WM2	-3.125	4.455	-2.806	15	.013*
Higher	Pair 1	WM1 – WM2	2.000	7.227	1.174	17	.257

(*p< 0,05)

Table 2 shows that the increase in working memory capacity scores in the lower span group proved to be statistically significant (t(15)=.013, p <.05. However, the same pattern did not hold for the higher span individuals who, conversely, did not show any significant change in working memory performance from phase one to phase two of the experiment.

The results just reported only partially support the first hypothesis of this study, which had predicted that *all participants*' working memory scores would vary significantly across testing phases. These results will be further discussed in the next section of this paper.

4.2 Working Memory Practice Effects for the control group

The difference between control participants' scores in the first and second working memory tests did not prove to be significant (t (9) = -0,978; p=0.354), and, therefore, no procedure was adopted to control for practice effects in this study.

4.3 Gains in Speech Production Scores in two phases

An additional objective of this investigation was to verify whether there was a relationship between gains in working memory capacity and gains in L2 speech production in this study, across testing phases. Hypothesis 2 predicted that participants who experienced more gains in working memory scores across testing phases would also be those who experienced more gains in speech production scores within tests. If that hypothesis is confirmed, the possibility of attributing working memory increase to L2 development might be considered.

Moreover, to identify to what extent the Speaking Span Test can predict L2 speech development was another aim pursued by the present study. In that sense, Hypothesis 3 predicted that the L2 speech development of higher span individuals would outperform that of lower span ones, in terms of fluency, accuracy, complexity and weighted lexical density. If that is the case, the Speaking Span Test might be considered in the future, as a result of this study, a predictor of an individual's L2 speech development as well as his or her L2 speech production.

Thus, in order to address hypotheses 2 and 3 restated above, T-test results are displayed in Table 3 for all speech production measures to verify whether there was significant L2 speech development between phases and how such development is related to working memory scores.

Table 3. Paired-samples T- tests for measures of L2 speech production for each memory group

Paired Samples Test							
			Paired Differences				
			Mean	Std. Deviation	T	Df	Sig(2-tailed)
WM_GROUP							
Lower	Pair 1	SRUN1 - SRUN2	-1.76	17.85	-.39	15	0.69
	Pair 2	SRP1 – SRP2	-2.70	19.65	-.55	15	0.59
	Pair 3	SPM1 – SPM2	-1.13	2.27	-2.00	15	0,06
	Pair 4	ACCURE1 – ACCURE2	1.39	5.72	.97	15	0.34
	Pair 5	ACCURC1 – ACCURC2	.63	24.88	.10	15	0.92
	Pair 6	COMPLT1 – COMPLT2	-.311	3.239	-.38	15	0.70
	Pair 7	WLD1 – WLD2	-1.87	2.96	-2.53	15	0.02*
Higher	Pair 1	SRUN1 – SRUN2	-2.77	24.60	-.47	17	0.63
	Pair 2	SRP1 – SRP2	-1.68	24.53	-.29	17	0.77
	Pair 3	SPM1 – SPM2	-.43	2.03	-.89	17	0.38
	Pair 4	ACCURE1 – ACCURE2	.99	3.08	1.36	17	0.19
	Pair 5	ACCURC1 – ACCURC2	.17	13.56	.54	17	0.95
	Pair 6	COMPLT1 – COMPLT2	-.98	1.88	-2.21	17	0.04*
	Pair 7	WLD1 – WLD2	.37	4.78	.32	17	0.74

(*p< 0,05)

According to the results in Table 3, both lower and higher span participants experienced gains in the following measures of speech production: speech rate unpruned and pruned, accuracy, and complexity. However, only gains in L2 weighted lexical density among lower span participants (t (15) = 1.88, p=0.02), and gains in complexity among higher span participants (t (17) = .98, p=0.04) can be considered statistically significant.

The results displayed in Table 3 allow the researcher to discuss the predictive ability of the Speaking Span Test in terms of L2 development. In this sense, results point to a tendency of the Speaking Span Test to differently predict the development of complexity and lexical density in L2. That is, higher span individuals seem to be more sensitive to developing more complex speech as they acquire the second language, while lower span individuals' speech development seems more sensitive to lexical development. This will be further developed in the next section.

5. Discussion

5.1 The developmental nature of the working memory system and its relation to L2 speech proficiency

Perhaps the greatest motivation for the present study has been the question of whether a person's working memory capacity experiences any sort of change in the course of L2 speech development and whether this change would be a function of L2 proficiency. Evidence of working memory expansion during L2 speech acquisition, in this sense, would support the hypotheses of this study and, consequently, the task-specific view[4] of working memory capacity (Carpenter & Just, 1989; Daneman & Carpenter, 1980; Daneman & Green, 1986; Daneman & Tardiff, 1987; Daneman, 1991; Just & Carpenter, 1992, among others). According to this view, working memory is related to the degree of proficiency in the cognitive task being predicted, in our case L2 speaking. Therefore, the main hypothesis guiding this study was: if participants improve their degree of L2 speech proficiency within data collection phases, their working memory scores will be likely to show some increase as well.

Conflated results in this study have shown that working memory capacity does indeed seem to experience some sort of change in the course of L2 speech development. However, results also indicate that this change does not accompany all participants' L2 speech development, as predicted. Evidence for that is in the fact that, while lower span participants experienced increase in both working memory scores and L2 speech production scores between testing phases (in terms of fluency, accuracy, complexity and weighted lexical density), higher span participants, on the other hand, experienced no significant increase in working memory scores, despite improved L2 speech proficiency (speech rate, accuracy and complexity) between phases.

Therefore, although, at first glance, results reported in this study seem to offer *some* support for the task-specific view of working memory capacity, caution needs to be exercised when drawing conclusions. It is true that an increase in working memory scores by lower span participants in this study accompanied an increase in L2 speech production measures by the same participants. However, the task-specific view of working memory does not seem to explain the fact that higher span participants did not show significant variance in working memory capacity scores within phases, despite their development in terms of L2 speech production.

In fact, the task-specific view of working memory capacity (Daneman, 1991) has been considered general and vacuous by other researchers (Fortkamp, 2000; Kane et al., 2001; among others) in the sense that it does not seem sufficient to clarify the relationship between the capacity of the working memory system and higher-level reasoning. In light of this caveat, Engle and his colleagues have proposed the attention-view of working memory capacity (Cowan, 1988; 1993; 1995; Engle et al., 1992; Conway & Engle, 1996; Engle et al., 1999; Engle & Oransky, 1999; Kane & Engle, 2002; Kane & Engle, 2003; Conway & Engle, 2005; Unsworth & Engle, 2007a, Unsworth & Engle, 2007b; Kane et al., 2007), which has been considered a more efficient, complete and sophisticated description of what the processing and storage mechanisms in working memory would entail (Fortkamp, 2007, personal communication).

According to the attention-view, working memory capacity reflects a domain-free ability to carry out higher-level cognitive tasks. More specifically, this view relates span scores of higher span individuals, primarily, to their more efficient domain-general ability to control attention when confronted with interference, and, secondarily, their more efficient domain-specific rehearsal and storage processes (Kane et al., 2007).

In relation to domain-general processes, Engle and his colleagues (Cowan, 1988; 1993; 1995; Engle et al., 1992; Cantor & Engle, 1993; Conway & Engle, 1996; Engle et al., 1999; Engle & Oransky, 1999; Kane et al., 2001; Kane & Engle, 2002; Kane & Engle, 2003; Conway & Engle, 2005; Kane et al., 2007; Unsworth & Engle, 2007a, Unsworth & Engle, 2007b, among others) have been emphasizing, for over 20 years, the general view of working memory limitations and the synergy of attentional processes in working memory capacity in maintaining and recovering access to information that is relevant to ongoing tasks and in blocking task irrelevant interference. Therefore, higher span participants in their studies have been interpreted as portraying a better ability to actively maintain task-relevant information outside of consciousness and to do the mental work necessary to quickly recover information from inactive memory despite interference (Kane et al., 2007). Lower span individuals, conversely, are poorer at actively maintaining information and more likely to lose access to the task goal. In addition, they are more likely to have their attention captured by distraction and to activate more irrelevant information than higher span individuals (Unsworth & Engle, 2007).

In terms of L2 speech production, Fortkamp (2000), also following Engle's attention-view theory of working memory capacity, was able to build the interface between the processes underlying working memory activity and L2 speech production. She concluded that individuals with a higher working memory capacity, in her study, had a greater amount of attentional resouces to be shared among 6 macro cognitive mechanisms involved in the encoding of L2 message – activation, maintenance, suppression, strategic search and retrieval, and monitoring. In other words, they were able to coordinate the processing and storage demands of the L2 production task (conceptualization, formulation and articulation of the L2 message) during the formulation of sentences in the span test, thus freeing more resources for keeping the words presented in an active state. More specifically, Fortkamp further claims that the processes that are captured by the speaking span test in her study are involved in the grammatical encoding of the L2 message (Levelt, 1989) which, in turn, qualifies as a *controlled processing activity*[5] (Engle & Oransky, 1999). In this sense, higher span individuals seem to be more able than lower span ones to devote controlled attention to the activation of appropriate lexical units and the syntactic information about these units, in order to build a surface structure of the message, among other things (Fortkamp, 2000).

At this point, after specifying the cognitive differences of higher and lower span individuals, one question remains to be answered: why did only lower span participants in this study show statistically significant variation in working memory span scores from phase one to phase two of the experiment? Based on the discussion so far, it would be plausible to suggest that a *variation* in lower span participants' span scores from phase one to two in the experiment may reflect their improvement in domain-specific processes - strategies, encoding, rehearsal - along the two phases of data collection, which eventually impacted their span scores.

An explanation to why higher span participants' working memory capacity scores remained stable within phases may be that these individuals were probably more efficient at controlling attention already in the first phase of the experiment, and also at employing strategies to encode and later retrieve information from memory. In other words, they may not have felt compelled to push their working memory capacity over a threshold level.

Lower span individuals, conversely, had more room for improvement in both domain-general and domain-specific aspects of working memory capacity, and that is probably why variation in working memory capacity among these individuals was more visible in T-test results[6]. Higher span individuals, as it has been claimed, may have started the first data collection at some sort of threshold level in terms of working memory capacity, being less sensitive to working memory variation among testing phases.

5.2 The relationship between the speaking span test and L2 speech development – the development of complexity and lexical density in L2

The focus in this last section of the discussion is to explain the greater development of L2 speech complexity among higher span individuals and of lexical density by lower span ones. In doing so, I want to, eventually, address the question of whether the speaking span test may serve as a potential predictor of L2 speech development, which represents an important aim of this investigation.

As previously reported, higher span participants in this study showed significant gains in terms of complexity of L2 speech within testing phases. At first sight, not considering the memory group involved, this result seems to corroborate the great majority of research on speech production, in which complexity is generally reported as one of the aspects most open to improvements when learners perform orally (Foster & Skehan, 1996; Bygate, 2001; D'Ely, 2006).

To summarize, in Foster and Skehan's (1996) study, the narrative task produced the highest level of complexity and such gains took place at the expense of accuracy. Similarly, Bygate (2001) found that speech complexity seemed to improve when participants repeated an oral task, which was not true for measures of accuracy and fluency. D'Ely (2003) found that her experimental group outperformed the control group in terms of fluency and complexity but not in terms of accuracy. Finally, D'Ely (2006) found that both gains in complexity and accuracy were significant for participants in her planning-for-repetition condition.

Although studies in the task-based approach to L2 teaching and learning, as the ones above, usually involve specific experimental conditions and/or instructional phases, they seem to be consistent in showing that gains in speech production, in general, are more prone to revealing significant changes in the degree of complexity of learners' speech.

In the present study higher span individuals' increase in complexity measures has been shown to be statistically significant, meaning that not only complexity seems to be the most sensitive aspect to change along speech development, but it is among higher span individuals that this sort of change seems to be more significant.

In order to understand why higher span individuals are more susceptible to developing complexity of speech in the course of L2 development, we need to first understand what the measure of complexity adopted in this study - number of dependent clauses per minute - is believed to capture. Foster and Skehan (1996) make an important distinction between accuracy and complexity in the sense that both features of speech production concern form but with a significant difference in emphasis. According to them, complexity emphasizes the organization of what is said and draws attention to more elaborateness of language and a greater variety of syntactic patterning that may be used by the speaker.

Similarly, research on working memory capacity and the acquisition of vocabulary (Mendonça, 2003) has shown that higher span individuals are better able to learn verbs than lower span ones. This difference is attributed by that researcher to the fact that higher span individuals are better able to learn words that are more difficult to visualize due to their ability to manipulate and use strategies more consistently and effectively (Lawson & Hogben, 1996 in Mendonça, 2003).

Based on what has been said, it is possible to assume that higher span individuals are better able to manipulate language, and more specifically grammatical items, which eventually leads to more gains in complexity of speech, than lower span ones. According to Foster and Skehan (1996), complexity is likely to be associated with the speakers' engagement in restructuring the language system, as more complex subsystems are developed. In this sense, higher span individuals' speech reflects more elaborateness, risk taking ability and willingness to exploit forms which are closer to the cutting edge of interlanguage development.

Following the thorough discussion of the issue of complexity, an unexpected finding cannot go without explanation. Contrary to the prediction in Hypothesis 3, lower span participants in this study had more gains in lexical density of speech across testing phases than higher span individuals. Thus, it seems reasonable to think that the development of L2 speech by higher and lower span individuals, in terms of lexical density, seems to be sensitive to different factors. While lower span individuals' speech seems to be characterized by the use of low-frequency words and less repetition, higher span individuals' speech seems to reflect the use of high-frequency words, that is, more repetitions of lexical items, and the elaboration of more complex structures. For both cases, there are advantages and disadvantages. The use of low-frequency words by lower span individuals results in denser speech but also in slower lexical searches and, consequently, reduced fluency. The use of high-frequency words by higher span individuals, on the other hand, allows them to speak more fluently, accurately and elaborately, but makes their speech sound more repetitive.

Finally, although the results are not conclusive in this respect, they seem to indicate that the speaking span test may serve as a potential predictor of L2 speech development, at least in terms of complexity of speech for higher span individuals and of lexical density for lower span ones.

6. Conclusion

The present study focused on investigating the relationship between working memory capacity and L2 speech development. It was predicted that working memory scores would increase over trials as a result of more command of cognitive processes related to L2 speech production. It was also hypothesized that the speaking span test would predict participants' fluency, accuracy, complexity and lexical density in L2 speech production and development.

As for the developmental nature of working memory capacity, it has been suggested that working memory capacity does not seem to vary *exclusively* as a function of how efficient an individual gets at the specific processes demanded by the task with which working memory is being correlated, in this case, L2 speaking. Evidence that lower span subjects improved both their working memory capacity and L2 speech production scores has led to the conclusion that the two are indeed related. However, the fact that higher span individuals' working memory scores did not suffer significant change, despite their improvement in L2 speech measures across phases, indicated that the relationship between working memory capacity and L2 speech development is not that straightforward and that there is more at stake, mediating such relationship. All in all, it has been suggested that working memory variation, in the case of lower span participants in this study, may be interpreted less as a function of L2 speech development *per se* and more as a result of improvement in domain-general and domain-specific processes in working memory across phases of the experiment.

Finally, the speaking span test also was found to be related to the *development* of individuals' L2 speech, in terms of complexity and lexical density. Higher span individuals' seemed more able to develop more complex speech over a period of time, which reflects their greater engagement in restructuring, organizing and elaborating language. Lower span individuals' speech development, conversely, seemed to be more related to the acquisition and use of low-frequency words.

The proposals made in the present study are relevant since they go beyond the general notion that working memory is an efficient predictor of L2 speech *performance*. This study represents a step forward, by showing how working memory capacity is involved in L2 speech *development*.

The present study represents a tentative and preliminary attempt to systematically examine the relationship between working memory capacity and L2 speech development. Although it has been theoretically and methodologically based on existing literature in the field, research on working memory capacity and L2 speech production to date has only started dealing directly with the issue considered here – the relationship between working memory and L2 speech development. Thus, this study is to be considered in its exploratory nature, and the results here presented should be seen as modest and suggestive rather than conclusive.

Notes

1. In order to obtain a more homogeneous sample in terms of L2 speech proficiency, thus being able to arrive at firmer conclusions concerning L2 speech development within the two testing phases, participants were submitted to a Proficiency Trial based on the speech generation task which they performed in the first phase of the experiment. The 55 remaining participants are described as having an intermediate level of English in terms of speaking based on their mean proficiency rating score of 2.87, which approaches the criteria for the intermediate level (3), according to the proficiency scale adopted. (D'Ely & Weissheimer, 2004)

2. Regarding Response Time, no significant correlations were found between the amount of time participants took to perform the memory tests and the working memory scores they obtained in the two phases of the experiemnt ($r(45) = .23$ and $.19$, $p<.05$).

3. Following Fortkamp (2000), speech rate **unpruned** was calculated by dividing the total number of semantic units (complete and partial words) produced, including repetitions, by the total time spoken (including pauses) in seconds. The result was then multiplied by 60 so as to express the number of words per minute. Speech rate **pruned** was calculated the same way, but all words that were repeated (excluding repetitions for rhetorical effect and

repetitions for immediate correction) were excluded from the count. In both cases, contractions were counted as one word. Speech rate unpruned is a more general measure that is assumed to reflect the relationship of articulation and silence, whereas speech rate pruned is a more specific measure that reflects a more straightforward expression of ideas and unimpeded articulation of words.

4. Although the terms *task-specific* and *domain-specific* have, sometimes, been used interchangeably in the literature (Hambick & Oswald, 2005), a distinction is adopted here, following Just and Carpenter (1992). *Task-specific* is taken to mean the variation across tasks (reading as opposed to writing and speaking, for instance) and *domain-specific* to mean variation across domains (language as opposed to visual-spatial processing, for instance).

5. Fortkamp (2000) defines *controlled processing activity*, following Engle and Oransky (1999), as "the activity of controlling or regulating attention so that it can be divided among the processing the activity entails, some of which being activation, temporary maintenance of active information, suppression, serial search, serial retrieval, and monitoring" (p. 164).

6. The claim that attentional limits in working memory fit a power law function (Newell & Rosenbloom, 1981) was first put forward by Woltz (1988). According to the power law of learning theory, the less capacity subjects have, the more room for improvement they will display and the more they will respond to treatment or learning. Conversely, the more capacity subjects have, the smaller the impact of treatment or learning on this capacity.

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