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Research on the Effect of Working Memory on Complexity, Accuracy and Fluency of Second Language Writing: Evidence from Theoretical Models and Empirical Studies

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Abstract: The relationship between working memory and specific domains of L2 input and output has been a growing research interest in psycholinguistics and SLA. This study begins with different working memory theoretical bases and orientations including the multicomponent WM model [4,5], the embedded-processes model of working memory [10,11] and the integrated framework of phonological and executive working memory in SLA [49], followed by reviews on significant and representative empirical studies on working memory and L1 & L2 acquisition. Then, some influential writing models are introduced including the updated Hayes-Flower writing mode [22,23,24], working memory model in writing process [31,32], direct and indirect effects model of writing [33] with relevant testing-hypothesis empirical studies on working memory and L2 writing. Finally, research gaps are created to role of working memory in Chinese multilingual learners' writing performance in second and third languages.

1. Introduction

Writing, both in first language acquisition or second language learning, is a challenging and demanding process that engages writers at holistic layers of cognitive, affective and social domains [42]. Exploring how cognitive mechanic resource including working memory, attention etc interplays and impacts language output performance including writing is receiving growing interest in second language acquisition and psycholinguistics on how such mechanism may differently contribute to the process of L2 performance [33]. Abundant empirical studies have been conducted to test various hypotheses on the role of working memory on sequential process of L2 writing on the basis of different theoretical models such as the multicomponent WM model [4,5], the embedded-processes model of working memory [10,11], and the phonological and executive model [49]. This focused literature attempts to systematically review the relationship between working memory and L2 writing from both theoretical and empirical perspectives.

2. Working memory: theoretical basis

Though different models give different interpretations and definitions of working memory due to

their various orientations and priority, most cognitive psychologists agree that working memory is cognitive mechanism that temporarily store and process mental information with three defining characteristics: limited capacity; multicomponent memory system; interacting with long term memory bidirectionally [4,5,49]. In other words, storing and processing information are two important functions for working memory, particularly significant and essential for our brain to process a sequence of higher hierarchy of complex mental initiatives like language acquisition or learning. Storage function correlates working memory with long term memory and processing information requires distributing attentional resources among storage and executive functions [30]. The most influential models in working memory is multicomponent model theory developed by Baddeley and Hitch [7]. The original version consists of phonological loop, which is important and significant for children's vocabulary and verbal development and visual and spatial sketch-pad processing visual and spatial information, the third subcomponent is central executive controlling the information stored and processed in the two-slave system. In 2000, Baddeley the fourth component episodic buffer into the model, which is capable of connecting the information from PN and VS system with central executive into long term memory [4,5]. As is shown in Figure 1, this model has been constantly enriched, modified and evolved into the latest updated version for over four decades [6].

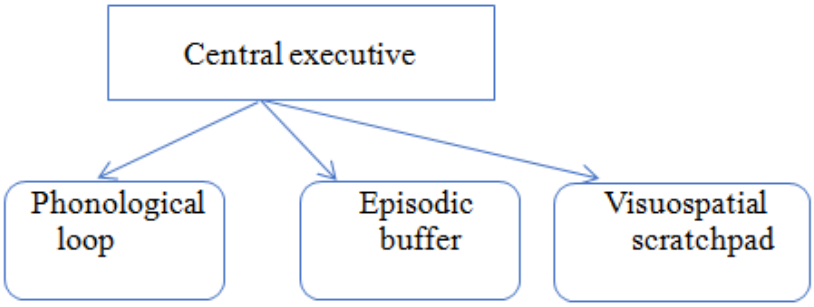

Figure 1: Multicomponent WM model

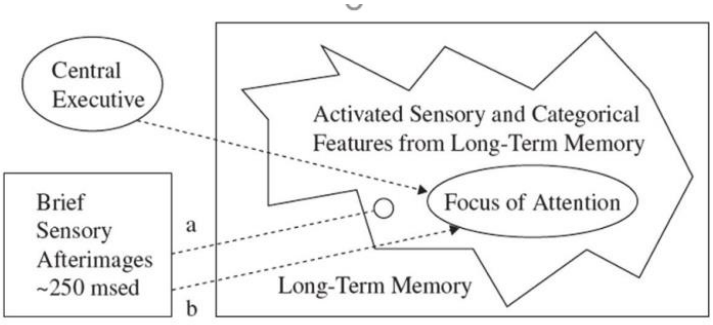

Figure 2: The WM embedded-processes model

Distinct from British and European tradition on working memory, psychologists from North America tend to view working memory as the focus of attention, which is embedded as part of long-term memory rather than the separate and independent phonological and visuospatial subsystem [10,11]. Instead, the embedded process model believes that stimuli of information are all the temporary activation of long term memory of semantic representations where attention plays a central role and includes several items at once [12,13]. This focus of attention is best represented in the magic number of four plus or minus one. As is shown in Figure 2, WM is synonymous with the embedded part of long term memory, with great focus on attention and executive function. For this

paradigm, working memory measurement usually consists of reading/speaking and final word recall (ie. Reading/speaking span task) [14,15,48,50].

Based on the working memory research from British/European and north American paradigms and some defining characteristics of working memory: limited capacity, multicomponent memory system; interacting with long-term memory bidirectionally, Wen proposed a Phonological Executive Model from the perspective of second language acquisition with the mixed methods and instruments from the above two theories, as is shown in Figure 3 [48,49,50]. He accentuates the phonological short-term store/memory (PSTM or PWM) and the central executive component of WM (EWM) as particularly important components for both first and second language acquisition. Phonological memory plays a vital role in chucking, L2 formulaic sequences and collocations and grammar learning while executive component mainly implicates intentional monitoring in L2 output performance [49]. The PE working memory model integrates multicomponent WM theoretical models [2,3,6] and WM measuring methods (simple and complex working memory span tasks) into an organic framework and converge working memory and long term memory (L1 competence and L2 knowledge) from the perspective of second language acquisition research.

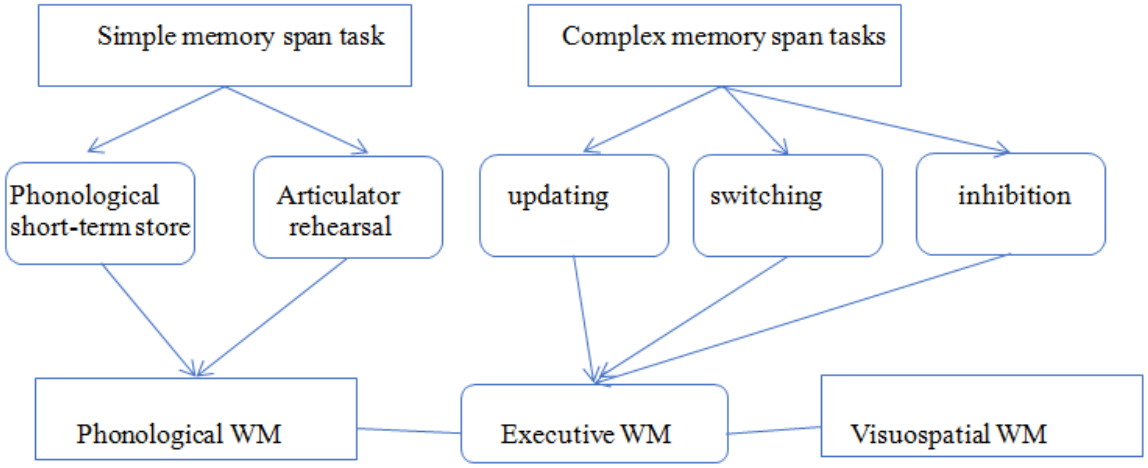

Figure 3: The Phonological/Executive working memory Model

3. Empirical studies on working memory and second language acquisition

Cognitive mechanic differences play a key cognitive role in both first and second language acquisition. Of these cognitive mechanisms is working memory, which is believed to have foundational and cascading effects on the input process and output performance of both L1 and L2 as previous empirical studies are conducted based on different theorical models, particularly the influential multicomponent model [6] with at specific language domains including reading skills [47], lexical development [38], grammar learning [19] and speaking performance proficiency [37], writing output [35,40]. Early empirical studies on working memory focus on testing the hypothesis of multicomponent model such as phonological WM in children's L1 language of vocabulary development and grammar learning [3,9,46,20]. Phonological working memory also particularly contributes to second language learners at beginning level and younger age [27,28]and studies have been extended beyond to second language acquisition to examine the role of WM in other specific language domains in SLA. For example, Walter reports transfers from L1 to L2 reading skills are positively related with verbal working memory in L2 reading comprehension by both measuring L1 and L2 working memory [47]. Hummel identified that phonological working memory contributes more to vocabulary development in lower proficiency than higher level, suggesting working

memory relation with proficiency [28]. Similar results are consistent with bilingual working memory study under different settings and at different age groups. The significant role of PN working memory in second language learning suggests that training in the second or foreign langauge phonology may enhance competence in the second/foreign language [16]. However, Executive function and visuospatial working memory has received fewer attention in its relation with second language acquisition. Kim et al., [33,34] investigates the role of visuospatial working memory (which is measured by letter rotation task) in reading and learning Chinese characters as L2 and concludes that stronger visuospatial working memory increases participants' capacity of L2 Chinese character reading and learning. Tonér and Gerholm [45] adopt a series of tasks to measure central executive function to examine the relationship between language executive function among the monolingual and multilingual Swedish preschoolers.

One of the key issues and difficult parts in working memory related research is what types of instruments or tasks should be employed for measurement as the domain-specific and domain-general measurement of simple or complex working memory tasks has different effects on research results [50]. Particularly, agreement over how to assess and measure central executive has not been reached in academia and several assessment tasks should be conducted to capture the nature of this construct [14,15]. Currently, complex tasks such as reading/listening span task are widely used WM measurement for the central executive working memory [36].

4. Writing model relating to working memory

Writing in both L1 and L2 requires conspicuous cognitive efforts like individuals' long term memory in the output performance of writing from early planning, executing, translating and reviewing, and executive function such as working memory, attention has cascading effects on writing as cognitive foundation [21,22,23,24]. How different components of WM involve in various stages of writing process is a constant research interest in psycholinguistics and second language acquisition. Built on Hayes and Flower's writing model, Kellogg [31,32] hypothesizes the role of cognitive foundation of working memory in L1 six subsequent writing process: planning, translating, programming, executing, reading and editing. In this model as is shown in Figure 4, the central executive working memory (which is commonly measured by operation task) is assumed to be the most important part which is required by almost all the sub-process in Kellogg's writing model while only planning requires visuo-spatial working memory and translating and reading highly relates to phonological working memory [29,31,32].

Basic Process	Working Memory Resource		
	Visuo-Spatial Sketchpad	Central Executive	Phonological Loop
Planning	✓	✓	
Translating		✓	✓
Programming		✓	
Executing			
Reading		✓	✓
Editing		✓	

Figure 4: Working memory model in writing process

Flower & Hayes' influential writing model has witnessed constant updating evolution and adaptation which enriches and complicates the original version [18]. The latest version [22] regroups the writing process and falls the whole process into three large categories: control level, writing process level and resource level. Task schema, together with motivation and goal setting are represented in control level. One significant change is the addition of transcribing and transcribing technology in the process level. Resource levels adds key cognitive foundation such as working

memory, attention, long-term memory etc. in addition, the new model involves motivation into control level. This is consistent with many empirical studies about the role of central executive of working memory in L1 children's writing development [46]. Another recently developed writing model is Direct and indirect effects model of writing [33] which hypothesizes hierarchical and interacting relations of foundational and higher orders from executive functions of working memory,inhibitory control, shifting or attention to vocabulary knowledge and reasoning or monitoring of the writing model. In this model, writing includes two essential skills: ideation (generation and translation of ideas) and transcription (encoding the translated ideas into print). All the above three writing models includes working memory as one of important element, which serves as the cognitive foundation interacting with other elements in the writing process.

In terms of measurement of writing, complexity, accuracy and fluency (CAF) is the most widely employed assessment indices in L2 output performance including writing and oral proficiency [17,51]. How CAF is validly operationalized is crucial in L2 measurement. Accuracy relates to the degree of deviancy from a correct norm (i.e.: errors) including error-free clauses and correct verb forms. Fluency typically refers to a writer's overall language proficiency. Different from the length of pause that is employed in oral production assessment for fluency, syllables/words per minute and number of dysfluencies are recommended as the L2 writing fluency measures. Complexity includes syntactic complexity (the ratio of clauses to T-units) and syntactic variety (verb forms). It implicates the complexity of language task and to properties of L2 performance and proficiency (L2 complexity). Individuals with higher complexity scores in their L1 writing also exhibited higher complexity scores in their L2 writing [44]. Complexity entails language performance at cognitive and linguistic levels [25].

5. Empirical studies relating to working memory and second language writing

In contrast to large number of empirical studies of relationship between working memory and specific domains like vocabulary, listening, reading and speaking, relatively fewer research has been carried out in L2 writing in this domain. Many empirical studies have been carried out to test the hypothesis of the role of working memory in sub-process of Kellogg's writing model with seemingly mixed even contradictory results. For example, Zalbidea & Sanz find that PN, VS and central executive working memory components are more predictive of morphosyntactic performance of L2 oral modality rather than written performance [53]. By contrast, some empirical studies suggest that working memory is a very strong predictor of both L1 and L2 writing [54,55]. And also, Adams et al. [1] identify the positive relation between phonological working memory and L2 writing proficiency, and similar result from other study with L2 writing accuracy and PN working memory measured by complex working memory tasks [8]. Some studies target at testing hypotheses of working memory in other writing process such as transcribing and editing [23], transcribing and planning [26] or the role of different components of WM in entire writing measured as CAF [8,21,38]. Different measurements and instruments of working memory may contribute to mixed and controversial findings about relationship between working memory and L2 writing with one possible interpretation that compared with first language writing, L2 writing demands higher challenges because of the lack of L2 knowledge and semantic representations in long term memory [39,52,53]. In this sense, second language writing requires stronger intensity and capacity of WM than the first language writing because mother language is basically subconscious and automated [49]. Another trend for working memory and L2 writing study is to examine the interactional role with affective factors like emotional intelligence in L2 output. Third language writing is an extension of second language writing. To my knowledge of literature, research on the relation of working memory in multilingual writing (L3 writing) performance is relatively

under-explored. Payant [41] adopts the qualitative methods to investigate how plurilingual writers draw on their linguistic resources to support their planning and executing process for their writing tasks, suggesting a link and transfer among the first, second and third writings. Some studies also identify the positive relation and transfer of L2 and L1 writing with the third language writing [43]. It is meaningful to investigate the potential direct and indirect effects of different subcomponents of working memory mechanism on the complexity, accuracy, and fluency (CAF) of multilingual writers' second and third language writing performance.

6. Future research on the role of working memory in second language writing

Based on the literature on working memory theoretical models, writing models and related empirical studies of working memory in first and second language acquisition and second language writing, research gaps can be identified in the related field to create a research niche as such:

1)Previous empirical studies report contrasting even contradictory results on the role of working memory in the specific domains in first and second language acquistion, and particularly in L2 writing. 2)Conflicting results in empirical studies are partly due to various instruments for the measurement on working memory with some on one instrument as a holistic measurement while others employ series of instruments of further classifying measuring different components of working memory. 3)Most of previous studies rely on WEIRD (Western Educated Industrialized Rich Democracy) sample background based on European or North American paradigms with relative fewer background from other first language. 4)Whether working memory serves as a strong predictor in third language writing of multilingual writers remains unknown since scant research on working memory and third writing have been conducted.

7. Conclusions

This study comprehensively reviews the potential direct and indirect effects of different subcomponents of working memory mechanism on the complexity, accuracy, and fluency (CAF) of L2 writing for the purpose of identifying research gaps and establishing research niche of the working memory role on Chinese multilingual writers' second and third language writing performance at different proficiency levels. The study also investigates some significant and representative empirical studies on working memory and L1 & L2 acquisition. For future research, some suggestions are given as the research niche from the perspective of the working memory role in Chinese multilingual learners' writing performance.

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