THE ROLE OF WORKING MEMORY CAPACITY IN THE ABILITY TO PRODUCE LEXICALLY DENSE L2 SPEECH

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Abstract

This study investigates the relationship between working memory capacity and lexical density (LD) in L2 speech production. The cohort involved 45 participants, who were submitted to a data collection procedure consisting of a speaking span test (adapted from Daneman, 1991) and an L2 speech production task. LD was measured by weighted lexical density, which refers to the proportion of new and repeated words in a text and provides a relationship between the number of words produced with lexical properties and the number of words produced with grammatical properties (O'Loughlin, 1995). Results show that participants' working memory spans were indirectly related to their L2 lexical density, that is, higher span participants used more repeated lexical items than lower span participants. These results regarding L2 speech production are explained based on the existence of competing goals in speech performance (fluency, accuracy, complexity and lexical density), reported by several researchers in the speech production field. The discussion suggests that trade-offs between these speech production goals explain the fact that higher span individuals in this study seemed to have relied a greater deal on high-frequency words in both phases of the experiment to guarantee supremacy at other aspects of speech production, such as fluency, accuracy or complexity.

KEY WORDS: working memory; lexical density; speech production; L2

Introduction

Research on speech production to date acknowledges the fact that limitations in individuals' working memory, the system that controls and regulates behavior for performance in cognitive tasks (JUFFS; HARRINGTON, 2011), may be seen as a possible independent constraint on the process of speaking in both L1 (e.g., DANEMAN; GREEN, 1986; DANEMAN, 1991) and L2 (e.g., FORTKAMP, 1999; HARSUIKER; BARKHUYSEN, 2006; MIZERA, 2006).

In attempting to unveil the complexities of L2 speech production, Fortkamp (1999) found a significant correlation between an L2 version of the Daneman's (1991) speaking span test and fluency and articulation in L2. In a follow-up study, Fortkamp (2003) found that participants who have larger working memory capacity are also able to produce faster and more continuous speech, as well as use fewer silent pauses. Interestingly, trade-off effects were found between accuracy, complexity and lexical density in this study. That is, more accurate and complex speech was attained only at the expense of the use of frequent lexical items.

Weissheimer and Fortkamp (2004) set out to closer investigate the relationship between working memory capacity and fluency, this time also focusing on an extra variable, namely the role of memory strategy use and practice in working memory capacity. As for the relationship between working memory scores and fluency

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measures, these researchers found positive and significant correlations, thus reassuring the predictive ability of the speaking span test.

With a more specific goal of trying to understand the particularities of spontaneous and planned speech performance, Guará-Tavares (2005) found correlations between working memory scores and fluency in spontaneous speech performance, and between working memory scores and accuracy and fluency in planned speech performance. Finardi and Prebianca (2006) aimed at investigating the relationship between working memory capacity and L2 fluency, accuracy, complexity and lexical density in a picture description task. The fact that working memory scores only correlated significantly with the measure of fluency in their study led the researchers to conclude that, to speak fast, participants were left with few resources to enable them to produce accurate, complex and lexically dense speech.

Xhafaj (2006) set out to investigate differences in the distribution of silent pauses in L1 and L2 speech production of Brazilian speakers, trying to disentangle the relationship between pause distribution as an indicator of lack of fluency in L2 speech and working memory capacity. Her results indicate that larger-capacity speakers are better able to sustain L2 fluency (with fewer pauses *within* boundaries and longer speech runs) than those speakers with fewer resources.

Mizera (2006) found a significant correlation between L2 working memory capacity and L2 oral fluency. Kormos and Sáfár (2008) found a significant correlation between phonological short-term memory capacity and the overall proficiency of pre-intermediate learners; and between the digit span test and the L2 acquisition of learners at a beginner's level of proficiency. Finally, Prebianca (2010) showed that bilingual lexical access is predicted by working memory capacity. In her study, higher spans retrieved lexical items faster than lower spans.

As one can see, there has clearly been substantial initiative towards investigating the role of working memory capacity in second language production, in general. However, only two studies among the ones reported above (FORTKAMP, 2003; FINARDI; PREBIANCA, 2006) addressed speech production in terms of lexical density. Thus, we believe there is enough room for scrutinizing the relationship between working memory capacity and lexical density, hoping to shed some new light on the lack of correlations found in the studies by Fortkamp (2003) and Finardi and Prebianca (2006), mentioned above.

The ultimate purpose of this study is to contribute to both theories of working memory, in that it further specifies the nature of capacity limits in working memory, and to theories of L2 speech production, since it demonstrates the relationship between working memory capacity and lexical density in L2 speech production. Finally, it may provide methodological suggestions for best assessing the relationship between working memory capacity and L2 speech production in the future.

Method

In order to address the relationship between working memory capacity and lexical density in L2 speech production, a longitudinal, experimental, quantitative study was carried out focusing on the following research questions: a) are working memory capacity and lexical density in L2 speech production related?; and b) how do higher and lower span individuals differ in production scores, in terms of lexical density? It is hypothesized, based on research which correlates working memory capacity with higher-order cognitive behavior that participants' working memory capacity scores will positively correlate with measures of L2 lexical density.

Participants

Sixty-two undergraduate students of the English course at a university in the northeast of Brazil integrated the original sample of this experiment. The cohort consisted of nineteen male and forty-three female participants, ages ranging between 18 and 35, with a mean of 23.5, thus a predominantly adult population. Because participants belonged to different semesters in the course, they were all submitted to a proficiency trial in order to obtain a more homogeneous sample in terms of L2 speaking proficiency[2]. All participants agreed to be volunteers in this study and signed a consent form.

After the proficiency trial, forty-five participants still integrated the cohort and seventeen were excluded from the sample, based on the judgment of three experienced raters[3]. The remaining participants were classified as intermediate-level subjects.

Instruments

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.

The Speaking Span Test (SSPAN)

Participants' working memory capacity in this study was assessed by means of the Speaking Span Test , developed by Daneman and Green (1986) and Daneman (1991), which has been traditionally used and has proven to be adequate in various attempts to elicit differences in working memory capacity among individuals and its relation to L2 speech production (FORTKAMP, 1999, 2000; D'ELY et al., 2005; FINARDI, 2005; FINARDI; PREBIANCA, 2006; GUARÁ-TAVARES, 2006; BERGSLEITHNER, 2007; WEISSHEIMER; MOTA 2009; PREBIANCA, 2010).

The speaking span test was based on Daneman's (1991) test and constructed with 60 unrelated words. An additional training test was developed with other 60 unrelated words and used in the data collection as demonstration and practice before the actual test took place.

Following Daneman (1991), the total number of 60 words was organized in three sets, each of 2, 3, 4, 5 and 6 words. Each word was presented individually, in the middle of a computer screen for one second. Participants were instructed to read the words silently. After ten milliseconds, the next word in the set appeared in the same position on the screen as the previous word was presented. After each participant finished generating the sentences for a given set, the next set would appear, and this procedure

[2] The proficiency trial consisted of a speech generation task which participants performed as part of the data collection. Three experienced raters assessed participants' speech samples using a Speaking Proficiency Scale (adapted from the Cambridge FCE Oral Assessment Scale). Participants' overall speech production was assessed in terms of fluency, accuracy and discourse management.

[3] 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.

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.

Participants' speaking span was defined as the maximum number of words (out of 60) for which they could generate grammatically and semantically acceptable sentences in English. Following Daneman (1991) and Daneman and Green (1986), in this study, participants' responses, which were recorded, transcribed and analyzed, generated two different speaking span scores: a speaking span strict score and a speaking span lenient score. In the speaking span strict score, as in Daneman (1991) and Daneman and Green (1986), one point was given to the sentences the subject produced containing the target word in the exact form and order of presentation. In the speaking span lenient score, similarly to Daneman (1991) and Daneman and Green (1986), one point was also given to sentences that contained the target word in a form other than that of presentation (e.g., target word being 'drug' and the word in the sentence produced being 'drugs'). However, differently from Daneman (1991) and Daneman and Green (1986), half a point was also awarded in the lenient score to: (a) sentences containing certain grammatical inaccuracies (article "the", prepositions or third person "s")[4] , and (b) words recalled in an order other than that of presentation. No credit was given to ungrammatical sentences in terms of syntax and semantics (except for those three cases described above).

The Speech Generation Task (SGT)

Participants' L2 speech production was assessed by means of a Speech Generation Task, which elicited scores of lexical density for each of the subjects involved in the data collection. The speech generation task consisted of participants describing a picture-cued narrative and was administered right after participants had completed the memory test.

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.

Following Mehnert (1998), O'Loughlin (1995), Fortkamp (2000) and D'Ely (2006), lexical density of L2 speech was measured by weighted lexical density. Lexical density refers to the proportion of new and repeated words in a text (O'Loughlin, 1995). Weighted lexical density is a more complete measure, which provides a relationship between the number of words produced with lexical properties and the number of words produced with grammatical properties (O'LOUGHLIN, 1995).

According to O'Loughlin (1995), in order to assess participants' weighted lexical density, it is first necessary to determine what a basic unit of lexical density is.

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[4] According to Ellis (1987) and Butler (2002), these specific mistakes - article "the", prepositions and third person "s"- among others, are very persistent mistakes for learners of English as a second language and their acquisition, when at all mastered, happens towards very late stages of interlanguage.

For this purpose, he suggests that the notion of a "linguistic item" rather than the "word" is more appropriate to analyze lexical density in speech data, because there is not a one-to-one correspondence between linguistic items and words in English (O'LOUGHLIN, 1995; FORTKAMP, 2003; D'ELY, 2006). Consequently, multiword verbs (i.e. *fall in love with*), phrasal verbs (*look for*), idioms (*head over hills*) and contracted forms (*I'm, aren't*), which consist of more than one word, are counted as one linguistic item in the present study.

Following Fortkamp (2000) and D'Ely (2006), under the category of grammatical items were included: (1) all modals and auxiliaries, (2) all determiners (articles, demonstrative, possessive adjectives, quantifiers and numerals). (3) all pronouns, and 'this' and 'that' when used to replace clauses, (4) interrogative adverbs (what, when, how) and negative adverbs (not, never), (5) all contractions of pronouns and auxiliary verbs (counted as one item), (6) all prepositions and conjunctions, (7) all discourse markers including conjunctions (but, so, and), sequencers (next, finally), particles (oh, well), lexicalized clauses (you know, I mean) and quantifier phrases (anyway, somehow, whatever), (8) all lexical filled pauses (so, well), (9) all interjections (gosh, really, oh) and (1) all reactive tokens (OK, No!).

Under the lexical category (FORTKAMP, 2003; D'ELY, 2006) nouns, adjectives, verbs, adverbs of time, manner and place were considered lexical items. As the notion of item rather than word is used here, multiword verbs, idioms and contractions (both of pronouns and main verbs) counted as one lexical item.

As a subsequent step to the analysis, lexical and grammatical items were divided into high-frequency and low-frequency lexical and grammatical items. High and low frequency lexical and grammatical items were determined in relation to their idiosyncratic use in each participant's speech samples(s). Thus, a high frequency grammatical or lexical item was considered the one which appeared more than once in the same speech sample. Inflections and derivations of the same lexical or grammatical item, which denote repetition, were counted as a high frequency item (i.e. fall/fell, this/these). A low frequency item was considered the one which appeared only once in the same speech sample. Subsequently, high-frequency items were assigned half the weight of low frequency items. This is a more refined analysis which is warranted in formal investigations of lexical density (O'LOUGHLIN, 1995; MEHNERT, 1998; FORTKAMP, 2003; D'ELY 2006).

As a final step to the analysis, in order to obtain an index of participants' weighted lexical density in the participants' narratives, the total number of weighted lexical items was determined, following O'Loughlin (1995), Fortkamp (2000), and D'Ely (2006). All lexical and grammatical items were counted and high-frequency items were given half of the weight of low-frequency lexical and grammatical items. So a score was obtained for both lexical and grammatical items. The sum of both scores resulted in the total number of weighted linguistic items. The score obtained from the weighted lexical items was divided by the total number of weighted linguistic items. The resulting figure was then multiplied by 100 to determine the percentage of weighted lexical items over the total number of weighted linguistic items in each participants' speech sample(s).

Results and discussion

The role of working memory capacity in the ability to produce lexically dense L2 speech

The main objective of this study was to further investigate the counter-intuitive evidence between span scores and weighted lexical density, found in Fortkamp (2000) and Finardi and Prebiana (2006). The initial hypothesis in those and this study was that working memory scores would correlate positively with measures of L2 weighted lexical density, in terms of the percentage of weighted (low-frequency) lexical items over the total number of linguistic items produced by the participants. In other words, it was predicted that higher span participants would be able to produce a higher range of vocabulary items, thus repeating fewer items than lower span participants. In this sense, they would have a greater amount of low-frequency items present in their speech as compared to lower span individuals.

However, results in Table 1 show the exact opposite direction of the one described above. As one can see, although not reaching significance and showing a weak relationship, results of working memory and lexical density show, in general, an opposite pattern from the one expected (r (45) = -.10 and -.13, p>.05) for strict and lenient scores, respectively.

Table 1

Correlations between working memory capacity scores and weighted lexical density.

	WLD
WMS	-.10
WML	-.13

N=45
WLD= weighted lexical density
WMS= working memory strict
WML= working memory lenient

As depicted in Figure 1, contrary to what was expected, a negative correlation was approached, meaning that, as working memory scores increased among participants, the number of low-frequency lexical items they produced slightly decreased. In other words, participants with a higher working memory capacity in this study tended to use a greater number of high-frequency lexical items in their speech.
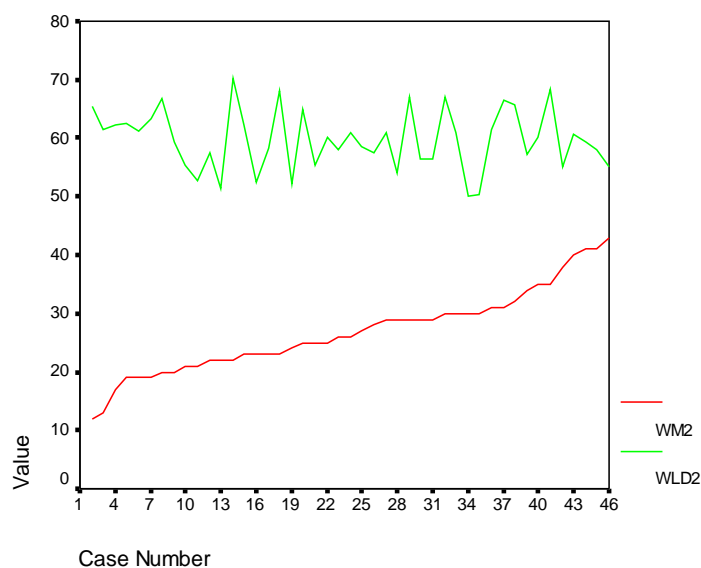

Figure 1. Participants' performance in the speaking span test and measures of weighted lexical density in the speech generation task.

The results regarding the relationship between working memory and weighted lexical density reported above are similar to those in Fortkamp (2000) and Finardi and Prebianca (2006), where the same pattern of relationship was observed.

Fortkamp (2000) found that individuals with a higher working memory capacity tend to produce speech with lower lexical density; that is, they use a smaller number of different lexical items when speaking in the L2. In attempting to explain this counter-intuitive finding in her study, she claims that the lower lexical density in participants' speech samples might be related to the fact that L2 speech production is lexically driven and speakers tend to re-use those lexical items that are already activated so that resources can be directed at other aspects of the production process.

Similarly, Finardi and Prebianca (2006) have also reported a negative relation of working memory and lexical density. Once again, they offer trade-off effects among different aspects of speech production as an explanation to account for such negative correlation. According to these researchers, because L2 processes seem to posit an extra load on the speakers' cognitive system and because they possess a limited working memory capacity, it is likely that when aiming at speaking more fluently and using more complex structures, L2 speakers seem to penalize other aspects of the skill, in this case, lexical density.

Taking together the results in Fortkamp (2000), Finardi and Prebianca (2006) and in this study, there appears to exist an association between working memory capacity and weighted lexical density, but this association (although weak) indicates that, in fact, individuals with a larger working memory capacity tend to use a smaller number of different lexical items. As a result, there seems to be room to claim that the relationship between working memory capacity and weighted lexical density in L2 seems to be negatively driven.

However, a question still remains: why do higher span individuals produce fewer low-frequency lexical items than lower span ones? It may be that, as argued by Fortkamp (2000), by using more high-frequency lexical items, in other words, by using repeated words more frequently in the speech generation task, higher span individuals are able to allocate more working memory resources to generate more accurate speech and to increase fluency by pausing less when speaking.

A closer look at our data reveals that high frequency lexical items in higher span individuals' speech seem to be composed of formulaic language[5] and ready-made chunks of language, among other items. These items, which may be called *islands of reliability* (DECHERT, 1983), seem to serve as an economy heuristic (ANDERSON, 1995) in the speech of higher span individuals, ensuring more fluent speech production.

The suggestion that the use of formulaic language might help L2 speakers to produce fluent stretches of speech is not new. Dechert (1983) coined the term *islands of reliability* which, similarly to formulaic language, represent "native-like utterances consisting of formula-like linguistic units of varying length and syntactic complexity, which serve as anchoring points for further planning and execution speech processes" (p.183). In terms of the speech processes, the use of formulaic language is believed to make language processing more automatized, which frees more cognitive space for other aspects of speech production.

Contemporary studies in the speech production area have devoted increasing attention to the analysis of formulaic speech (KORMOS; DÉNES, 2004). Towell,

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[5] Formulaic language consists of lexical chunks that result from binding frequent collocations (Ellis, 2002)

Hawkins, and Bazergui (1996) investigated what qualitative changes take place in the use of formulaic language parallel to the increase of fluency after participants spent a year in the target language environment. They found that the participants improved in how they employed different types of formulae after their study abroad. Similarly, Ejzenberg (2000) compared how fluent and non-fluent speakers employ formulaic language. Her results also showed that fluent students were able to make use of prefabricated chunks more efficiently, whereas non-fluent learners frequently used formulae inappropriately.

To illustrate this discussion, we compare a higher span individual's speech sample to a lower span individual's one in an attempt to identify potential *islands of reliability* which may account for the increase in fluency:

Participant 33 (higher span):

Ok the story there it goes the there is a couple in a restaurant and they are just having their dinner <u>and so on</u> but the woman was <u>like</u> talking a lot <u>bla bla bla</u> and the man was <u>like</u> oh my god what can I do I'm just here sitting and doing anything and she's talking a lot a lot a lot <u>bla bla bla</u> so then he just started to think on hitting her and he just thought I can break this bottle of wine in her in her head or better I can bite her nose oh no I can just kick her her head <u>I don't know</u> but I have to do something I'm so bored here and she's talking a lot <u>bla bla bla</u> how silly he got something and threw on her nose she was <u>like</u> what did you do why did you do that and he was just eating his meal <u>and so on</u> and she said this is not polite and he just was just there eating and <u>that's it</u> finish

Weighted lexical density: 51,40
Speech rate unpruned: 147,94
Silent pauses per minute: 0,00

Participant 32 (lower span):
Well, the story is very sad. A man, he's begging for a woman his pardon, he wants to marry her, but she don't care...she doesn't care about him. She ...he brings her many presents: a ring, necklace, brilliant, <u>you know</u>, many presents...many gifts to her. But she doesn't care. She doesn't want anything with him, she doesn't want to mary him. And he does many impossible stuffs for her to pay attention him, to marry him, because he loves her too much. But anything he does calls her attention. So, in the end, as he sees that anything he does it will be necessary to change her mind, or to change her mood, so he appears in front of her house with another girl, and...in a beautiful and big new car, to make her impressed. So this case, finally, she feels that she has lost him to another woman and that's the end of the story. I guess it's good for him, not for her because she's alone and she has...and he has another company, another affair to be with him as long as it lasts.

Weighted lexical density: 64,34
Speech rate unpruned: 75,00
Silent pauses per minute:7,24

It is possible to observe in the two samples above that the higher span participant seems to employ a greater amount of formulaic language and ready-made chunks (*and so on, bla bla bla, that's it, I don't know, like*) , and to repeat him/herself more. The lower span individual, conversely, does not seem to make such great use of formulaic

language, and seems to repeat him/herself less, which is reflected in their higher score of weighted lexical density.

The fact that higher span individuals use formulaic language and tend to repeat these items corroborates Fortkamp's (2000) claims that higher span individuals tend to re-use already activated items. According to Ashcraft (1994) and Ellis (2002), words that are used more frequently are stored more strongly in memory (mental lexicon), and stronger memory traces can easily yield faster search times. As a result, higher span individuals are able to faster access high frequency words, increasing their speech rate and having to pause less. On the long run, higher span individuals seem to keep benefiting from the frequency effect, once, as argued in Ellis (2002), language acquisition is a process of dynamic emergence and learners' language is a product of their history of usage.

Final Considerations

The main objective of the present study was to verify whether and how working memory capacity and lexical density in L2 speech production are related. To address the research questions in this study, forty-five intermediate learners of English as an L2 were submitted a data collection process, consisting of a working memory test (SSPAN) and a speech generation task (a picture-cued narrative). Participants' speaking samples were analyzed in terms of weighted lexical density (percentage of low-frequency items over linguistic items).

The results, although not statistically significant, seem to contradict the original hypothesis of this study, namely that working memory scores would positively correlate with L2 lexical density. On the contrary, the data here show that higher span individuals seem to produce speech which is, in general, less lexically dense, i.e. it contains fewer low-frequency lexical items and more lexical repetitions, in comparison to the one of lower span individuals. These results regarding L2 speech production seem to support the existence of competing goals in speech performance (fluency, accuracy, complexity and lexical density), reported by several researchers in the speech production field (FOSTER; SKEHAN, 1996; SKEHAN; FOSTER, 1995; BYGATE 2001; FORTKAMP, 2003; D' ELY et al. 2004; FINARDI 2005; GUARÁ-TAVARES 2006; FINARDI; PREBIANCA 2006; XHAFAJ 2006; FORTKAMP; BERGSLEITHNER, 2007; and BERGSLEITHNER, 2007; WEISSHEIMER; MOTA, 2009). Trade-offs between these speech production goals may explain the fact that, in this study, higher span individuals are generally more fluent while speaking the L2, but, conversely, they repeat themselves more and are less able to produce lexically-dense speech than lower span ones.

The present study represents a tentative and preliminary attempt to systematically examine the relationship between working memory capacity and lexical density in L2 speech. Although it has been theoretically and methodologically based on existing literature in the field, this work has limitations. First of all, the reduced sample size of the two span groups involved in this study may have been responsible for the weakening of some correlations and the lack of significance of gains in performance. Moreover, weighted lexical density, as it was applied in this study, measures the frequency in which items appear in the learners' speech samples. It taxes repetitions of items, but repetitions are devices that bring cohesion to discourse, and also function as emphatic devices. Weighted lexical density does not account for different degrees of complexity in speakers' lexical choices. Consequently, a careful analysis of how

repeated items are used in participants' speech and the inclusion of a lexical measure which tackles differences in complexity of lexical items should be considered in the future.

All in all, despite the noted limitations, 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, shedding some new light on the peculiar relationship between working memory and L2 lexical density.

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