Working Memory Models in Language and Bilingualism Research

Subjects: Linguistics

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Working memory (WM) generally refers to our ability to ‘mentally maintain information in an active and readily accessible state while concurrently and selectively processing new information’. WM, as the primary memory, plays a fundamental role in multiple facets of human cognitive life, including language learning and processing.

Keywords: working memory ; affective working memory ; language ; bilingualism ; emotion regulation ; N-back task

1. Introduction

Working memory (WM) generally refers to our ability to ‘mentally maintain information in an active and readily accessible state while concurrently and selectively processing new information’ [1]. Since its inception in the 1960s (e.g., [2]), WM has become a buzzword concept permeating a broad range of disciplines in the cognitive sciences (cf. [3][4][5]), straddling psychology, linguistics, neuroscience, human–computer interactions, anthropology, and philosophy as well as the more applied domains of human cognition and communication, such as cognitive development, education, and language learning/teaching. The implications of WM capacity and executive functions are pervasive and consequential for constraining and shaping everyday cognitive activities in language comprehension, arithmetic, reasoning, and many other cognitive tasks [6].

Affective WM (AWM), also called emotional WM, can be defined as the ability to successfully deploy WM in emotionally stressful contexts [7]; cf. [8]). However, previous theoretical and empirical studies on WM have predominantly focused on exploring its structure and functions in human cognition from multiple theoretical perspectives [9], while its emotional connotation, or affective WM, has received much less attention in general psychology and neuroscience, not to mention more practical domains such as language learning and bilingual development. In the realms of the WM–language enterprise [10][11][12][13], most previous and current research has adopted cognitive WM models (e.g., those listed in [4][14][15]) as conceptual and theoretical frameworks to investigate the putative effects of WM with a view to investigating the overall or specific implications of multiple WM components (e.g., Baddeley’s model) and executive control functions (e.g., Cowan’s and Engle’s model) for miscellaneous domains of language acquisition and bilingual processing [16]. In sharp contrast, research probing the role of affective WM (AWM) in language and/or bilingualism/SLA has been meager until recently [17]; see also [18].

To fill the gap, this entry proposes not only that WM in language and bilingualism/SLA has cognitive implications but also that its affective dimensions should not be neglected. It is argued that affective WM may hold great promise in making distinctive and unique theoretical and methodological contributions to future SLA/bilingualism research. Towards this goal, researchers first summarize the cognitive approaches to WM conceptions and the assessment procedures implemented in current language and bilingualism/SLA research, unearthing some remaining issues besetting theory and methodology. Following these, researchers turn to elaborate on the construct of affective WM and integrate it with cognitive WM perspectives on bilingualism/SLA studies. To facilitate future studies, researchers also propose some practical guidelines for constructing a series of affective WM span tasks that can be readily implemented in future affective WM–language research as complementary to current cognitive paradigms. Overall, researchers argue that both cognitive and affective WM dimensions provide important, albeit distinctive, insight into the WM–language nexus [19][20], and therefore, future research in the language sciences and bilingualism/SLA should incorporate both perspectives.

2. Cognitive WM Models and Measures in Language and Bilingualism/SLA

WM, as the primary memory (cf. [21]), plays a fundamental role in multiple facets of human cognitive life, including language learning and processing [10][22][23]. Research on WM drawing on the integration of a large number of empirical investigations of typical and nontypical participants constituted a major source of and the catalyst for the formulation of the

seminal multicomponent model by Baddeley and colleagues [10][24]. This multicomponent model of WM by Baddeley [25][26] has thus become the most widely cited framework across multiple disciplines, including language and bilingualism/SLA research [27][28][29].

Among the four components as conceived in Baddeley's fractionated WM model, the phonological loop (or phonological WM; [20]), comprising a phonological store and an articulatory rehearsal mechanism, has been postulated to play an instrumental role in the storage and processing of novel phonological forms [30], rendering it the '*language learning device*' [25](see also [31]). Inspired by this hypothesis, numerous empirical studies adopting diverse research methodologies have corroborated the positive links between phonological WM (measured by some simple storage-focused versions of memory-recall tasks such as the digit span and the nonword recognition/repetition span; [32]) and a broad range of language-learning domains among both typical and non-typical developmental participants [33]. These language domains include, most obviously, the acquisition and development of lexical knowledge or word learning in both L1 and L2 (e.g., [30][34][35][36]). Longer linguistic units, such as phrases or multi-unit formulaic chunks, have been found to rely on phonological WM as well (e.g., [37][38][39][40]), though its role in morpho-syntax or grammatical structure is debatable (largely depending on the different epistemological stances on the very definition of 'grammar' and the specific models of language; cf. [41][42]).

Additionally, phonological WM, with its putative articulatory rehearsal mechanism, has also been found to be closely related to oral fluency and development at the early stages of language learning in both L1 and L2 (e.g., [43][44][45]). As such, the pivotal role of phonological WM as conceived in Baddeley's multicomponent model in storage- and sound-based language acquisitional and developmental aspects is now firmly established (see also [46][47][48]. In contrast to phonological WM, other WM components, such as visuospatial WM and the episodic buffer in Baddeley's model, have received much less enthusiasm among second-language researchers [22][49], nor have the linguistics- and psycholinguistics-oriented components, such as semantic WM and orthographic WM, been vigorously researched (e.g., [50]). In more recent years, though, Baddeley and colleagues [26] have explored the role of the episodic buffer in binding visual information such as objects. This emerging trend will hopefully renew momentum towards investigating the implications of visuospatial WM and the episodic buffer for sentence recall (e.g., [51][52]) and for following spoken instructions (i.e., the enactment effect) [53][54].

Despite the paucity of empirical studies directly probing the central executive in language and SLA/bilingualism and adopting Baddeley's structural view of WM [22], other functional WM models have witnessed increasing theoretical and empirical investigations into the individual variations in the executive control or attentional control aspects of WM [55]. Two theoretical frameworks are gaining increasing prominence in this line of inquiry, namely the embedded-processes model by Cowan [9] and the executive control or attentional control paradigm touted by Engle [56][57]. Though controversies and debates still linger over the sources of such inherent variations [1] and constituent sub-processes, executive WM conceived this way (i.e., EWM in [20]) is generally operationalized and measured by more cognitively demanding dual-processing (e.g., storage plus manipulation) span tasks in both the psychological and language sciences [58][59], including bilingualism/SLA research [60][61].

These 'complex' versions of executive WM span tasks include the seminal reading span task that measures sentence judgment accuracy and serial recall of final words [62], the scoring procedures of which have been further refined by Waters and Caplan [63] to also take into account participants' reaction time for the judgment component. Other formats of the complex memory span tasks are gaining popularity [60], including the domain-general operation span task, which taxes participants' dual-processing ability to solve arithmetic equations and recall final items [64] as a way to avoid confounding linguistic proficiency in the reading span paradigm. Another format, i.e., the *N-back* task, is commonly applied in both neuropsychology (e.g., cognitive and WM training); [65]) and language-cum-SLA/bilingualism research ([66]), though its underlying mechanism is far more controversial [67].

Regarding the effects of these executive aspects of WM (i.e., EWM [20]), empirical studies have pointed to their close links with cognitively demanding language processes and activities both online and offline during L1 reading and parsing (e.g., ambiguity resolutions, morphological and grammatical processing, e.g., [68][69]) and L2 sub-skills such as listening, speaking, reading, writing, and bilingual interpreting (e.g., [70][71][72]).

The most recent trend of executive functions related to WM is the '*unity and diversity*' framework [73][74] that is making its inroads into language and SLA/bilingualism research. Scholars endeavor to explore the componential and separate effects of these executive functions (e.g., updating, task switching, and inhibitory control) on L1 and L2 learning and development [16]. Among the three key executive functions, memory updating and inhibitory control, as measured respectively by the running memory span task [75] and the *N-back* task [76], have garnered increasing attention in SLA

(e.g., [77]) and task-based language-teaching research [18][28][78]. Similarly, the well-articulated attentional control paradigm by Engle and colleagues [79][80] has been cited widely in the language sciences (cf. [81]) and interpreting models [82].

Overall, an increasing body of empirical studies as discussed in comprehensive narrative reviews [15][20] and meta-analytic surveys (e.g., [69][71][83]; see also [47][84]) has reinforced the positive links between the putative WM components (esp., phonological WM and executive WM) and executive control functions (e.g., updating, task-switching, inhibitory control, attentional control, etc.) as they relate to nuanced language-learning domains and skills in L1 and L2. These emerging patterns, when effectively integrated and synthesized further, lend theoretical support and empirical evidence to the formulation of an integrated cognitive account that portrays the intricate relationships between WM components and functions on the one hand, and language as well as bilingualism/SLA on the other. These hypothetical links thus culminate in the phonological/executive (P/E) model [12][20][85][86].

Moreover, as the theoretical models of WM evolve, WM measurement procedures are also evolving [61]. As such, the integrated account of WM and language/SLA has also identified and regrouped the array of WM span tasks currently available from cognitive psychology and neuroscience (e.g., [58][59]). Specifically, the P/E model [20] has stipulated that the simple (storage-only) versions of memory span tasks (e.g., digit span, nonword repetition span) are approximating phonological WM, while the complex (storage-plus-processing) versions of memory span tasks serve as a proxy for executive WM. Furthermore, in alignment with the emerging '*unity and diversity*' framework, finer-grained sub-process-oriented WM measures (e.g., storage, articulatory rehearsal, updating, task switching, inhibitory control) are in place to tap into granulated executive or attentional control mechanisms and functions that impact language and bilingualism/SLA domains.

To sum up, previous and current empirical studies adopting cognitive WM perspectives have pointed to the positive, albeit distinct, roles of phonological WM and executive WM as they relate to specific SLA domains and L2 sub-skill learning ([20]; cf. [87] for semantic WM vs. phonological and orthographic WM). For example, Linck et al. [71] reported an overall (population) effect size of 0.255 between WM and L2 processing and products. Such an effect size is small, but the reasons behind this finding are still unclear. On the one hand, it is possible that WM may be a necessary but not an essential factor in SLA. On the other hand, such a small effect size can also be partly due to the differences in methodology such as the inconsistency of WM span tasks across the empirical studies [60]. Though an enormous number of studies have adopted these dominant cognitive paradigms to investigate WM effects and their potential consequences for language and bilingualism/SLA, they are not the only approaches and are not readily embraced by all linguists and psycholinguists. It is even true that in 'mainstream' theoretical linguistics and psycholinguistics, for example (cf. [88]), the role of WM or general memory as a whole is generally downplayed and marginalized, sometimes to the extent of negligibility (e.g., [89][90]; cf. [91]).

For example, Chomsky [92] has unequivocally speculated that the language acquisition device (LAD; or universal grammar) should be unaffected by such 'grammatically irrelevant conditions as memory limitations, distractions, shifts of attention and interest, and errors (random or characteristic) in applying knowledge of the language in actual performance'. (p. 3) Contrary to Chomsky's dominant view in mainstream linguistics, other processing- and performance-oriented theoretical linguists (e.g., [41][93]) as well as emergentist-oriented (e.g., [94]) and typological or dependency grammar–oriented linguists ([95]; cf. [96]), have all attached great emphasis to the role of WM, holding the view that WM limitations are part and parcel of the language parser (or the language device; [84][91]). It is even claimed that WM limitations play a pervasive, albeit sometimes 'hidden', role in key domains of language design, acquisition, and processing of linguistic structures and constructions ranging from phonology to grammar and discourse ([94]; cf. [97]). Other psycholinguists-cum-neuroscientists (e.g., [29]) have recently advocated studies of domain-specific WM components such as semantic WM and orthographic WM alongside the prevailing phonological WM, derived from distinct neural correlates from neuropsychological evidence (e.g., [29][87]). On a cautionary note, some psycholinguists (e.g., [90]) have not ruled out the possibility that WM may be no more than an 'emergent' (parasitic) by-product of language comprehension and production (cf. [89][98]).

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