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The Effects of Working Memory Capacity on the Use of Formulaic Language in L2 Speech Production

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Abstract. Working memory (WM) has been widely acknowledged as a significant cognitive mechanism responsible for multiple tasks including information storage and processing. L2 oral production, as a complex cognitive activity, has been found to be restricted by working memory capacity (WMC). However, the specific aspects of L2 oral speech affected by WMC remain controversial due to methodological variations, which suggests the need of a mediating factor to reveal the underlying cognitive dynamic. In order to fill this gap, the current study focuses on a potential mediating variable, the use of formulaic language, which requires the involvement of WM and also proves to be an effective tool to mitigate cognitive load during L2 oral production. By comparing the low and high WM groups' performances in L2 impromptu speech in terms of the use of formulaic sequences, the study has found that the high WM group showed an overall higher frequency of the use of formulaic language, with a significant advantage in the frequency and diversity of polywords over the low WM group. Moreover, the errors in the speeches could be classified into interlingual, intralingual, redundancy, and blending ones. By delving into the causes of each type of errors, the retrospective interviews revealed that a larger WMC supported more efficient multitasking, greater attentional and inhibitory control, and more complex online processing, which contributed to high-level L2 oral production. The results offer implications for improving L2 learners' oral competence and serve as a lens into the interaction between WM and L2 oral performance.

Keywords: working memory, working memory capacity, formulaic language, L2 oral production

1. Introduction

Working memory (WM) is a cognitive system responsible for the control, regulation, and active maintenance of information in the face of distracting information [1]. The first and the most important design feature of WM relates to its core nature of being a limited capacity of human cognition [2], which affects individuals' cognitive and storing abilities [3,4]. Thus, differences in WMC may lead to different levels of efficiency and accuracy in information processing and storing.

L2 oral production, as a complex cognitive activity, has been found to be restricted by WMC [5-8]. The production process involves a series of processing tasks such as organizing communicative intentions, activating relevant concepts, and retrieving meaning, structures and phonological

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information, which places a considerable load on WM. In order to ease the cognitive pressure, L2 learners often rely on the use of formulaic sequences. These prefabricated linguistic chunks are stored and retrieved as holistic units, which can free up cognitive resources for other aspects of production [9,10].

However, empirical findings are generally inconsistent in the specific impact of WMC on L2 oral performance due to methodological variations [11,12], and the underlying cognitive processes remain under-explored. To address the problem, the current study aims to investigate the dynamic interplay between WM and L2 oral production by examining how individual differences in WMC influence the use of formulaic language among Chinese EFL learners.

2. Literature review

2.1. Theoretical models of working memory

There are three dominant models of WM in cognitive psychology: Baddeley's [13,14] multiple-component model, Cowan's [15] embedded-processes model, and Engle and Kane's [16] executive control model.

Baddeley and Hitch [17] first proposed a model of working memory, which conceptualizes WM not as a passive store but as an active system capable of storing and processing information simultaneously. It consists of three components: a central executive acting as an attentional control system, a visuospatial sketchpad associated with visual or spatial information, and a phonological loop that holds auditory or verbal information. Later, Baddeley [18] added a new component to the original model, the "episodic buffer", which serves as a temporary storage of chunks, providing an interface between working memory and long-term memory. This concept not only supplement the early theory, but also correspond well with the focus of the current research on L2 learners' use of formulaic language. Therefore, the model is adopted as the theoretical framework for the present study.

Nonetheless, in order to delve into the psychological and cognitive processes involved, the other two models are also incorporated in the analysis of retrospective interviews given their different emphases. Cowan's model [15] views WM as a portion of activated long-term memory, where the core lies in the focus of attention with a limited capacity of 4±1 chunks. This perspective is crucial for explaining why WMC is a restraining factor in the use of L2 formulaic language. Furthermore, Engle and Kane [16] shifted the focus to cognitive control, attributing individual differences in WMC to variations in the ability to activate relevant information and inhibit irrelevant information. This model includes the demand of inhibitory control inherent in the accurate use of formulaic language by L2 learners, thereby offering insights into the errors identified in the current research.

2.2. Working memory and L2 oral production

WM, as an important cognitive system with the functions of information storage and processing, is believed to have a significant restricting effect on oral production [5], especially for L2 oral production which is considered more challenging than L1 speaking [19].

However, findings of previous research are inconsistent in the specific aspects of L2 oral production being affected by WMC, including proficiency, accuracy, and complexity [8,20]. This can be attributed to different tools used for testing WMC and means to analyze the data [11,12]. Furthermore, the use of different research methodologies often leads to difficulties in qualitatively comparing the studies [21].

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In order to address the problem, the current study focuses on the effect of WMC on the use of formulaic language, aiming to reveal the mechanism inside the black box concerning the relationship between WMC and L2 oral production through the mediating variable—formulaic language. The rationality of choosing this variable will be explained in the following section.

2.3. Formulaic language as a mediating factor

Formulaic language refers to a sequence of words or other meaning elements that are stored and retrieved as a whole from memory [22]. A substantial body of studies have suggested the contribution of formulaic language to L2 oral fluency [23,24]. As Skehan [9] has pointed out, "we rely on such chunks to ease processing problems, using them to 'buy' processing time while other computation proceeds, enabling us to plan ahead for the content of what we are going to say, as well as the linguistic form" (p. 40). Some studies have also found the correlation between the use of formulaic language and L2 oral complexity as well as accuracy. Boers et al. [25] proposed that the pre-fabricated chunks constitute "zones of safety" and appropriate use of them thus confines the risk of "erring" to the space between formulaic sequences in one's discourse. The established connection between formulaic language and L2 oral production indicates that the use of formulaic language has the potential for serving as a lens through how WMC influences L2 speech.

Moreover, formulaic language is also closely related to WM. Language users often compensate for their limited WMC by storing bound pieces of information in multidimensional codes in the episodic buffer which prepares the resources for speech production [18]. Therefore, a learner's WMC may constrain the ability to acquire, store and efficiently retrieve formulaic language units during real-time production. Based on this hypothesis, the current research analyzes the frequency, diversity and accuracy of formulaic language used by Chinese EFL learners with different WMC, and seeks to illuminate the cognitive mechanisms through which WM affects L2 oral production. The research questions are presented as follows:

(1) Do Chinese EFL learners with high and low WM capacities differ in their use of formulaic language in terms of frequency and diversity?

(2) What types of errors occur in the two groups' use of formulaic language, and what are the reasons behind?

3. Methodology

3.1. Participants

The participants were 66 English major students in a university in Beijing, and they were all in the first or second year with similar levels of English proficiency. Their mother tongue is Chinese, and their second language is English. They have all taken the course of English public speaking for a term, which involved the teaching of certain speaking skills. The course mainly trained students' ability in performing prepared speech rather than impromptu speech. Thus, the participants could be considered as students with limited experience in English impromptu speech.

3.2. Materials

3.2.1. Composite speaking span test

A composite speaking span test [5,8] was adopted to assess WMC in the current study, and the specific design imitated the one from Fortkamp [7]. The test was in Chinese to exclude the

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influence of the level of L2 proficiency. Specifically, Deepseek was used to randomly generate 60 commonly used Chinese two-word phrases, and divide them into three groups, each including five sub-groups made up of 2, 3, 4, 5, and 6 daily phrases unrelated in meaning. The phrases in every sub-group were presented on the computer screen one at a time, each with the appearance of 2 seconds, and then the participant was required to create one or more than one sentences which involved the phrases. The instruction was to try one's best to include all the phrases and maintain their order of appearance in the created discourse. The time limit for creating sentences in a sub-group was ten times of the number of phrases being presented [26].

3.2.2. L2 production task

As for the oral production, some previous research on the use of chunks has adopted the form of story retelling, but given that participants may borrow the chunks from the original text which leads to an inaccurate reflection of their ability in production of chunks, this study utilized the form of impromptu speech. This approach facilitated L2 learners' independent use of language forms and free expressions of thoughts [27]. There were six topics for participants to choose, which were all from the part of composition in IELTS. In order to encourage the use of chunks, three of them asked for agreement or disagreement of an opinion, and the other three required discussions of two opposing stances on an issue. The preliminary test invited 10 students who did not participate in the formal test to grade the level of difficulty for each topic, and the results showed there were no significance differences.

3.3. Data collection

The whole experiment last for two weeks. On the first week, the participants were asked to take the composite speaking span test one by one. The whole process was accompanied by the researcher in order to ensure their focus on the tasks assigned to them. After the speaking span test, the participants could choose a topic to perform impromptu speech. The time for preparation was 2 minutes, and they were not allowed to use pens or paper so as to exclude the influence of the use of certain skills in impromptu speech, the writing speed and other intervening variables. After the preparation, they were given 1.5 to 3 minutes to perform their speeches.

On the second week, there was a retrospective interview for each participant which focused on different kinds of errors in the use of formulaic language revealed in the impromptu speech. They were asked to hear the recordings of their speeches and recall the reasons for these errors.

3.4. Data analysis

The recordings of the sentence construction tests were transcribed and used to produce the final score of verbal WMC for each participant, which was related to three signifiers: the processing accuracy, storing ability, and processing efficiency [26]. According to Jin [8], the accuracy of processing referred to the number of sentences reasonable in meaning and syntax regardless of the order of phrases. The storing ability referred to the total number of phrases that participants could remember, including those not in reasonable sentences but having been produced. The processing efficiency referred to the ratio of the time of creating sentences to the number of correct sentences. The three scores were then standardized, among which the one on processing proficiency should time -1. The means of these scores was the final assessment result of each participant's WMC.

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The recordings of the participants' speeches were also transcribed and coded by the researcher in terms of different kinds of used formulaic language based on the taxonomy proposed by Nattinger and DeCarrico [28] (see Table 1). However, given the remaining ambiguity of identifying formulaic language in practice [29], an inter-coder was invited. The index of Kappa generated by the consistency test on the category labels assigned to the aligned units was 0.782.

Table 1. The taxonomy of formulaic language

Category	Features	Examples
Polywords	Operate as single words, allowing no variability or lexical insertions.	for the most part; by the way; in a nutshell
Institutionalized expressions	Sentence-length, invariable, and mostly continuous.	how do you do; be that as it may; long time no see
Phrasal constraints	Allow variations of lexical and phrasal categories, and are mostly continuous.	a day ago; a year ago
Sentence builders	Lexical phrases that allow the construction of full sentences, with fillable slots, allowing lots of variation and insertions.	I think that X; not only X, but also Y

4. Results

Table 2 presents the descriptive statistics of participants' scores on each signifier in the composite speaking test. After the standardization of scores, the participants were divided into two groups based on the negative or positive final scores: the low WM group (N=36, Mean=-0.97, SD=0.892, Range=-1.85–-0.02) and the high WM group (N=30, Mean=1.17, SD=1.080, Range=0.25–3.67).

Table 2. The descriptive statistics of working memory capacity

		Minimum	Maximum	Mean	Std. Deviation
Low WM Group (N=36)	Processing accuracy	33.00	56.00	43.17	7.28
	Storing ability	34.00	51.00	38.88	4.41
	Processing efficiency	3.60	7.07	5.31	1.05
High WM Group (N=30)	Processing accuracy	35.00	94.00	49.40	19.02
	Storing ability	37.00	54.00	43.95	6.04
	Processing efficiency	3.59	9.14	6.61	1.95

Regarding the frequency of the use of formulaic language, the two groups showed similar distribution patterns across the four types of formulaic sequences. They all preferred polywords most (M1=7.50, M2=12.80), followed by sentence builders (M1=5.00, M2=7.30) and phrasal constraints (M1=2.58, M2=3.70), and they seldom used institutionalized expressions (M1=0.58, M2=0.90). This shared pattern could be attributed to the processing demands of impromptu speech. Under time pressure and a considerable cognitive load, participants tended to use familiar formulaic sequences they could retrieve without difficulty [30]. A large number of short polywords and sentence builders in the speeches (such as first of all and I think/believe) were frequently-used expressions in English speech which have been proceduralized, and thus could be retrieved directly from the memory without much mental efforts.

Despite the shared distribution, the high WM group showed a higher frequency in the use of all four types of formulaic language than the low WM group (see Table 3), which indicates that a larger

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WMC may facilitate the retrieval and processing of pre-stored formulaic sequences in the brain. However, it is crucial to note that this difference reached a significant level only in polywords ($t(64)=-2.286$, $p=0.033<0.05$). Given that polywords are structurally fixed and characterized by short lengths, their retrieval is highly dependent on the efficiency of direct access to long-term memory, which tends to be facilitated by a large WMC for rapid and accurate research. In contrast, the use of the other three types, especially phrasal constraints and sentence builders which allow for variations based on the specific context, involves more online processing and syntactic integration. Thus, they may be susceptible to various cognitive and psychological processes in WM rather than individual differences in WMC alone, which will be further investigated in the discussion part.

Table 3. The result of independent T-test on the use of different kinds of formulaic language between high and low working memory groups

	Low WM Group (N=36)		High WM Group (N=30)			
	Means	Std. Deviation	Means	Std. Deviation	t	p
Polywords	7.50	4.54	12.80	6.32	-2.286	0.033
Institutionalized expressions	0.58	0.79	0.90	0.74	-0.962	0.347
Phrasal constraints	2.58	2.39	3.70	4.35	-0.764	0.454
Sentence builders	5.00	2.95	7.30	3.59	-1.649	0.115

In order to provide a more accurate result with regard to the diversity of the formulaic sequences used, the frequency of repeated expressions has been compared with the total number of formulaic sequences for both groups (see Table 3). While the high WM group used formulaic sequences more frequently, they also showed a higher repeat rate. The only exception was in polywords. Considering the high frequency and low repeat rate of polywords manifested in the high WM group, it can be deduced that WMC was closely related to the retrieval and processing of polywords characterized by invariable and short structures.

Table 4. The repeat rate of the formulaic sequences

	Polywords	Institutionalized expressions	Phrasal constraints	Sentence builders	Total
Low WM Group	0.20	0.00	0.13	0.33	0.223
High WM Group	0.13	0.11	0.27	0.47	0.247

5. Discussion

Based on the analysis of the participants' impromptu speeches, there are mainly four types of errors occurred in the use of formulaic language: interlingual, intralingual, redundancy, and blending ones [31]. The reasons for specific errors have been investigated via retrospective interviews and presented as follows.

5.1. Interlingual errors

Under the influence of L1 transfer, L2 learners may produce unidiomatic expressions, which belong to the type of interlingual errors. The current study found that the low WM group made this kind of mistakes more frequently than the high WM group, which could be attributed to different levels of executive attention based on Engle and Kane's model [16]. Compared with native speakers, L2

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learners often have to pay extra efforts to search for relevant expressions and grammatical information due to their incomplete L2 language system [32]. Meanwhile, they must inhibit activated L1 knowledge in order to ensure that L2 forms are selected. However, those with a low WMC may have already exhausted their attentional resources in the planning of content, failing to achieve idiomatic production by choosing appropriate L2 forms [8].

Furthermore, it is found that interlingual errors mainly occurred in polywords. For example, one participant used the expression from the economic layer to express the meaning of from an economic perspective due to the direct translation of ceng (mian) in Chinese to layer in English. Another instance was the use of the phrase come in the plane instead of a more idiomatic one board a plane. Compared with the other three types of formulaic language units, polywords are characterized by short lengths and invariable structures. Thus, they often rely on being retrieved as a whole directly from long-term memory instead of being formed through the chunking of small language units in the episodic buffer [18]. When L2 learners find it difficult to extract appropriate polywords due to a limited WMC, they naturally turn to corresponding L1 expressions.

5.2. Intralingual errors

Different from interlingual errors, intralingual errors are not rooted in cross-linguistic influence. Rather, they often represent incomplete learning of L2 rules or overgeneralization of them [33]. In this study, a large number of intralingual errors in the use of formulaic sequences made by both groups lied in the wrong choice or the loss of preposition, as shown in (1) and (2).

(1) It is very important to have a good foundation to our future life.

(2) They want to share the favorite food to others.

This phenomenon can be explained in terms of the weak association between prepositions and other words in a formulaic sequence according to the connectionist view. In a formulaic language unit, the content words or expressions (i.e. "have a good foundation" and "share") are easily activated nodes given their rich semantic meaning and high frequency of use, while the prepositions, as function words, contain little meaning and have variable collocations, which contributes to their weak attachment to specific core words. This deficiency in L2 mental representation results in the arbitrary use or loss of prepositions during real-time L2 processing.

In addition to the shared reason, the low WM group reported another factor which contributed to intralingual errors—interference caused by competition among a set of pre-stored expressions. Participants with limited WMC often unconsciously retrieved the most accessible expressions in their mental lexicon, even when they were not appropriate to the specific context. For example, a participant reported the automatic production of the phrase think of where the phrase think about was contextually required, and attributed the error to the recent acquisition of the former expression. This was a vivid demonstration of similarity-based interference where an item that partially matches the retrieval cues is retrieved as the cues are matched against all items in memory in parallel [34]. In the search of the proper expression think about, she was susceptible to distractions with similar structures, especially the phrase think of since it was highly activated in her brain at that time. It can be deduced that for the low WM group, the main goal of the retrieval of formulaic sequences was to reduce the cognitive load, sometimes even at the cost of precision and appropriateness. In contrast, with superior attentional control systems, high-WM learners were able to inhibit highly accessible but contextually unsuitable competitors more effectively, and invest extra effort to search for the most appropriate expression.

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5.3. Redundancy errors

Redundancy errors refer to the superfluous use of expressions with the same meaning. The present study found that such errors occurred exclusively in the speeches of the low WM group, including expressions like as far as I'm concerned, I think and I think from my perspective. This is closely related to the executive component in Baddeley's model of WM [14], which encapsulates the various executive operations and functions responsible for supervising and coordinating of attention allocated to the other three modality-based buffer systems. Most participants in the low WM group reported that they did not realize the redundancy errors they committed during L2 oral production, which suggested their shortage of attentional resources for monitoring language output, especially when WM was occupied with the planning of content and other tasks. In contrast, the high WM group allowed for the simultaneous operation of multiple functions, including supervising language production, which contributed to a high level of L2 oral accuracy.

Besides, the use of redundant expressions was also found to be a strategy to maintain speech fluency, underlying which was the limited WMC. Given the high demand of language fluency in L2 impromptu speeches, this method was adopted mainly to buy time for L2 learners to plan upcoming content and retrieve appropriate language forms. However, as attentional resources were limited, the low WM group often failed to monitor the intermediate and final form of language production, which led to low accuracy and quality [8]. In order to solve the problem, teachers should seek to mitigate the negative effects of a low WM on L2 learners' oral production by increasing their speed of retrieving relevant information.

5.4. Blending errors

When learners merely focus on meaning and overlook grammar, they tend to blend expressions with similar meaning but completely different usage [30]. Such errors were found in both the low and high WM group. However, they have reported different reasons for the phenomenon.

For those with limited WMC, the majority of blending errors occurred in sentence builders. They often omitted the latter part of a sequence and started a new sentence because of excessively long insertions or fillable slots. This was a direct reflection of WM's nature of being a limited capacity of human cognition. Cowan [15] has proposed that WMC is unlikely to surpass "four plus or minus one" chunks of information. When the insertions were too long, the latter part of the sentence builder would be squeezed out of the limited focus of attention, and thus be deactivated and return to long-term memory. For example, in (3), the participant originally intended to use the structure "between…and…" but failed due to the long insertion. Furthermore, the low WMC was also demonstrated by the transient duration of the simultaneous storage and processing of information in the head when carrying out a cognitive task. According to Waugh and Norman [35], the information being held usually remains accessible to our immediate consciousness only for a few seconds. It was especially true for the low WM group that the longer it took to plan and produce the filling content, the higher the possibility of forgetting the previously used formulaic language unit was.

(3) I think there is no connection between allowing children to make their own choices on everyday matters will cause a society of individuals who only think about their own wishes.

Regarding the high WM group, they made blending errors mainly because of the interruption of thoughts, the insertion of new ideas, and competition among a set of expressions. For instance, in (4), the participant said there were two parallel structures being activated in her brain at that time, where…might lead and what…might lead to, which resulted in interference caused by cue competition. As proposed by MacWhinney [36], if the monitoring system did not select the most

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appropriate expression from multiple activated nodes in time, blending errors would be likely to occur.

(4) You have to know what their decision might lead*.

(5) As for the age has become older and older, we might face some emergency like illness or disease.

Some in the high WM group have also mentioned the intentional sacrifice of accurate grammar for additional content. For instance, in (5), the participant said her original thought was to produce the phrase As for the age, but then she came up with new ideas and decided to disobey the grammatical usage of the sequence as for. Such conscious actions showed learners' flexible adjustment of production goals based on contexts supported by their large and complicated executive system.

6. Conclusion

In a nutshell, via the investigation into the use of formulaic language among Chinese EFL learners with different levels of WMC, the current study has found that: (1) The high WM group showed a higher frequency in the use of formulaic language but a lower level of diversity than the low WM group in general; (2) Among the four types of formulaic sequences, the high WM group had a distinct edge in the retrieval of polywords in terms of frequency and diversity; (3) There were mainly four types of errors occurred in the use of formulaic language, including interlingual, intralingual, redundancy, and blending errors; (4) A larger WMC allowed for more efficient multitasking, a higher level of attentional and inhibitory control, and more complex online processing, which led to fewer errors in L2 oral production in general. As noted by Baddeley and Hitch [17], working memory is responsible for not only the storage of incoming data but also information processing such as reasoning, language comprehension, and problem-solving. Investigating the role of working memory in L2 oral production reveals the complex dynamic of cognitive processes in learners' brains.

Based on the results of quantitative and qualitative analysis in the current study, it can be concluded that a large WMC contributes to the efficient retrieval and appropriate use of formulaic language during L2 oral production. While working memory capacity is a relatively stable cognitive mechanism which cannot be manipulated or changed easily [37], it has been found that L2 proficiency helps moderate the restriction of WMC on L2 processing [8,38]. Other teaching methods can be adopted to increase learners' level of encoding automaticity, reduce the cognitive load, and weaken the constraining effects of working memory, such as promoting the acquisition of various formulaic language units [25] and offering regular training for the rapid processing of information, in order to improve the quality of L2 learners' oral production.

Nonetheless, the current study is limited in the small sample size and the homogeneity of the sample group, which leads to skepticism about the generalizability of the findings. Future research is encouraged to cover a wider range of L2 learners in various disciplines and with different L2 proficiency levels. Moreover, while this research has proved that the use of formulaic language was a qualified mediating factor between WM and L2 oral performance, quantitative measurements of learners' oral proficiency, complexity, and accuracy are needed to further investigate the specific relationship among WM, the use of formulaic language, and L2 oral production.

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