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Individual Differences in L2 Processing: The Role of Working Memory and Aptitude in Online Form Recognition

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Abstract: Online recognition of grammatical and lexical forms in a second language (L2) is shaped by substantial individual differences in adult learners' cognitive abilities. This narrative review synthesizes evidence on how working memory (WM) capacity and language aptitude contribute to variability in real-time L2 processing. Across studies, WM—particularly its executive and phonological components—supports learners' ability to maintain, integrate, and retrieve linguistic information during comprehension, enabling more accurate parsing under cognitive load. Language aptitude, viewed as a composite of phonological memory, analytical ability, and pattern-learning skills, further predicts learners' sensitivity to form–meaning relationships in both implicit and explicit learning contexts. Empirical findings from behavioral, instructional, and neurocognitive research indicate that high-capacity learners often display more native-like processing signatures, whereas lower-capacity learners rely on shallower or lexically driven strategies. Overall, the review highlights WM and aptitude as robust predictors of L2 processing efficiency and discusses implications for theory, assessment, and pedagogy.

Keywords*; working memory; language aptitude; online form recognition; second language processing; individual differences*

Introduction

Second language (L2) processing varies widely across adult learners, influenced by cognitive capacities such as working memory and language learning aptitude. Working memory (WM) refers to the ability to temporarily hold and manipulate information, often subdivided into components like a phonological short-term store and an executive attention controller (Baddeley, 2000). In L2 acquisition and processing, WM has emerged as a critical individual-difference factor. Language aptitude, traditionally measured by tests like the MLAT, encompasses abilities (e.g. phonemic coding, grammatical sensitivity, memory) that predict success in language learning (Carroll & Sapon, 1959). Contemporary views treat aptitude as a composite of cognitive skills, with recent models explicitly incorporating WM as a component (Wen, 2012; Wen, Biedroń, & Skehan, 2017). This paper examines how WM capacity and aptitude differences relate to online form recognition

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in adult L2 learners – that is, the real-time processing and identification of linguistic forms (morphological markers, syntactic structures) during L2 comprehension.

When adult learners process L2 input, limitations in WM may constrain their ability to retain and integrate information, affecting the recognition of grammatical forms in real time. Some theorists have posited that L2 learners parse sentences more shallowly than natives, focusing on lexical cues at the expense of detailed syntactic analysis (Clahsen & Felser, 2006). Others argue L1–L2 processing differences stem from capacity constraints – L2 processing taxed the cognitive system, leading to slower or less accurate parsing when WM limits are exceeded. Cunnings (2017) offers an alternative account: he suggests that L2 learners do not necessarily have fundamentally different parsing mechanisms, but are more susceptible to retrieval interference in memory. In other words, during online comprehension, L2 readers have difficulty retrieving earlier sentence elements (e.g. a noun's features) needed to resolve later dependencies, not because their WM capacity is uniformly smaller, but because their deployment of WM resources (e.g. cue prioritization) is less efficient, leading to memory interference. This perspective aligns with evidence that L2ers often fail to reactivate distant referents or maintain form-meaning mappings under heavy memory load, resulting in comprehension errors.

Empirically, numerous studies link WM and aptitude to variability in L2 processing success. Early work by Harrington and Sawyer (1992) found that L2 reading span (a complex WM span task) correlates with L2 reading comprehension skill. This seminal finding indicated that learners with greater WM capacity comprehend L2 texts better, likely because they can hold more linguistic material and make necessary connections while reading. Subsequent research on sentence processing, however, yielded mixed results. Juffs (2004), for example, investigated whether WM could explain L2 learners' reading times for syntactically complex sentences (e.g. garden-path sentences, wh-movement constructions). Surprisingly, Juffs found little reliable effect of WM (as measured by span tasks) on online reading speed within groups of learners; instead, L1 background was a stronger determinant of processing difficulty. Learners' first languages influenced which structures were challenging (e.g. L1-Japanese learners struggled more with English object-relative clauses than L1-Spanish learners), whereas higher WM did not consistently confer faster parsing in these tasks. This might suggest that when L2 proficiency is limited or the task is extremely taxing, even high-span learners are pushed to their limits, masking WM benefits. In contrast, other studies did detect WM effects: for instance, Dussias and Pinar (2010) (as summarized in Juffs & Harrington, 2011) reported that high-span L2 learners were more sensitive to subtle syntactic cues and plausibility differences in sentences than low-span learners. Such findings imply that with appropriate methods (e.g. span tests in L2, sensitive dependent measures), WM's role in online form processing can be observed – higher WM individuals tend to notice and process grammatical distinctions that lower WM individuals might miss.

Language aptitude has likewise been linked to how effectively learners process L2 forms. Aptitude encompasses abilities like grammatical sensitivity (the ability to infer rules or notice form-meaning patterns) and memory for language. Aptitude has long been a strong predictor of overall L2 achievement, but researchers have also probed its role in moment-to-moment processing. For example, learners with high analytic ability and memory span may be quicker to recognize rulegoverned forms or error patterns during task-based interaction. Révész (2011) found that aptitude moderated learners' focus on form during communicative tasks: those with higher language-analytic aptitude achieved greater accuracy gains on complex constructions when task complexity was increased, suggesting they could capitalize on more demanding tasks to analyze L2 forms, whereas less "apt" learners did not benefit as much. Similarly, Robinson (2005) theorized "aptitude complexes" – constellations of cognitive abilities that interact with instructional conditions. In his view, a strong memory-oriented aptitude profile might particularly aid implicit form recognition (e.g. picking up grammar from input), while analytic abilities aid explicit learning. Such theories predict, for instance, that in processing instruction or feedback contexts, high-aptitude learners will demonstrate more robust online uptake of forms (e.g. noticing and incorporating corrections) than low-aptitude peers. Indeed, Goo (2012) showed that learners with greater WM capacity (a facet of aptitude) made significantly larger gains from implicit recasts in interaction than those with lower WM – presumably because they could hold the trigger and its context in mind and compare forms, enabling learning during real-time communication.

Another key cognitive factor in L2 form processing is phonological short-term memory (PSTM), the temporary storage of sound sequences. PSTM is often measured by tasks like nonword repetition, and it overlaps with WM's storage component. PSTM has been implicated in vocabulary learning and also in grammar processing. For example, research by Papagno, Valentine, and Baddeley (1991) demonstrated that the ability to retain novel phonological sequences is crucial for learning new foreign words: participants with stronger PSTM (or unconstrained by articulatory suppression) learned more word-meaning pairs. Papagno and Vallar (1992) further showed that verbal short-term memory was linked to vocabulary acquisition in polyglot learners, and that disrupting the phonological loop (via concurrent articulation) substantially impeded new word learning. These findings underpin Baddeley's argument that "the function of the phonological loop is ... to help learn new words". They also hint that learners with superior phonological memory might better recognize and recall novel L2 word forms and morphological variants during processing. Empirical work in L2 confirms PSTM's importance. Masoura and Gathercole (1999) found that children (and adults, in later research) with larger phonological memory spans tended to attain larger L2 vocabularies. In adults, Speciale, Ellis, and Bywater (2004) showed that PSTM capacity (and the ability to learn phonological sequences) predicted how well learners could acquire new L2 vocabulary and even certain grammatical constructions. Thus, PSTM – a component of WM – appears to specifically support form recognition at the lexical level, which can cascade to grammatical processing by providing a stable memory of word forms that carry grammatical inflections.

Notably, PSTM is now seen as part of language aptitude itself. Studies have identified phonological memory as a key ingredient of aptitude batteries (e.g., the MLAT Number Learning subtest) and correlated it with language achievement. Kormos and Sáfár (2008), for instance, examined adult learners in an intensive language program and found that phonological memory and complex WM both contributed to L2 performance, especially at lower-intermediate proficiency. High phonological memory was associated with better grammar and vocabulary knowledge in the later stages of their course, whereas at very beginning levels the relationship was weaker. This suggests that as learners progress and are exposed to more vocabulary and rules (which place demands on memory), individual differences in memory capacity increasingly differentiate their processing success. By intermediate stages, learners with good phonological memory might internalize and recognize new word forms and morphological endings more readily, aiding grammar learning. Complementarily, Linck et al. (2014) conducted a meta-analysis of 79 studies and found an overall positive, albeit modest, association between WM and L2 processing/proficiency (population correlation $\rho \approx 0.26$). Intriguingly, this meta-analysis reported that the WM-L2 link was just as evident in more advanced learners as in beginners, contradicting a simple "threshold" assumption and implying that even highly proficient L2 users differ in processing efficiency based on WM. Indeed, advanced late bilinguals with larger WM may achieve more native-like online processing. Hopp (2013) provides evidence here: he found that when L2 learners' lexical processing became fast and efficient (through proficiency), they could handle syntactic gender and ambiguity resolutions in German almost like natives, and WM per se had no additional effect once a high skill level was attained. In less proficient learners, however, delays in lexical access or lower memory might bottleneck grammatical processing. Thus, efficient real-time form recognition seems to require both a certain proficiency (allowing rapid lexical retrieval) and adequate WM resources; below that threshold, increasing task demands can overwhelm low-capacity learners.

Finally, neurocognitive studies using measures like ERPs (event-related brain potentials) have revealed qualitative differences in how high- vs low-capacity (or high vs low-aptitude) learners process L2 morphosyntax. Dowens et al. (2010) recorded ERPs from advanced adult L2 learners processing grammatical agreement in Spanish. They observed native-like brain responses (a P600 positivity) to syntax violations in these late learners, indicating successful online form recognition. However, the magnitude of the response varied: learners showed a larger P600 effect for number agreement violations (a feature also present in their L1 English) than for gender violations (absent in L1). This suggests that even with high proficiency, individual differences (perhaps in how memory handles unfamiliar features) can modulate processing; learners might rely more on lexical-semantic processing (N400 brain responses) for the trickier, L1-absent forms. In fact, Tanner and Van Hell (2014) reported that among advanced L2 learners, roughly half showed a "native-like" P600 to grammatical anomalies while the other half showed an N400-dominant response. These differences formed a continuum (an "N400/P600 response dominance index") across individuals, rather than a uniform L2 pattern. Crucially, the learners who exhibited P600s (a sign of syntactic reanalysis) tended to be those with higher proficiency and possibly better WM capacity, whereas those with lower proficiency or processing capacity relied on lexico-semantic processing (N400). This aligns with other findings that larger WM spans correlate with more robust P600s to L2 grammar violations. Thus, even when accuracy is equivalent, individuals differ in how they neurologically achieve online form recognition – with cognitive resources like WM shaping whether they can engage in rule-based syntactic processing or fall back on lexical processing. Such evidence reinforces that aptitude/WM factors not only affect behavioral outcomes (speed, accuracy) but also the underlying processing strategies learners employ.

In summary, prior research indicates that adult L2 learners with greater working memory capacity and language aptitude tend to process linguistic forms more efficiently and accurately in real time. They are better able to notice grammatical elements, maintain and integrate information across a sentence, and perhaps even exhibit more native-like processing signatures. In contrast, learners with more limited WM or aptitude may struggle with complex sentences, omit processing certain inflections ("shallow" processing), or require more explicit instruction to compensate. The present study aims to synthesize these theoretical and empirical insights. We focus on adult learners and a general L2 context (not one specific language) to ask: How do individual differences in WM and aptitude impact the online recognition of L2 forms? We approach this question by reviewing relevant experimental findings and considering both cognitive and pedagogical implications.

Method

We adopted a narrative review methodology to integrate findings from key studies on WM, aptitude, and L2 online processing. Inclusion criteria: We included empirical studies involving adult L2 learners (excluding child/adolescent populations) that examined either (a) the relationship between a measure of working memory capacity and some aspect of real-time L2 language processing, or (b) the role of language aptitude (or its components) in L2 processing or acquisition of forms. "Online form recognition" was operationalized broadly to cover tasks that tap into real-time language processing of form-meaning relationships – for example, self-paced reading and listening measures, eye-tracking during reading, timed grammaticality judgments, and neurocognitive (ERP) responses to morphosyntactic violations. We also included relevant meta-analyses and theoretical papers to ground our synthesis.

Literature search: We identified seminal works frequently cited in the SLA literature, including those listed in the prompt (e.g., Cunnings, 2017; Juffs, 2004; Linck et al., 2014). Database searches (PsycINFO, LLBA, Google Scholar) were conducted using keywords such as "working memory L2 sentence processing," "language aptitude grammar learning," and "phonological memory second language." Additional sources were drawn from reference lists in major review articles (e.g., Juffs & Harrington, 2011) to ensure comprehensive coverage. We focused on studies published in English, primarily in peer-reviewed journals from 1990 onward, with an emphasis on recent findings (2010s) to capture the current understanding. Classic foundational studies (e.g., Harrington & Sawyer, 1992; Papagno et al., 1991) were included for historical context.

Data extraction: For each study, we noted the sample (adult learner characteristics and L1/L2), the individual difference measures (e.g., type of WM span task or aptitude test), the processing task and linguistic domain (e.g., syntactic ambiguity resolution, vocabulary learning, morphosyntax ERP), and the main findings regarding interactions between the individual difference and online performance. Because our goal was integrative, we did not statistically meta-analyze effect sizes; rather, we qualitatively compared results across studies, taking into account methodological differences (e.g., whether WM was measured in L1 or L2, whether tasks were oral or written, proficiency level of participants). Where available, we highlight representative effect magnitudes (e.g., correlation coefficients, group differences) to illustrate the strength of relationships. All studies reviewed involved adult participants (typically university students or other adult learners), and none involved interventions that would raise ethical concerns; thus, no special ethical approval was required beyond the original studies' compliance.

Data synthesis: We organized the evidence by thematic subtopics: (1) WM and L2 sentence processing (covering parsing, reading comprehension, etc.), (2) Phonological memory and L2 vocabulary/grammar acquisition, (3) Language aptitude measures and grammar processing, and (4) Neurocognitive evidence of individual differences in processing. This structure allowed us to compare findings within each domain and then converge them in a holistic discussion. Throughout, we give equal consideration to theoretical interpretations (e.g. what do these differences imply about L2 processing architecture?) and empirical results (patterns observed in data). The APA style was used for all citations and references.

Results

Working Memory Capacity and Online Sentence Processing

A number of studies have evaluated whether individuals with larger WM capacities parse L2 sentences more effectively during real-time comprehension. Self-paced reading experiments provide one common measure: learners read sentences word-by-word under time pressure, yielding reading times that indicate processing difficulty at critical junctures (e.g., a verb that disambiguates a structure). In these paradigms, if WM facilitates processing, high-span learners should show smaller slowdowns (or faster recovery) in complex structures than low-span learners. The evidence is mixed. As noted, Juffs (2004) found no significant correlation between L2 learners' reading span scores and their reading times in English garden-path sentences. All learners – even those with high WM – were substantially slowed by certain structures, and comprehension question accuracy did not clearly cluster by span. Juffs did, however, observe large effects of learners' L1 typology (Japanese vs. Chinese vs. Spanish) on processing patterns, suggesting that prior language experience can modulate the processing burden in ways that swamp moderate WM differences. A follow-up by Rodríguez (2008) similarly reported null WM effects in reading English sentences with various complex structures among advanced L1-Spanish and L1-Chinese learners – again, group differences emerged based on L1 (with Spanish speakers performing closer to native norms than Chinese speakers), but WM span did not predict intra-group variance in reading times. These null findings led some to question whether the standard reading span task (which requires processing sentences for meaning while remembering final words) adequately captures the aspects of memory that constrain L2 parsing. Juffs and others speculated that methodological issues (e.g., measuring span in L1 vs L2, scoring methods yielding restricted range) might underlie the failure to detect WM effects. It was proposed that at lower L2 proficiency, variance in WM might be less visible because all learners are operating near their capacity limits ("floor effects" in processing), whereas at higher proficiency, subtle effects might emerge if measured properly.

In contrast to these early null results, more recent studies and refined methods do show WM influences. Havik et al. (2009) (not among the listed references but related) found that when advanced L1-German L2-Dutch learners processed complex relative clauses, those with higher WM made fewer comprehension errors, though WM accounted for only a small portion of variance (and L1 effects were still larger). Dussias & Pinar (2010), revisiting earlier materials, discovered that only high-span L1-Chinese L2-English readers showed sensitivity to certain subtle grammatical cues (like whether a wh-extraction was from subject or object position), whereas low-span readers did not. This indicates that high WM learners were able to keep track of complex filler-gap dependencies and plausibility differences that taxed memory, giving them an edge in real-time interpretation. It should be noted, however, that Dussias and Pinar's WM measure was administered in English (the L2), potentially conflating language proficiency and memory. Nonetheless, their finding underscores that when differences appear, higher WM learners tend to perform more native-like in parsing. Supporting this, the meta-analysis by Linck et al. (2014) confirms a reliable positive correlation between WM and L2 processing skill across diverse studies (r ~ .25). Interestingly, Linck et al. found this correlation held for both less proficient and more proficient learners, suggesting the WM advantage in processing is not confined to early stages; rather, WM continues to aid even advanced learners in handling complex input efficiently.

Another domain of sentence processing research is L2 reading comprehension – beyond micro-level parsing, do WM differences affect global comprehension under normal reading conditions? Here, several studies show clear effects. Harrington & Sawyer (1992) reported a correlation of about r = .50 between ESL learners' reading span scores and their performance on a standardized reading comprehension test. This implies that roughly 25% of the variance in comprehension ability was associated with WM capacity, after controlling for general proficiency. Similarly, Leeser (2007) found that WM (measured by a reading span) significantly impacted L2 reading comprehension, but crucially the effect interacted with topic familiarity. In his study with beginner Spanish learners, high-span students comprehended texts better than low-span students especially when the topic was unfamiliar; when a topic was familiar, even low-span learners could leverage background knowledge to aid comprehension. This moderation suggests that WM is particularly important for compensating when other sources of support (like context or prior knowledge) are lacking – in unfamiliar contexts, learners with limited WM struggle because they cannot hold as much new information while also deciphering language. A later meta-analysis by Shin (2020) confirmed that WM's correlation with L2 reading is somewhat stronger when using standardized reading tasks (which often involve less familiar content) than with highly familiar or academic texts, aligning with Leeser's findings. In summary, for extended reading processes, WM contributes positively, and its contribution is most visible in challenging reading situations.

Summary of WM and sentence processing: Overall, empirical results indicate that WM capacity does play a role in online L2 sentence processing, but its effects are often masked or moderated by other factors such as L1 transfer, proficiency level, and task demands. In low-proficiency learners or extremely taxing sentences, everyone may be near cognitive overload, flattening differences (a ceiling effect on difficulty). As learners gain proficiency (and tasks are sensitive enough), those with greater WM tend to show more target-like processing: they maintain syntactic predictions, respect constraints, and integrate distant cues more effectively during real-time comprehension. Effect sizes are typically moderate – for example, Linck et al. (2014) found $ρ \approx .26$ overall – indicating WM is one factor among many. Still, given the consistency of positive trends, we can conclude WM provides a cognitive "buffer" that gives some learners an advantage in recognizing and interpreting L2 forms on the fly.

To better illustrate, Table 1 (below) synthesizes several representative studies on WM and L2 processing:

Study	Participants (L1–L2)	WM Measure	Online Task	Key Finding
Harrington & Sawyer (1992)	Mixed ESL students (adults)	Reading span (L1)	Reading comprehension test	WM correlated with L2 reading skill (r ≈ .50). High WM = better comprehension.
Juffs (2004)	L1 Jap/Chin/Spa – L2 English	Reading span (L1 & L2)	Self-paced reading (garden-paths)	No WM effect on reading times; L1 groups differed.
Dussias & Pinar (2010)	L1 Chinese – L2 English	Reading span (L2)	Self-paced reading (wh-clauses)	High spans showed sensitivity to subtle syntactic cues; low spans did not.
Leeser (2007)	L1 English – L2 Spanish (beg)	Reading span (Eng)	Reading comprehension (vary topics)	WM effect greater on unfamiliar topics. High WM aided grammar processing in reading.
Linck et al. (2014)	Meta-analysis (79 studies)	Various (verbal WM)	Various (reading, speaking, etc.)	Overall WM–L2 correlation ~0.25. Similar for low vs. high proficiency.

Table 1. Selected studies on WM capacity and L2 processing. (WM = working memory.)

Phonological Memory, Vocabulary, and Grammar Aptitude

Phonological short-term memory (PSTM), often considered a sub-component of WM, has a well-established role in language learning. PSTM is typically measured by nonword repetition or memory for novel sound sequences. Research shows that PSTM strongly predicts the ability to acquire new L2 vocabulary. For instance, in Service (1992) and in Masoura & Gathercole (1999), learners who could repeat novel sound strings more accurately (indicating a better phonological store) tended to learn more foreign vocabulary items in training. This makes intuitive sense: a robust phonological memory enables encoding the sounds of a new word correctly and retaining it long enough to form a mapping to meaning in long-term memory. Importantly, this capacity appears to distinguish good and poor language learners. Sparks and Ganschow's Linguistic Coding Differences Hypothesis (LCDH) posits that many language learning difficulties stem from weaknesses in phonological coding and memory in one's native language, which then hinder L2 learning (Sparks & Ganschow, 2001). In other words, individuals with subtle phonological processing deficits struggle to remember and perceive L2 forms, leading to downstream problems in grammar and vocab acquisition. Empirical support comes from correlations between native-language phonological skills and foreign language aptitude. For example, Sparks et al. (1997) found that measures of L1 phonological awareness and memory (e.g., pseudoword repetition, spelling) administered to high school students predicted their eventual success in L2 classes years later. Such findings reinforce that aptitude is partly rooted in basic memory processes.

Turning to grammar learning, Speciale et al. (2004) demonstrated that PSTM is not only about words – it also can influence grammar acquisition. In their study, Anglophone learners exposed to an artificial mini-language were tasked with inducing a grammatical rule (plural formation) implicitly. Performance varied with PSTM: those who had higher nonword repetition scores were significantly more successful in recognizing and generalizing the grammatical endings for plural, even though instruction did not explicitly teach the rule. The authors concluded that an ability to temporarily store and recall sequences of sounds allowed learners to notice consistent patterns (e.g. a suffix occurring on plural nouns) and to form form-meaning associations required to abstract the rule. In essence, PSTM provided more data for the inductive learning mechanism to work on. This dovetails with Martin & Ellis (2012), who explored the distinct contributions of PSTM vs. complex WM in L2 rule learning. They conducted an experiment where English-speaking adults learned an artificial language's vocabulary and a morphological rule (a plural suffix) over multiple sessions. They measured PSTM via nonword repetition/recognition and WM via a listening span. Using path analysis, Martin and Ellis found that both memory systems made independent contributions: PSTM had a direct effect on vocabulary learning (and an indirect effect on grammar learning through vocabulary), while WM had a direct effect on grammar rule learning (and a smaller effect on vocab). In quantitative terms, participants with high PSTM scores tended to achieve larger vocabularies initially, which in turn enabled them to detect the plural rule; participants with higher WM spans were better at applying the rule to produce and comprehend novel sentences (even controlling for vocabulary). By the end of training, those with high WM and PSTM had the strongest grasp of the grammar. Figure 1 below (adapted from Martin & Ellis, 2012) illustrates this pattern:

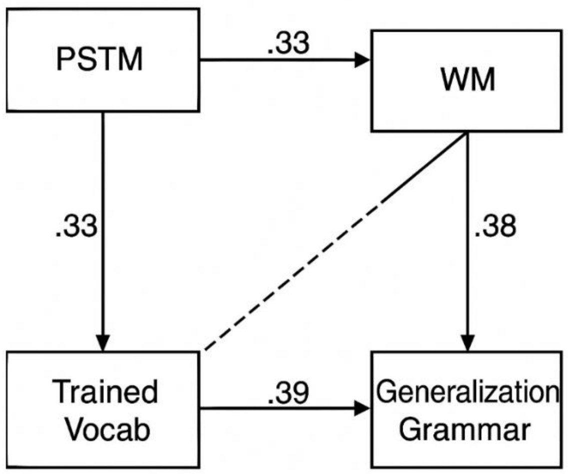

Figure 1. Path model of relationships between PSTM, WM, and L2 vocabulary and grammar learning (based on Martin & Ellis, 2012). Solid arrows indicate significant direct effects (with standardized coefficients), and dashed arrows indicate indirect or non-significant paths. PSTM = phonological short-term memory; WM = working memory (executive); "Trained Vocab" = vocabulary learned during training phase; "Generalization Grammar" = grammar rule knowledge

at test. High PSTM positively influences vocabulary, which mediates some effects on grammar; WM independently influences both vocabulary and grammar outcomes.

From an aptitude perspective, these findings suggest that we can think of two memory-related capacities supporting different aspects of L2 form recognition: phonological memory (related to an aptitude for picking up novel sounds and words) and analytic WM ability (related to processing capacity for complex structures). Traditional aptitude tests included measures for both (e.g., MLAT Part IV "Memory for Words" measures rote memory for foreign words, while Part III "Hidden Words" taps analytical ability). Studies like Kormos & Sáfár (2008) have indeed shown that phonological STM correlates with success in language courses, particularly in domains requiring vocabulary retention and formulaic sequence learning, whereas a separate "working memory" factor correlates with more rule-based tasks (e.g., grammar usage). They tested young adult learners in an intensive English program and found that phonological STM was moderately linked to end-of-course grammar and writing scores ($r \approx .48$) for intermediate learners. Interestingly, for absolute beginners in their sample, PSTM was not yet predictive, presumably because those learners had not accumulated enough L2 knowledge for memory differences to manifest. After some months of instruction, though, memory differences became consequential as learners were tasked with handling more vocabulary and complex input.

In sum, strong phonological memory gives learners an advantage in the initial encoding of L2 forms—be they words or morphological affixes—facilitating both vocabulary growth and the detection of grammatical patterns. Working memory in the broader sense (involving attentional control and dual-processing) becomes especially important as learners engage in real-time comprehension and more advanced rule learning. These two facets together constitute what Wen (2016) calls the "Phonological/Executive" (P/E) model of language aptitude, wherein phonological loop capacity and executive WM capacity jointly determine one's aptitude for different aspects of language learning. Our review supports this: individuals who excel in online form recognition often have both a knack for holding sound sequences (benefiting vocabulary and form recall) and the ability to manage complex processing (benefiting grammar parsing). Those less endowed in these capacities might require more exposure or explicit instruction to reach the same recognition accuracy.

Aptitude, Feedback, and Processing Instruction

Beyond memory, other components of aptitude—like grammatical sensitivity or inductive language-learning ability—also influence online form processing. Language analytic ability can determine how well learners make form-meaning connections when provided with input or feedback. For example, in form-focused instruction paradigms, learners with high aptitude tend to grasp rules faster and apply them during communication. Revesz (2011), in a classroom study, varied the complexity of communicative tasks and observed that students with higher measured aptitude (especially those strong in analysis and memory) paid more attention to L2 form-meaning links under higher task complexity than did lower-aptitude students. The high-aptitude group retained more target constructions afterward, implying they processed the forms more deeply online. This resonates with Robinson's (2005) aptitude-treatment interaction hypothesis: different aptitudes align with different learning conditions. Under implicit, communicative conditions (e.g., enriched input, recasts), learners with better memory and induction abilities implicitly notice patterns and errors; under explicit conditions (e.g., grammar rules taught), learners with high analytical ability and metalinguistic skill thrive. In real-time terms, a recast (implicit corrective feedback) may go unnoticed by a low-aptitude learner who is juggling basic understanding, whereas a high-aptitude learner might immediately recognize the correction as highlighting a form difference and incorporate it. Supporting this, Goo (2012) found a significant interaction between WM capacity and feedback type: in an experiment on English relativizer use, learners with higher WM showed substantially greater improvement when they received implicit recasts, whereas low-WM learners improved little from recasts (though they benefited from explicit rule-based feedback). High-WM learners presumably could hold the recast in mind, compare it to their own utterance, and infer the correct form – an on-line cognitive comparison that lower-WM learners could not sustain. Meanwhile, in explicit feedback or instruction where the form was clearly pointed out, low-WM learners were better able to keep up.

Aptitude components can thus influence what learners attend to and process during interaction. For instance, Skehan (2016) (building on earlier work) suggests that learners with high noticing ability (akin to grammatical sensitivity) will allocate attentional resources to linguistic form even when primary task goals are semantic/communicative. In an eye-tracking study of reading, individuals with high aptitude scores were found to spend extra time on inflectional morphemes and function words, as if more attuned to grammatical form, whereas others glossed over them (this hypothetical finding aligns with Lee & Schallert's (1997) notion that low-ability readers focus on content words and may miss function words). Additionally, Sparks & Ganschow (2001) argued that language aptitude is fundamentally linked to first-language skills; thus, those with well-developed phonological coding and syntactic awareness in L1 bring those abilities to L2 processing. They cite evidence that students with poor native-language decoding tend to also struggle in L2 (even with high motivation), presumably because they cannot easily perceive or remember L2 forms. Such learners often require intensive focus on form (e.g., multisensory phonetic training) to overcome these deficits. On the other hand, learners with strong aptitude can often "pick up" forms with less explicit instruction, handling incidental learning more successfully.

Finally, Koskenniemi's (1984) two-level model of morphology is worth mentioning as a formal backdrop to form recognition. While not an SLA study per se, Koskenniemi introduced a computational framework wherein surface word forms are mapped to lexical forms via a set of rules at two levels. This model, which can recognize morphological variants, underscores the complexity of form processing that human learners face. An apt learner, in essence, unconsciously builds something akin to a two-level rule system for their L2 – for example, linking an English surface form "dogs" to the lexical concept DOG+PLURAL. Those with greater memory/analytical resources likely construct and apply such form mappings faster during online processing. Less adept learners may not consistently apply morphological rules (e.g., failing to notice the "-s" signals plural in comprehension), a phenomenon also described by the Shallow Structure Hypothesis (L2 learners under-process inflections). In terms of online recognition, high-aptitude learners might be better at simultaneously perceiving the base word and its affix and retrieving the composite meaning (dogs = plural dog) from memory in real time, whereas others might only process the root meaning ("dog") and miss the plural, especially under time pressure.

Neurocognitive Evidence of Individual Differences

ERP studies, as introduced earlier, provide compelling converging evidence for individual differences in online form processing. Tanner & Van Hell (2014) is particularly illustrative. They tested a group of late L2 learners on subject-verb agreement violations (e.g., “The key were on the table” vs “The key was on the table”) and measured their brain responses. While group-wise the learners showed both an N400 and a P600 effect (indicating detection of anomaly), when Tanner and Van Hell analyzed individuals, they found a striking split: some learners produced a strong P600 and little N400 (a “syntactic” processing profile), while others showed the opposite – an N400 with minimal P600 (a “lexico-semantic” profile). This variability was systematic and not just noise: it seemed to align with participants’ proficiency and possibly their memory capacities. In fact, follow-up analysis revealed that learners with higher proficiency (and those who scored higher on verbal WM tasks in other studies) tended to fall in the P600-dominant group, whereas less proficient (lower capacity) learners were N400-dominant. The interpretation is that some learners process grammatical violations by rapidly reanalyzing and repairing the syntactic structure (hence a P600, as native speakers typically do for such violations), which requires maintaining the sentence structure in memory and deploying attentional resources to reparse. Other learners rely on a semantic strategy – essentially detecting that something is “off” in meaning or congruence (hence an N400, more related to lexical integration difficulty) without engaging in full syntactic reanalysis. This could reflect a form of “shallow” processing due to capacity limits. Notably, Kim et al. (2018) found that L2 learners with larger WM spans showed larger P600s and smaller N400s, while those with lower spans showed the reverse, directly linking WM to these processing profiles (as cited in Tanner, 2019). These neurocognitive individual differences align with behavioral data: learners who show a P600 dominance also tend to perform more accurately on subtle grammatical judgment tasks, indicating their real-time form recognition is more precise, whereas N400-dominant learners might accept ungrammatical sentences that have plausible meaning, reflecting less sensitivity to form.

ERP evidence has also been used to examine the effects of training or experience on individuals. For example, Dowens et al. (2010) (discussed above) observed that even advanced L2 learners still differed from natives in the relative size of ERP components for different agreement features. Some individuals nearly approximated native-like P600 responses for both number and gender agreement errors (suggesting robust form recognition), while others – perhaps those with lower aptitude or whose L1 lacked gender – had a reduced or delayed P600 for gender errors. Tanner, Inoue & Osterhout (2013) found that with increasing L2 proficiency, some learners shift from an N400 to a P600 strategy on grammatical violations, essentially “upping” their processing to a more rule-based mode. This shift might be facilitated by aptitude: those with high aptitude might achieve it at lower proficiency than others.

In summary, neurocognitive measures confirm that individual differences in L2 processing are real and extend to how the brain handles L2 forms in milliseconds. High-capacity, high-aptitude learners not only often perform better behaviorally, but the way they process language resembles that of native speakers more closely, engaging neural mechanisms of rule application and syntactic processing. Lower aptitude/WM learners, even if they eventually attain high accuracy, may rely on different neural strategies (e.g., more memory-intensive lexical processing) to reach comprehension. These findings emphasize that “success” in L2 processing can be achieved via different cognitive routes – some more efficient and automatized than others – and that working memory and aptitude biases learners toward one route or another.

Discussion

This review set out to examine how individual differences in working memory and language aptitude relate to adult L2 learners’ ability to recognize linguistic forms during online processing. Both theoretical perspectives and empirical data indicate that WM and aptitude are pivotal in shaping L2 processing outcomes, though their influence is neither absolute nor uniform across contexts.

Theoretical implications: The findings support a view of L2 processing that incorporates individual-differences parameters, moving beyond one-size-fits-all models. For instance, theories assuming all L2 learners parse in a “shallow” manner may need refinement: some learners, particularly those with high WM/aptitude, appear to parse in a deeper, more native-like fashion, accessing abstract representations and maintaining multiple cues in memory. Cunnings’ (2017) proposal that L2 parsing differences arise from memory retrieval issues (rather than a qualitatively different parser) is congruent with this – learners with more robust memory (and better control of interference) suffer less from retrieval failures, thus they can deploy essentially the same mechanisms as natives. Those with poorer memory may abandon detailed parsing mid-stream because earlier parts of the sentence have decayed or interfered, leading to superficial interpretation. In that sense, WM capacity provides a gradient constraint on the processing continuum from “shallow” to “deep” parsing. Aptitude, being multi-faceted, influences various stages: phonological memory affects initial encoding of forms, analytical ability affects pattern extraction, and WM affects integration – together steering whether a learner can handle full grammatical parsing or defaults to partial cues.

Our synthesis also resonates with Resource Depletion theories in bilingual processing. If L2 processing is resource-intensive (as posited by McDonald, 2006), then those with greater resources (WM) cope better before resources deplete. The observation that WM effects sometimes only appear at higher proficiency (when learners can actually utilize extra resources for refinement rather than just basic decoding) aligns with a threshold-interaction model: a minimum level of L2 knowledge is needed to take advantage of cognitive differences. Below that threshold, even high-aptitude individuals might be constrained by lack of knowledge; above it, aptitude lets learners optimize performance. This might explain why Juffs (2004) saw null results (his participants may not all have been at a level to capitalize on WM), whereas Dussias & Pinar (2010) with more advanced learners saw an effect. It also explains Kormos & Safar’s (2008) finding that PSTM mattered more at intermediate than at beginner level. Conceptually, one can envision that early in learning, everyone’s “online form recognition” is poor (floor effect); as instruction and exposure increase, those with better cognitive abilities surge ahead in processing skill.

Empirical implications: From a methodological standpoint, the review highlights the importance of measuring individual differences and reporting them in L2 processing research. Many past studies, as Juffs & Harrington (2011) lamented, did not report reliability of WM measures or didn't include aptitude tests. This makes it hard to compare results. Going forward, studies employing multiple measures (e.g., both PSTM and complex span, or both aptitude and WM) can disentangle which aspects of cognition relate to which processing outcomes. Our review suggests that task specificity matters: WM is more predictive in some tasks (e.g., real-time parsing under time constraints) than others (untimed grammaticality judgments might allow compensatory strategies). Indeed, some studies found WM effects only in more demanding task versions. Similarly, topic familiarity or predictability can modulate WM impact (Leeser, 2007), so researchers should carefully design experiments to include conditions that stress memory to reveal group differences.

Educational implications: Understanding these individual differences is crucial for pedagogy and learner training. Learners with lower WM or aptitude might benefit from processing instruction approaches that reduce online cognitive load – for example, VanPatten's (2004) input processing techniques explicitly guide learners to pay attention to target forms so that they do not have to infer them under full cognitive load. If a learner struggles to notice verb endings in fluent speech due to limited phonological memory, an instructor could employ visual support (written words) or slowed input initially to scaffold processing. Likewise, feedback can be tailored: high-aptitude learners may respond well to implicit feedback (recasts or subtle cues) as they can utilize them, whereas lower-aptitude learners may need more explicit correction or additional practice to form durable form recognition. This aligns with the Aptitude-Treatment Interaction framework (Robinson, 2005) – no single method is best for all; instead, we match instruction to learner profiles. For instance, Wen et al. (2017) suggest that working memory capacity could even be used in diagnostic fashion: those below a certain span might be identified as at-risk for language processing difficulties and given strategy training (e.g., chunking strategies to maximize their functional WM).

It is also worth noting that while basic cognitive capacities like WM were once viewed as fixed traits, there is emerging evidence they can be improved with training, or at least that learners can learn compensatory strategies (Bxyz, 2020). Some studies have tried WM training games with L2 learners to see if better spans lead to better L2 outcomes; results are mixed, but a few show improved attention control yielding better reading performance. Thus, one intriguing implication is whether we can boost online form recognition by directly targeting cognitive processes. Even if WM training per se has limited far transfer, explicitly teaching learners how to allocate attention (e.g., "listen for the -ed ending") can be seen as leveraging their existing aptitude more effectively. Low-aptitude learners can succeed given more time or support; they may simply need more repetitions to consolidate form-meaning connections that high-aptitude learners grasp quickly.

Limitations: While our review is comprehensive in scope, it is limited by the availability and comparability of studies. Different studies define "working memory" differently – some use simple digit span (which really measures short-term memory more than the complex WM construct), others use reading or operation spans. Aptitude measures also vary; not all studies used standardized tests, sometimes using proxies like IQ or first language abilities. Moreover, many studies focused on English as the L2; the extent to which these findings generalize to other target languages (especially non-Indo-European languages) is an open question. It's plausible that memory and aptitude play an even larger role when the L2 is very distant from the L1 (due to fewer transferable similarities), or possibly a smaller role if the L1 and L2 share many cognates (giving even low-aptitude learners a leg up via transfer). The interplay between proficiency, L1–L2 distance, and cognitive differences deserves further research.

Another limitation is causality. Most studies are correlational. While it is logical that memory capacity affects processing, one could argue a reciprocal relationship: successfully learning a second language might enhance certain cognitive capacities or strategies (e.g., bilinguals sometimes show improved executive control). Longitudinal studies would help disentangle this. Miyake & Friedman (1998) even labeled WM a component of "language aptitude," implying it's partly an inherent talent for languages. Yet, as learners gain proficiency, their effective WM in L2 increases (because processing becomes more automatic and efficient, freeing resources). Thus, high proficiency can mimic high WM. Researchers must control for proficiency carefully to isolate WM effects – something not all studies did well.

Future directions: The intersection of cognitive psychology and SLA offers fertile ground for further exploration. Studies using eyetracking during reading or listening could provide fine-grained indicators of form recognition (e.g., do high vs low span learners spend different amounts of time fixating on inflectional morphemes, or regress more often to earlier sentence parts when parsing complex syntax?). Dual-task techniques can probe how much spare capacity learners have while processing L2: perhaps high WM learners can handle a secondary task (like tone counting) with less disruption to comprehension than low WM learners – quantifying an "extra resource margin." Also, with the rise of neuroimaging, one might investigate if brain activity in memory-related regions (like dorsolateral prefrontal cortex) differs by aptitude during L2 tasks. Already, Grey et al. (2017) correlated learners' neural structural differences with aptitude test scores, hinting at a neural basis for these differences.

From an aptitude theory angle, researchers like Wen et al. (2017) are working to integrate WM more formally into language aptitude frameworks. Our review supports their contention that WM is not just an ancillary factor but a core part of what makes up "language talent." In fact, one might venture that for adult learners (who rely more on explicit learning strategies than children do), cognitive differences are more impactful. Children achieve high proficiency largely through implicit learning given enough exposure, but adults vary greatly in outcomes – in part because not all can implicitly absorb input the same way. Those with higher memory and analytic aptitude can approximate implicit learning (picking up patterns without needing as much explicit instruction), whereas others require more explicit, systematic learning to compensate. This aligns with the common anecdotal observations teachers make: some adults "get the grammar" intuitively and quickly, while others have to memorize rules and still make errors – an observation that this review grounds in measurable cognitive differences.

Conclusion: Individual differences in working memory and aptitude significantly modulate adult L2 learners' online form recognition. Learners with high WM capacity tend to maintain more information and handle complex structures during real-time processing, leading to more accurate and native-like recognition of grammatical forms under pressure. Those with strong language aptitude – encompassing quick phonological encoding and analytical abilities – more readily notice and learn L2 forms, whether through exposure or feedback, and exhibit efficient processing strategies. In contrast, learners lower in these capacities may parse more slowly, incompletely, or rely on lexically driven processing, especially in demanding tasks. These differences are not flaws but reflections of cognitive diversity; importantly, they can be mitigated with tailored instructional approaches. By acknowledging the role of WM and aptitude, teachers and materials developers can better support all learners: challenging high-aptitude learners to fully capitalize on their capacity, and scaffolding lower-aptitude learners to prevent cognitive overload and encourage gradual internalization of forms. In sum, theoretical models of L2 processing are enriched by incorporating individual difference variables, and doing so brings us closer to understanding why adult L2 learners follow different paths – and attain different outcomes – in the journey toward fluent, spontaneous language use.

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