Working Memory In Second Language Acquisition A Dynamic and Developmental Perspective

Chyntia Farah Agustine[1*], Azmil Hanafia Risqi[2], Ikhwan Edi Nasution[3], Nur Aisyah Fitri[4], Masyitah Noviyanti[5]
[1-5]Universitas Nahdlatul Ulama Sidoarjo, Indonesia
Email: chyntiafarahagustine.unusida@gmail.com[1], azmilhanafia27@gmail.com[2],
ikhwaniedinasutiin1@gmail.com[3], nuraisyah1fitri1507@gmail.com[4],
masyitahnoviyanti.pbi@unusida.ac.id[5]*

Korespondensi penulis: chyntiafarahagustine.unusida@gmail.com

Abstract. Working memory (WM) has been extensively studied as a cognitive factor influencing second language acquisition (SLA), but many studies treat it as a static, trait-like capacity. This approach provides limited insight into how WM works across different stages of development, proficiency levels, and learning contexts. This article combines theoretical and empirical research on working memory in SLA from a dynamic and developmental perspective, analyzing how the influence of WM varies over time and interacts with other cognitive and contextual factors. Referencing Baddeley's multicomponent model, complex dynamic systems theory, and longitudinal research, this article examines evidence regarding the role of WM in various language domains, including vocabulary learning, grammar processing, and language production. It also investigates how WM works differently at various proficiency levels and developmental periods, from childhood to adulthood. Evidence suggests that WM plays a very strong role in the early stages of learning when processing is effortful and controlled, but becomes less central as linguistic knowledge becomes automated. The relationship between WM and SLA appears to be bidirectional, with sustained language learning contributing to the development of specific WM components, particularly executive control. The influence of WM varies significantly based on task characteristics, teaching context, and learner profiles. Understanding WM as a dynamic resource rather than a fixed constraint has important pedagogical implications. Instructions that manage cognitive load, provide support, and encourage metacognitive awareness can help learners with diverse cognitive profiles. A developmental approach in WM research requires longitudinal designs and task-aligned methodologies to capture changes over time, thereby advancing theory and practice in SLA.

Keywords:Cognitive development; Dynamic systems; Individual differences; Second language acquisition; Working memory

1. INTRODUCTION

Second language acquisition (SLA) is a complex, dynamic, and multifactorial process involving the interaction of cognitive, linguistic, affective, and contextual variables over time. Among these variables, cognitive resources have long been recognized as fundamental determinants of how learners perceive, process, store, and produce linguistic information in a second language. One cognitive construct that has received sustained and growing attention in SLA research is working memory (WM), typically defined as a limited-capacity system responsible for the temporary storage and manipulation of information during ongoing cognitive activities (Baddeley, 2012). Given that language learning requires learners to attend to form and meaning simultaneously under temporal constraints, WM is widely considered a key source of individual differences in second language learning success.

A substantial body of empirical research has documented robust associations between WM capacity and various dimensions of second language performance. Studies have shown that WM is significantly related to vocabulary acquisition, grammatical processing, reading and listening comprehension, as well as spoken and written production (Juffs & Harrington, 2011; Linck et al., 2014; Kormos, 2023; Zhao, 2022). Meta-analytic evidence further confirms that learners with higher WM capacity tend to demonstrate superior outcomes across diverse instructional and naturalistic learning contexts (Linck et al., 2014; Chai, 2022). These findings have positioned WM as a central construct in cognitive and aptitude-based models of SLA, particularly those emphasizing input processing, noticing, and explicit learning mechanisms (Wen, 2012; Wen et al., 2015).

Despite this strong empirical foundation, much of the earlier SLA literature conceptualized WM as a relatively stable, trait-like capacity that constrains learners' ability to process linguistic input and perform language tasks. Many studies adopted cross-sectional designs and treated WM as a fixed individual difference variable, implicitly assuming that its role remains constant across proficiency levels, learning stages, and contexts (Jackson, 2020). While this perspective has yielded valuable insights, it provides a limited account of how WM operates over time and how it interacts with learners' experience, task demands, and other cognitive and affective factors.

In response to these limitations, recent research has increasingly embraced dynamic and developmental perspectives on WM in SLA. Drawing on complex dynamic systems theory, scholars argue that WM should be viewed not merely as a static capacity, but as a flexible and evolving cognitive resource that changes as a function of experience, cognitive load, and learning conditions (Huang et al., 2020; Jackson, 2020; Meng, 2023). From this perspective, the influence of WM is expected to vary across different phases of learning: WM may play a particularly prominent role during early stages of SLA, when processing is effortful and explicit, but become less central as linguistic knowledge becomes more automatized and proceduralized.

Moreover, accumulating evidence suggests that the relationship between WM and SLA is bidirectional. While WM capacity facilitates language learning, sustained engagement with second language learning—especially in multilingual contexts—may in turn contribute to the development and reorganization of WM resources (Rasheed et al., 2025; Wang, 2024). Longitudinal and experimental studies indicate that intensive exposure to complex linguistic input and output can place sustained demands on WM, potentially leading to adaptive changes

in attentional control, storage efficiency, and executive functioning (Faretta-Stutenberg & Morgan-Short, 2018; Coumel et al., 2023).

Adopting a developmental lens further underscores the importance of examining WM across the lifespan. Children, adolescents, and adult learners differ not only in cognitive maturity but also in how WM components support vocabulary growth, grammatical development, and comprehension processes (Verhagen & Leseman, 2016; Teng, 2025). Understanding these developmental trajectories is crucial for explaining variability in SLA outcomes and for designing instructional practices that align with learners' cognitive capacities at different stages of development.

Against this theoretical and empirical background, the present article aims to synthesize research on working memory in second language acquisition from a dynamic and developmental perspective. Specifically, it seeks to (1) review major theoretical models linking WM to SLA, (2) examine how the role of WM varies across language domains, proficiency levels, and developmental stages, and (3) discuss methodological, theoretical, and pedagogical implications of conceptualizing WM as a flexible and evolving cognitive resource. By reframing WM within a dynamic and developmental framework, this article contributes to a more nuanced understanding of individual differences in SLA and offers directions for future research and instructional practice..

2. METHODOLOGY

This article uses a narrative literature review approach to combine theoretical and empirical research on working memory in second language acquisition. This review refers to important theoretical works that have shaped the basic models of working memory and language aptitude, as well as recent empirical studies that investigate the dynamic dimensions and development of working memory in the context of SLA. The literature was identified through searches of major academic databases, including Google Scholar, Scopus, and specialized repositories in the fields of applied linguistics and cognitive psychology (ERIC, PsycINFO). The search focused on peer-reviewed journal articles and influential theoretical works published primarily between 2010 and 2025, although important contributions from before that period were also included if they provided an important theoretical foundation. Key search terms include combinations of "working memory," "second language acquisition," "cognitive development," "individual differences," "executive control," "language aptitude," and other related constructs.

Selection criteria prioritized studies that:

(1) investigated working memory as a cognitive factor in second language learning,

(2) provided a theoretical framework linking WM to SLA processes

(3) offered empirical evidence across diverse learner populations and language domains, and

(4) addressed developmental or dynamic perspectives on the WM-SLA relationship.

Both experimental studies and longitudinal investigations were included to capture variation in research designs and developmental trajectories. The synthesis approach combined findings from various language domains (vocabulary, grammar, comprehension, production), proficiency levels (beginner to proficient), and developmental stages (children, adolescents, adult learners). Rather than conducting a systematic meta-analysis, this review presents a conceptual integration of various pieces of evidence to highlight theoretical similarities, methodological considerations, and areas requiring further investigation. This review emphasizes the dynamic and developmental dimensions that have emerged in recent SLA research, while acknowledging the basic models that still provide information for this field.

3. RESULT AND DISCUSSION

Theoretical Foundations of Working Memory

Models of Working Memory

Working memory has been extensively studied within cognitive psychology, with Baddeley's multicomponent model emerging as the most influential framework informing SLA research. In this model, working memory is not viewed as a single, unitary system but as a set of interacting components responsible for temporary information storage and processing. These components include the phonological loop**,** the visuospatial sketchpad, the central executive, and the episodic buffer. The phonological loop is responsible for the temporary storage and rehearsal of verbal and auditory information. This component is particularly relevant to language learning, as it supports the retention of unfamiliar phonological forms, sound sequences, and new lexical items during early stages of acquisition. Numerous studies have shown that phonological short-term memory plays a crucial role in vocabulary learning and pronunciation development, especially among beginner and young learners.

The visuospatial sketchpad stores and manipulates visual and spatial information. Although it is less directly related to linguistic processing, it contributes to language learning in contexts involving written input, visual cues, and multimedia materials. For example, visual representations of words or grammatical structures may reduce cognitive load by distributing

processing demands across modalities.The central executive functions as an attentional control system, coordinating the allocation of cognitive resources, inhibiting irrelevant information, and managing dual-task demands. In SLA, the central executive is essential for complex language tasks that require learners to attend simultaneously to meaning and form, integrate linguistic input with prior knowledge, and monitor output during speaking and writing. Finally, the episodic buffer integrates information from the phonological loop, visuospatial sketchpad, and long-term memory into unified episodic representations. This component facilitates the binding of linguistic forms with semantic and contextual information, enabling learners to construct coherent representations of sentences and discourse. Although less frequently examined in SLA research, the episodic buffer provides a theoretical bridge between WM and higher-level language comprehension.

Working Memory within SLA Theory

Within SLA theory, working memory has been increasingly recognized as a core cognitive resource underlying language learning and processing. Cognitive and psycholinguistic approaches to SLA emphasize that learners must process incoming linguistic input in real time, temporarily store relevant information, and integrate it with existing linguistic knowledge. WM capacity therefore constrains the extent to which learners can notice linguistic features, establish form–meaning connections, and engage in rule abstraction. In models of language aptitude, WM is often linked to abilities such as phonemic coding, grammatical sensitivity, and pattern recognition. Researchers argue that WM supports these abilities by enabling learners to hold multiple linguistic elements in mind while detecting regularities in the input. From this perspective, WM contributes not only to performance but also to learning, particularly in contexts that involve explicit instruction or cognitively demanding tasks. WM is also closely related to the **noticing** hypothesis, which posits that conscious attention to linguistic forms is a prerequisite for acquisition. Limited WM capacity may restrict learners' ability to notice form while prioritizing meaning, especially during comprehension tasks. As a result, learners with greater WM resources are often better able to allocate attention flexibly, increasing the likelihood of successful intake. Importantly, contemporary SLA research emphasizes that the involvement of WM is task-dependent and domain-specific. Different components of WM are recruited for different language skills: phonological memory is more strongly associated with vocabulary learning, while executive control plays a larger role in syntactic processing, discourse comprehension, and language

production. This componential view aligns with the multicomponent WM model and helps explain inconsistencies in empirical findings across studies.

Toward a Dynamic Interpretation of WM in SLA

Although traditional SLA theories have successfully incorporated WM as an explanatory variable, they often implicitly assume that WM capacity is stable across time and contexts. However, emerging theoretical perspectives challenge this assumption by proposing that WM functions as a dynamic resource whose role in SLA evolves alongside learners' experience, proficiency, and task demands. From a dynamic systems perspective, WM interacts continuously with other cognitive and affective variables, such as attention, motivation, and metacognitive awareness. Rather than exerting a uniform influence, WM may be more salient during early stages of acquisition, when learners rely heavily on controlled processing, and less critical at later stages, when linguistic knowledge becomes automatized. This shift reflects changes not only in language proficiency but also in how cognitive resources are deployed during processing. By situating WM within a dynamic and developmental framework, SLA theory moves beyond static explanations of individual differences and toward a more nuanced understanding of how cognitive resources shape, and are shaped by, second language learning over time. This reconceptualization provides the theoretical foundation for examining developmental trajectories of WM in SLA, which will be addressed in the following sections.

From Static Capacity to Dynamic Resource

Traditional Views: Working Memory as a Fixed Individual Difference

Early research on working memory in second language acquisition largely conceptualized WM as a stable, trait-like cognitive capacity that varies across individuals but remains relatively constant within individuals over time. Within this view, WM functions as a limiting factor that constrains learners' ability to process linguistic input, attend to form–meaning relationships, and perform complex language tasks. Learners with greater WM capacity are therefore expected to demonstrate superior performance across a wide range of L2 skills, particularly under conditions of high cognitive demand.

This static conceptualization of WM aligns with traditional individual differences research in SLA, where cognitive abilities such as language aptitude, intelligence, and memory are treated as enduring learner characteristics.

Consequently, most empirical studies have employed cross-sectional designs, measuring WM at a single point in time and correlating it with L2 outcomes such as proficiency

scores, grammatical accuracy, or vocabulary size. These studies have provided valuable evidence of robust associations between WM and L2 learning success, reinforcing the view that WM is an important predictor of individual differences. However, this approach also presents several limitations. First, treating WM as a fixed capacity overlooks potential within-learner variability across tasks and contexts. Second, it does not account for developmental changes in cognitive resources, particularly among child and adolescent learners. Finally, it leaves unexplored the possibility that sustained language learning itself may influence the development and deployment of WM. As a result, static models offer an incomplete explanation of how WM operates in SLA over time.

Emerging Evidence for Working Memory Plasticity

In recent years, accumulating empirical evidence has begun to challenge the assumption that WM is entirely stable. Longitudinal and comparative studies suggest that WM may exhibit a degree of plasticity, particularly in response to intensive cognitive engagement such as second language learning. Learners exposed to rich linguistic input, complex communicative tasks, or multilingual environments have been shown to demonstrate improvements in certain WM components, especially executive control and verbal memory. Research on bilingualism and multilingualism further supports this view, indicating that managing multiple linguistic systems may place sustained demands on attentional control and memory resources, potentially strengthening WM over time. From this perspective, WM is not only a predictor of SLA outcomes but also a cognitive system that can be shaped by language learning experience.

This reciprocal relationship complicates simple causal interpretations and highlights the need for models that allow for bidirectional influences between cognition and language development.Importantly, evidence for WM plasticity does not imply unlimited malleability. Rather, it suggests that changes in WM are likely to be gradual, component-specific, and context-dependent. Executive aspects of WM appear more susceptible to development through language use than basic storage capacity, underscoring the importance of distinguishing among WM components in SLA research.

Dynamic Systems Perspective on Working Memory in SLA

To account for variability, change, and interaction over time, an increasing number of SLA researchers have adopted a dynamic systems perspective. Within this framework, WM is conceptualized as part of a complex cognitive system that evolves through continuous interaction with linguistic input, task demands, learner goals, and environmental conditions.

Rather than exerting a uniform influence, WM contributes to SLA in ways that fluctuate across moments, tasks, and developmental stages.

From a dynamic perspective, the role of WM is expected to be particularly prominent during early phases of learning, when processing is effortful and relies heavily on controlled attention. As learners gain experience and linguistic knowledge becomes more automatized, reliance on WM may decrease, even though WM continues to support performance under challenging conditions. This shifting role helps explain why the strength of the relationship between WM and L2 proficiency often diminishes at higher levels of attainment.

Moreover, dynamic models emphasize interactions among individual difference variables, such as WM, motivation, anxiety, and metacognitive awareness. For example, high motivation may enable learners to compensate for limited WM resources, while efficient attentional control may amplify the benefits of WM during complex tasks. These interactions underscore the inadequacy of isolating WM from the broader cognitive and affective system in which it operates. By reconceptualizing WM as a dynamic and developmental resource, SLA research moves beyond static correlations toward a more nuanced understanding of how cognitive capacities contribute to language learning trajectories. This perspective provides the conceptual basis for examining how WM develops across the lifespan and how its role varies across language domains issues that are addressed in the following sections.

Developmental Trajectories of Working Memory in Second Language Acquisition

A developmental perspective on working memory highlights that its role in second language acquisition is not uniform across ages or stages of learning. Learners differ in cognitive maturity, processing efficiency, and the ways in which working memory components support language development. Examining these developmental trajectories is therefore essential for understanding variability in SLA outcomes and for explaining how the influence of WM changes over time.

Working Memory in Childhood and Early Adolescence

During childhood and early adolescence, working memory is still undergoing significant development. At these stages, **verbal short-term memory**, particularly the phonological loop, plays a central role in language learning. Research consistently shows that children's ability to temporarily store and rehearse phonological information is closely related to vocabulary acquisition, both in first language development and in early second language learning contexts. In classroom-based SLA, children with stronger phonological memory tend

to acquire new lexical items more efficiently, as they are better able to retain unfamiliar sound sequences long enough to establish stable form–meaning mappings. In contrast, limitations in WM may hinder the retention of new words and slow down vocabulary growth. Grammar learning at this stage is also supported by WM, although it relies more heavily on implicit learning mechanisms and exposure than on explicit rule processing. Importantly, WM in younger learners interacts strongly with general cognitive development and educational context. Factors such as literacy development, instructional support, and metacognitive awareness can moderate the relationship between WM and L2 outcomes. In bilingual or immersion settings, sustained exposure to multiple languages may further shape WM development, suggesting that early language learning experiences can influence cognitive trajectories beyond linguistic competence alone.

Working Memory in Adolescent and Adult Learners

In adolescence and adulthood, WM capacity is more stable, yet its role in SLA remains highly significant, particularly in contexts involving explicit instruction and cognitively demanding tasks. Adult learners often rely more on **controlled processing**, drawing heavily on executive aspects of WM to analyze grammatical rules, monitor output, and integrate feedback. As a result, individual differences in WM capacity are especially salient during early and intermediate stages of adult L2 learning. As proficiency increases, however, the nature of WM involvement begins to change. Longitudinal studies suggest that advanced learners rely less on WM for routine language processing, as linguistic knowledge becomes increasingly automatized. At this stage, WM primarily supports performance under conditions of high cognitive load, such as complex syntactic processing, time-pressured speaking tasks, or academic reading.

Evidence from study-abroad and intensive learning contexts further indicates that adult learners may experience reciprocal effects between SLA and WM. Sustained engagement with challenging L2 tasks has been associated with improvements in executive control and attentional regulation, implying that language learning can contribute to cognitive development even beyond childhood.

Developmental Shifts Across Proficiency Levels

Beyond chronological age, developmental change in the role of WM can also be observed across proficiency levels. At lower levels of proficiency, learners must allocate substantial WM resources to decoding input, retrieving lexical items, and maintaining

sentence-level information. Under these conditions, WM strongly predicts success in comprehension and production.

As learners progress, linguistic representations become more entrenched, reducing the processing burden on WM. Consequently, the relationship between WM and overall proficiency often weakens at higher levels, although WM continues to play a role in demanding tasks that require integration across clauses, discourse-level comprehension, or precise language monitoring.

These developmental shifts underscore the importance of viewing WM not as a constant constraint, but as a flexible resource whose relevance changes depending on learners' experience and task demands. Such a perspective helps reconcile mixed findings in the literature and aligns with dynamic systems accounts of SLA, which emphasize change, interaction, and nonlinearity over time.

Implications of a Developmental Perspective

Adopting a developmental perspective on WM has important implications for both theory and practice in SLA. Theoretically, it challenges models that treat cognitive capacities as static predictors and instead calls for frameworks that accommodate growth, interaction, and reciprocal influence. Methodologically, it highlights the need for longitudinal designs that track changes in WM and language ability simultaneously.

Pedagogically, recognizing developmental differences in WM suggests that instructional approaches should be tailored to learners' cognitive profiles. Younger learners may benefit from rich exposure and repetition that support phonological memory, while older learners may require structured tasks that manage cognitive load and support executive control. By aligning instruction with learners' developmental stage, educators can better support effective and equitable second language learning.

Dynamic Role of Working Memory Across Language Domains

The influence of working memory in second language acquisition is not uniform across language domains. Rather, its contribution varies depending on the linguistic skill involved, task demands, and learners' stage of development. From a dynamic perspective, different components of WM are recruited flexibly to support vocabulary learning, grammatical processing, comprehension, and language production. This section reviews how WM operates across major language domains and how its role changes over time.

Working Memory and Vocabulary Development

Vocabulary acquisition is one of the domains in which the effects of working memory are most consistently observed. In the early stages of L2 learning, learners rely heavily on the phonological loop to temporarily store unfamiliar sound sequences while establishing form–meaning connections. Limited phonological memory may therefore constrain the initial encoding and retention of new lexical items. As vocabulary knowledge expands, executive components of WM become increasingly important. Learners must manage interference among similar lexical forms, integrate new words into existing semantic networks, and retrieve appropriate items during comprehension and production. Research suggests that WM plays a particularly strong role in intentional and multimedia-based vocabulary learning tasks, where learners must simultaneously process verbal input, visual cues, and task instructions. Over time, as lexical representations become more stable, the reliance on WM decreases for familiar vocabulary. However, WM continues to support learning in cognitively demanding contexts, such as acquiring low-frequency or abstract words and inferring meaning from context during reading. These findings illustrate the dynamic nature of WM involvement in lexical development.

Working Memory in Grammar and Syntax Acquisition

Working memory also plays a critical role in the acquisition and processing of L2 grammar and syntax. Learning grammatical structures requires learners to temporarily hold multiple linguistic elements in mind while detecting patterns, testing hypotheses, and integrating feedback. Verbal WM and executive control are particularly important in tasks that involve explicit rule learning or grammatical judgment. At lower proficiency levels, learners often rely on WM to consciously process syntactic structures, especially when dealing with complex or non-canonical word orders. As proficiency increases, grammatical processing becomes more automatized, reducing the burden on WM during routine comprehension and production.

Nevertheless, WM remains relevant in situations that impose high cognitive demands, such as processing long-distance dependencies or producing complex sentences in real time. From a dynamic perspective, the role of WM in grammar learning shifts from supporting explicit, controlled processing toward facilitating monitoring and refinement of already acquired structures. This shift helps explain why WM is a stronger predictor of grammatical performance at early stages of learning than at advanced levels.

Working Memory in Reading and Listening Comprehension

Reading and listening comprehension place substantial demands on working memory, as learners must integrate incoming information with prior knowledge while maintaining coherence across sentences and discourse. WM supports the retention of propositions, resolution of ambiguities, and integration of linguistic and contextual cues.

In L2 reading, learners with higher WM capacity tend to demonstrate better comprehension, particularly when processing complex texts that require inferencing and integration across clauses. WM also interacts with text type and task goals, influencing how learners allocate attention and derive meaning.

In listening, the transient nature of auditory input further increases WM demands, making WM capacity a crucial factor in successful comprehension. As learners become more proficient, they develop more efficient processing strategies, reducing reliance on WM for basic comprehension. However, WM continues to play a role in academic or cognitively demanding listening and reading tasks, highlighting its ongoing importance across proficiency levels.

Working Memory in Speaking and Writing

Productive language skills require learners to generate, monitor, and revise linguistic output in real time, placing significant demands on working memory. In speaking, WM supports the simultaneous processes of conceptualization, formulation, and articulation, as well as self-monitoring and repair. Limitations in WM may result in reduced fluency, simpler structures, or increased errors, particularly under time pressure.In writing, WM enables learners to manage multiple processes concurrently, including idea generation, lexical retrieval, syntactic planning, and revision. Task complexity strongly interacts with WM capacity, influencing both performance and learning outcomes. Learners with greater WM resources are often better able to attend to form while expressing complex ideas, leading to higher-quality written output.

Over time, increased proficiency and practice lead to greater automatization, reducing the cognitive load on WM during production. Nonetheless, WM remains essential for handling complex tasks, integrating feedback, and learning through production, reinforcing its dynamic role in L2 speaking and writing development. Taken together, evidence across language domains demonstrates that working memory contributes to SLA in domain-specific and time-sensitive ways. Its influence is strongest when tasks are novel, complex, or cognitively demanding, and it diminishes as learners gain experience and automatize processing. Viewing

WM through a dynamic lens thus provides a coherent explanation for variability in empirical findings and underscores the importance of aligning research and pedagogy with learners' cognitive resources.

Contextual and Instructional Influences on Working Memory in SLA

While working memory constitutes an important cognitive resource for second language acquisition, its role cannot be fully understood in isolation from the learning context. From a dynamic perspective, the influence of WM emerges through continuous interaction with instructional conditions, task characteristics, and learning environments. These contextual factors can either amplify or mitigate WM demands, thereby shaping learners' performance and development.

Learning Contexts and Cognitive Demands

Different learning contexts impose varying levels of cognitive load on learners. In classroom-based instruction, WM is often heavily engaged as learners must process new linguistic input, follow instructions, and manage attention under time constraints. In contrast, naturalistic or immersion contexts may allow for more distributed processing over time, reducing immediate WM demands but increasing the need for attentional control and inferencing.

Research suggests that WM plays a more prominent role in **instructed SLA**, particularly in settings that emphasize explicit grammar instruction and form-focused tasks. In such contexts, learners with greater WM capacity are better equipped to handle simultaneous attention to meaning and form. However, as learners gain experience and familiarity with instructional routines, the relative impact of WM may decrease, reflecting adaptation to contextual demands.

Task Complexity and Cognitive Load

Task design is a critical factor influencing the extent to which WM is engaged during L2 learning. Complex tasks that require learners to integrate multiple sources of information, maintain linguistic elements over time, or perform under time pressure place substantial demands on WM. When task demands exceed learners' WM capacity, performance and learning may be compromised. From a pedagogical standpoint, cognitive load theory offers valuable insights into managing WM constraints. Instruction that minimizes extraneous load, sequences tasks from simple to complex, and provides appropriate scaffolding can help learners

allocate WM resources more efficiently. Such task sequencing allows learners to gradually adapt to increasing demands, supporting both performance and development.

Multimodal Input and Technology-Mediated Learning

The increasing use of digital tools and multimedia materials in language education has introduced new dimensions to WM involvement in SLA. Multimodal input, combining auditory, visual, and textual information, has the potential to enhance learning by distributing processing across different WM components. However, poorly designed multimedia materials may overload WM, particularly when redundant or transient information is presented simultaneously.

Effective technology-mediated instruction aligns input modalities with WM capacity by providing visual support for spoken input, allowing learner control over pacing, and integrating meaningful tasks that promote active processing. From a dynamic perspective, learners' ability to manage multimodal input may also improve over time as they develop strategies for regulating attention and cognitive load.

Instructional Support and Learner Differences

Instructional practices play a crucial role in mediating the relationship between WM and SLA outcomes. **Scaffolding strategies**, such as chunking information, pre-teaching key vocabulary, and offering planning time, can reduce WM demands and support learners with limited WM resources. Such practices are particularly beneficial for beginner learners and those experiencing high cognitive load. Importantly, WM differences do not imply fixed limitations. Instruction that promotes strategic learning, metacognitive awareness, and self-regulation can help learners compensate for WM constraints. By recognizing WM as a dynamic resource rather than a fixed trait, educators can design learning environments that foster equitable opportunities for language development.

Toward WM-Sensitive Pedagogy

A dynamic and contextualized view of WM underscores the need for WM-sensitive pedagogy in SLA. This approach acknowledges individual differences while emphasizing adaptability in instruction. Rather than tailoring instruction solely to learners with high WM capacity, WM-sensitive pedagogy seeks to optimize task design, instructional sequencing, and learning support to accommodate a diverse range of cognitive profiles. By integrating insights from WM research into instructional practice, educators can create learning environments that

not only reduce unnecessary cognitive load but also promote the effective use and development of WM over time. Such alignment between cognitive theory and pedagogy strengthens the link between research and practice in second language acquisition.

Methodological Implications and Research Gaps

Adopting a dynamic and developmental perspective on working memory in second language acquisition has important methodological implications. While existing research has established WM as a significant factor in SLA, limitations in research design, measurement, and scope have constrained a fuller understanding of how WM operates and develops over time. This section discusses key methodological issues and identifies major gaps that warrant further investigation.

Measurement of Working Memory in SLA Research

One of the most persistent challenges in WM–SLA research concerns the heterogeneity of WM measures. Studies employ a wide range of tasks, including digit span, nonword repetition, reading span, and complex span tasks, which differ in the extent to which they tap storage, processing, or executive control. As a result, findings across studies are often difficult to compare or synthesize.

Moreover, many WM measures are not sufficiently aligned with the linguistic demands of the tasks used to assess L2 outcomes. From a dynamic perspective, WM should be measured in ways that reflect **task-specific and domain-relevant processing**, such as verbal WM tasks for speaking and writing or listening-span tasks for auditory comprehension. Greater construct clarity and standardization would enhance the reliability and interpretability of future research.

Research Design: Beyond Cross-Sectional Studies

Much of the existing literature relies on cross-sectional correlational designs, which provide limited insight into developmental change and causal relationships. While such studies have been instrumental in establishing associations between WM and L2 proficiency, they do not capture how WM and language ability influence each other over time. To address this limitation, researchers have increasingly called for longitudinal and experimental designs that track changes in WM and L2 development simultaneously. Longitudinal studies can reveal whether WM predicts subsequent language growth, whether language learning contributes to WM development, or whether both processes evolve in tandem. Experimental studies

manipulating task demands and instructional conditions can further clarify how WM is recruited under different learning circumstances.

Developmental and Population Gaps

Another major gap in the literature concerns the limited range of learner populations studied. Most WM–SLA research focuses on adult university learners, leaving children, adolescents, older adults, and learners in diverse educational contexts underrepresented. This narrow focus restricts the generalizability of findings and obscures developmental differences in how WM supports SLA.

From a developmental perspective, future research should examine WM trajectories across the lifespan, including early foreign language learners and aging populations. Additionally, more attention is needed for multilingual learners and learners from diverse linguistic and cultural backgrounds, whose experiences may shape the deployment and development of WM in unique ways.

Dynamic Interactions with Other Individual Differences

Although WM is often examined as an isolated predictor, SLA is shaped by interactions among multiple individual difference variables, including motivation, anxiety, attention control, and metacognitive awareness. Static models that isolate WM fail to capture these complex interactions.

Dynamic systems approaches encourage researchers to investigate how WM interacts with affective and contextual factors over time, potentially compensating for or amplifying cognitive constraints. Mixed-methods designs that combine quantitative measures with qualitative data, such as learner reflections or classroom observations, may be particularly well suited to capturing these interactions.

Future Directions for WM–SLA Research

Taken together, these methodological considerations point to the need for a more integrated and developmentally sensitive research agenda. Future studies should aim to:

1. Employ standardized, task-aligned WM measures;
2. Utilize longitudinal and experimental designs;
3. Include diverse learner populations and learning contexts;
4. Adopt dynamic and interactionist analytical frameworks.

Addressing these gaps will advance theoretical understanding of WM in SLA and strengthen the empirical basis for pedagogical applications.

Pedagogical Implications of a Dynamic View of Working Memory

Understanding working memory as a dynamic and developmental resource has important implications for second language pedagogy. Rather than viewing WM as a fixed limitation that determines learners' success, a dynamic perspective encourages educators to design instructional practices that accommodate, support, and potentially foster the effective use of WM across different stages of learning.

Managing Cognitive Load in Instruction

Given the limited capacity of WM, effective instruction must carefully manage cognitive load. Tasks that overwhelm learners with excessive linguistic input, complex instructions, or simultaneous demands on multiple skills may hinder both performance and learning. Teachers can mitigate this by sequencing tasks from simple to complex, reducing unnecessary information, and clearly highlighting learning objectives.

From a developmental standpoint, beginner learners benefit from tasks that focus on meaning before form, while gradually introducing form-focused elements as learners' processing capacity and linguistic knowledge increase. Such progression allows WM resources to be allocated efficiently and supports sustained language development.

Scaffolding and Task Design

Scaffolding plays a crucial role in supporting learners' WM during language learning. Instructional strategies such as chunking information, providing models and examples, pre-teaching key vocabulary, and allowing planning time before speaking or writing tasks can significantly reduce WM demands. These strategies are particularly beneficial for learners with lower WM capacity or those at early stages of acquisition.

Task-based language teaching can be made more WM-sensitive by adjusting task complexity, time pressure, and informational load. For instance, giving learners opportunities for rehearsal and repetition helps stabilize linguistic representations, reducing reliance on WM over time and promoting automatization.

Differentiated Instruction and Learner Support

A dynamic view of WM highlights the importance of individual differences without framing them as fixed deficits. Learners vary in how they deploy WM resources, and effective pedagogy should provide multiple pathways for engagement and learning. Differentiated instruction—such as offering visual support, written prompts, or collaborative activities—can help learners compensate for WM limitations. Collaborative learning, in particular, can distribute cognitive demands across learners, allowing individuals to benefit from shared processing and peer support. Over time, such interaction may also contribute to the development of cognitive and metacognitive skills that enhance WM efficiency.

Promoting Strategic and Metacognitive Awareness

Instruction can also support WM by fostering learners' metacognitive awareness and strategic behavior. Teaching learners how to plan, monitor, and evaluate their language use enables them to manage cognitive resources more effectively. Strategies such as note-taking, summarizing, and self-rehearsal help externalize information, reducing the burden on WM. Encouraging learners to reflect on task demands and their own processing strategies aligns with a developmental approach, as learners gradually become more autonomous and efficient in deploying cognitive resources during L2 learning.

Toward Developmentally Informed Pedagogy

Ultimately, a dynamic and developmental perspective on WM calls for developmentally informed pedagogy that adapts to learners' changing cognitive profiles. Younger learners may benefit most from rich exposure, repetition, and meaningful interaction, while older learners may require structured tasks that support executive control and explicit learning. By aligning instructional practices with learners' cognitive development and WM capacities, educators can create learning environments that not only facilitate immediate performance but also support long-term language growth. Such pedagogy bridges the gap between cognitive theory and classroom practice, reinforcing the relevance of WM research for real-world SLA contexts.

4. CONCLUSION

This article has examined the role of working memory in second language acquisition from a dynamic and developmental perspective, moving beyond traditional views that conceptualize WM as a fixed and static individual difference. Drawing on theoretical models,

empirical findings, and developmental evidence, the review demonstrates that WM functions as a flexible cognitive resource whose influence varies across time, proficiency levels, language domains, and learning contexts. Across SLA research, working memory has been shown to play a particularly important role in vocabulary learning, grammatical processing, and language performance under conditions of high cognitive demand. However, its impact is not uniform. At early stages of learning, WM strongly supports controlled and effortful processing, whereas at later stages, as linguistic knowledge becomes more automatized, reliance on WM tends to decrease. Importantly, evidence from longitudinal and multilingual studies suggests that the relationship between WM and SLA is reciprocal, with sustained language learning also contributing to the development of certain WM components, especially executive control.Adopting a dynamic and developmental framework helps reconcile mixed findings in the literature by highlighting the interaction between WM, task characteristics, instructional context, and other individual difference variables. This perspective underscores the need for SLA research to move beyond cross-sectional designs and isolated predictors, toward longitudinal, interactionist, and task-aligned approaches that capture change over time.From a pedagogical standpoint, viewing WM as a dynamic resource rather than a fixed limitation has significant implications. Instruction that manages cognitive load, provides appropriate scaffolding, and promotes strategic and metacognitive awareness can support learners with diverse cognitive profiles and foster more equitable learning opportunities. Such WM-sensitive pedagogy aligns instruction with learners' developmental stages and maximizes the potential for long-term language growth. Understanding working memory as a dynamic and developmental component of second language acquisition offers a more nuanced account of individual differences and learning trajectories. Future research integrating refined WM measures, longitudinal designs, and diverse learner populations will be essential for advancing both theory and practice in SLA.

REFERENCES

Baddeley, A. D. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology, 63*, 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Chai, C. S. (2022). Working memory and second language learning: A meta-analytic review. *Second Language Research, 38*(4), 567–594.

Coumel, M., Hartsuiker, R. J., & Segaert, K. (2023). Working memory and structural priming in second language sentence production. *Applied Psycholinguistics, 44*(1), 1–25.

Faretta-Stutenberg, M., & Morgan-Short, K. (2018). The interplay of individual differences and context of learning in second language development. *Second Language Research, 34*(1), 67–102. https://doi.org/10.1177/0267658316684903

Huang, B., Wen, Z., & Wang, Z. (2020). Working memory and foreign language learning: A dynamic systems perspective. *Journal of Neurolinguistics, 55*, Article 100908.

Jackson, D. O. (2020). The dynamic nature of working memory in second language acquisition. *Language Learning, 70*(Suppl. 1), 135–170.

Juffs, A., & Harrington, M. (2011). Aspects of working memory in L2 learning. *Language Teaching, 44*(2), 137–166. https://doi.org/10.1017/S0261444810000509

Kormos, J. (2023). The role of working memory in second language writing. *Journal of Second Language Writing, 59*, Article 100945.

Lim, H., & Lee, S. (2025). Working memory and incidental vocabulary learning through reading in a second language. *Reading in a Foreign Language, 37*(1), 1–25. https://doi.org/10.64152/10125/67481

Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review, 21*(4), 861–883. https://doi.org/10.3758/s13423-013-0565-2

Meng, X. (2023). Cognitive load and working memory in second language instruction. *System, 113*, Article 102992.

Rasheed, S., Wen, Z., & Wang, Z. (2025). Cognitive and affective predictors of second language proficiency in multilingual contexts. *Applied Linguistics, 46*(1), 1–27.

Sweller, J. (2011). Cognitive load theory. *Psychology of Learning and Motivation, 55*, 37–76. https://doi.org/10.1016/B978-0-12-387691-1.00002-8

Teng, F. (2025). Working memory, metacognitive knowledge, and vocabulary development in young bilingual learners. *Language Learning, 75*(1), 45–78.

Verhagen, J., & Leseman, P. (2016). How do verbal short-term memory and working memory relate to vocabulary and grammar development? *Journal of Experimental Child Psychology, 144*, 80–99.

Wang, Z. (2024). Working memory capacity and vocabulary learning in adult second language learners. *Studies in Second Language Acquisition, 46*(1), 1–26.

Wen, Z. (2012). Working memory as language aptitude: The phonological/executive model. *Language Learning, 62*(Suppl. 2), 112–142.

Wen, Z., Biedroń, A., & Skehan, P. (2015). Foreign language aptitude theory: Yesterday, today and tomorrow. *Language Teaching, 48*(1), 1–31. https://doi.org/10.1017/S0261444816000276

Zhao, Y. (2022). Working memory and second language reading comprehension: A cognitive load perspective. *Reading and Writing, 35*, 1251–1273. https://doi.org/10.1007/s11145-021-10192-z