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Psycholinguistic and age factors in foreign language learning: a meta-analysis

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Abstract. *Introduction.* Contemporary research in second or foreign language (L2) acquisition integrates cognitive, affective, and sociocultural factors. However, variability in findings arises from methodological heterogeneity and differences in learner age. *Aim.* The present study *aimed* to systematise empirical data on the influence of working memory (WM), executive functions (EF), motivation, emotional intelligence, and anxiety on L2 acquisition success across different age groups, and to identify moderators related to task type and learning context. *Methodology and research methods.* In accordance with PRISMA guidelines, a systematic review and meta-analysis of studies published from 2000 to September 2025 was conducted using the Web of Science, Scopus, PsycINFO, and Google Scholar databases. The inclusion criterion was the presence of a quantitative assessment of the relationship between at least one specified psycholinguistic factor and L2 performance. Random-effects models (REML), heterogeneity assessments (Q, τ^2, I^2), Egger's test for bias detection, and the trim-and-fill method were applied. Age, type of language task, and context (ESL/EFL/language environment) were included in the moderator analysis. *Results.* Out of 1,246 publications, 38 studies met the criteria. Strong correlations were found between L2 success and WM ($r \approx 0.54$) and EF ($d \approx 0.46$), as well as positive associations with motivation ($r \approx 0.32$) and emotional intelligence ($r \approx 0.29$). A negative correlation was observed with anxiety ($r \approx -0.25$). These effects were more pronounced for lexical and reading tasks, in English as a Second Language (ESL) and language immersion contexts, and among young adults. For learners over 60, significant but more variable improvements were noted. *Scientific novelty.* Subject-specific and age-dependent mechanisms linking WM/EF to L2 outcomes have been identified. Methodological moderators related to research design have been quantitatively assessed for the first time. *Practical significance.* The results underscore the necessity of developing age- and context-specific methodologies that integrate a focus on form with the enhancement of EF/WM and anxiety regulation, utilising adaptive technologies – particularly for teaching older age groups.

Keywords: second language acquisition, working memory, executive functions, motivation, emotional intelligence, anxiety, meta-analysis, ageing, cognitive reserve, ESL/EFL

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Психолингвистические и возрастные факторы в изучении иностранного языка: мета-анализ

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Аннотация. *Введение.* Современные исследования в области усвоения второго/иностранного языка (L2) интегрируют когнитивные, аффективные и социокультурные факторы. Однако вариативность полученных результатов обусловлена методологической неоднородностью и возрастными различиями обучающихся. *Цель* исследования – систематизация эмпирических данных о влиянии рабочей памяти (РП), исполнительных функций (ИФ), мотивации, эмоционального интеллекта и тревожности на успешность овладения L2 в различных возрастных группах, а также выявление модераторов, связанных с типом задач и контекстом обучения. *Методология, методы и методики.* В соответствии с принципами PRISMA проведен систематический обзор и метаанализ исследований (2000 – сентябрь 2025 г.) на основе баз данных Web of Science, Scopus, PsycINFO и Google Scholar. Критерием включения служило наличие количественной оценки связи хотя бы одного из указанных психолингвистических факторов с результативностью в L2. Применялись модели со случайными эффектами (REML), оценка гетерогенности (Q, τ^2, I^2), тест Эггера для анализа систематической ошибки и метод «trim-and-fill». В анализ модераторов включены возраст, тип языковой задачи и контекст (ESL/EFL/языковая среда). *Результаты.* Из 1246 публикаций критериям соответствовали 38 исследований. Установлены устойчивые корреляции успешности в L2 с РП ($r \approx 0{,}54$) и ИФ ($d \approx 0{,}46$), положительные связи с мотивацией ($r \approx 0{,}32$) и эмоциональным интеллектом ($r \approx 0{,}29$), а также отрицательная связь с тревожностью ($r \approx -0{,}25$). Эффекты усиливались при выполнении лексических заданий и заданий на чтение, в контекстах ESL и языковой среды, а также среди молодых взрослых. У обучающихся старше 60 лет зафиксированы значимые, но более вариативные улучшения. *Научная новизна.* Выявлены предметно-специфические и возрастно-обусловленные механизмы связи РП/ИФ с результатами овладения L2. Впервые количественно оценены методологические модераторы, связанные с дизайном исследований. *Практическая значимость.* Результаты обосновывают необходимость разработки возрастно- и контекстно-ориентированных методик, сочетающих focus-on-form с развитием ИФ/РП и регуляцией тревожности, с применением адаптивных технологий, особенно для обучения старших возрастных групп.

Ключевые слова: усвоение второго языка, рабочая память, исполнительные функции, мотивация, эмоциональный интеллект, тревожность, метаанализ, старение, когнитивный резерв, английский как второй / иностранный язык

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Introduction

Second language (L2) acquisition has long been recognised as a complex and multidimensional phenomenon that encompasses cognitive, affective, and sociocultural determinants, as E. Bialystok [1] and J. F. Kroll and E. Bialystok [2] argue. Contemporary research demonstrates that bilingualism not only provides professional and social advantages but also enhances cognitive flexibility and executive control at the individual level. For example, L. L. Kapa and J. Colombo [3] highlight cognitive benefits, while P. Li, J. Legault and K. A. Litcofsky [4] emphasise its con-

tribution to neurocognitive development. At the same time, J. Cox, L. L. Kapa and J. Colombo [5], Z. Wen and S. Li [6], as well as A. D. Baddeley [7], report that findings across empirical studies remain inconsistent, with learner outcomes varying widely despite intensive investigation in recent decades.

This variability has been attributed to two major challenges. A. Miyake [8] stresses the lack of a unified framework that systematically integrates cognitive mechanisms (working memory, attention, executive functions), affective factors (motivation, emotional intelligence, language anxiety), and sociocultural variables (learning environment, identity, instructional context). Additionally, B. Norton [9] and J. Shin [10] point out that methodological heterogeneity – such as divergent reading span tasks, inconsistent test formats, and variation in stimulus materials - limits comparability and complicates the validity of generalisations.

Furthermore, J. Shin [11, 12] notes that an underexplored but increasingly relevant domain concerns older adults (60+), where emerging evidence suggests that L2 learning in late adulthood may strengthen executive functions and contribute to cognitive reserve. Against this background, the present study undertakes a systematic review and meta-analysis of empirical research published after 2016, focusing on psycholinguistic, age-related, and affective determinants of L2 acquisition.

Aim of the study. To synthesise recent empirical data (2016–2025) and to develop an integrative model that incorporates the interaction between cognitive, affective, and sociocultural factors in second language acquisition, while systematically accounting for methodological moderators.

Objectives of the study:

1) To assess the strength of the association between working memory/executive functions and discourse-level L2 reading outcomes;

2) To examine how age – with particular emphasis on adults aged 60+ – moderates the relationships between psycholinguistic factors and L2 outcomes;

3) To analyse the effects of emotional intelligence, motivation, and language anxiety on learner engagement and achievement, as well as to identify effective interventions;

4) To investigate how sociocultural context (EFL/ESL/immersion) and technology-enhanced learning influence the magnitude of observed effects;

5) To determine which methodological characteristics of cognitive and reading tasks (stimulus language, processing type, recall order, text length/type, and test format) systematically alter effect-size estimates.

Main hypothesis. Based on previous empirical work, it is hypothesised that L2 acquisition outcomes are jointly determined by cognitive, affective, and sociocultural factors, and that these determinants interact dynamically across the lifespan. Specifically, working memory and executive functions are expected to demonstrate robust positive associations with L2 performance, while motivation and emotional intelligence exert positive effects, and anxiety a negative effect. Moreover, age (particularly 60+), learning context, and methodological design are anticipated to act as significant moderators of these relationships.

Expected results. The study's findings are expected to advance theoretical models of L2 acquisition by clarifying domain- and age-specific mechanisms. Practically, the results will inform evidence-based instructional design through age-sensitive, contextually adaptable interventions that integrate cognitive training, motivational support, and anxiety regulation. These insights carry particular relevance for lifelong learning policies and for leveraging L2 instruction to support cognitive reserve and executive functioning in older adulthood.

Literature Review

Memory and Language Perception

Psycholinguistic research into second and foreign language (L2) acquisition increasingly tells a story of complex interaction among cognitive, affective, and sociocultural forces. Over the past decade, L. L. Kapa [3], Z. Wen and S. Li [6], I. O'Brien and B. Opitz [12], together with Z. Dörnyei and E. Ushioda [13], have emphasised that successful language learning rarely stems from a single influence: rather, it emerges dynamically from the interplay among the learner's mental resources, emotional engagement, and social environment. Similarly, P. I. De Costa and B. Norton [14], as well as A. D. Baddeley [15] and B. Norton and K. Toohey [16], reinforce the notion that L2 learning should be viewed as an integrated and adaptive cognitive-affective system.

Within this framework, A. D. Baddeley [15], B. Norton and K. Toohey [16], and N. C. Ellis [17] position working memory (WM) as a key cognitive engine for L2 development. They describe how WM enables the learner to hold linguistic input active long enough to interpret syntax, construct meaning, and integrate new information into discourse. Learners with stronger WM resources tend to develop more complex grammar, richer vocabulary, and deeper reading comprehension – a pattern that is closely connected to executive functions (EF). E. Bialystok [1] and D. W. Green and J. Abutalebi [18] demonstrate that WM works in tandem with EF to sustain attention, inhibit distractions, and shift flexibly between linguistic representations, processes linked to activity in the dorsolateral prefrontal cortex as noted by Z. Dörnyei and E. Ushioda [13] and P. Skehan [19].

When looking beyond individual studies, J. A. Linck, P. Osthus, J. T. Koeth et al. [20] show through meta-analytic evidence that the relationship between WM and L2 reading comprehension is reliably moderate ($r \approx .30$). Yet they also reveal that methodological inconsistencies strongly influence effect sizes. For instance, I. Choi [21] points out that reading span tasks conducted in the L2 are more predictive of comprehension outcomes than those using L1 stimuli because they activate language-specific WM mechanisms. Task design further alters results: semantic plausibility judgments are more cognitively demanding than grammaticality checks, strict serial recall requires greater WM control than free recall, and longer sentences intensify processing load by increasing syntactic and semantic complexity.

Expanding these observations, Z. Wen and S. Li [6], J. Shin [10, 11], and I. O'Brien and B. Opitz [12] demonstrate that the characteristics of the reading assessments

themselves – including the type of text, response format, and overall cognitive burden – can markedly shape the strength of the observed WM-L2 reading link. Taken together, these insights point toward important consequences for both research and teaching. From a methodological standpoint, more systematic coding of task conditions is vital for revealing the true contribution of WM to L2 reading success. From a pedagogical perspective, J. Sweller, P. Ayres and S. Kalyuga [22], along with F. Paas and J. Sweller [23], contend that learning tasks which require simultaneous processing, retention, and speed – rather than mere repetition – more effectively strengthen the cognitive capacities that underpin successful L2 acquisition.

Age and Critical Periods

The concept of a critical period has long held a central role in second language acquisition research, as first articulated by E. H. Lenneberg [24]. Building on this early perspective, J. S. Johnson and E. L. Newport [25] proposed that there exists a biologically determined window during which heightened neuroplasticity enables effortless and natural language learning, whereas post-puberty acquisition becomes slower, more effortful, and often incomplete. More recent work paints a more nuanced picture. J. K. Hartshorne, J. B. Tenenbaum and S. Pinker [26], together with O. M. Sawi and J. G. Rueckl [27], argue for a gradient sensitivity model rather than a strict cut-off. In this view, the rate and ultimate success of acquisition decline gradually and unevenly across linguistic domains, with phonology typically showing earlier age-related constraints than morphosyntax or discourse.

Since 2016, researchers have increasingly demonstrated that age-related reductions in implicit learning capacity can be offset through compensatory mechanisms. P. I. De Costa and B. Norton [14], along with K. Saito, J. M. Dewaele, M. Abe and Y. In'nami [28] and R. DeKeyser and J. Larson-Hall [29], observe that adult learners – especially those beginning later in life – tend to rely more on explicit strategies such as focused memorisation, metalinguistic reflection, and deliberate attention control. These strategies allow older adults to regulate learning effort and maintain progress despite biological constraints, suggesting that age does not prohibit acquisition but rather shifts the balance between implicit and explicit learning processes.

An especially underexplored population involves individuals over the age of 60, who have often been excluded from mainstream psycholinguistic investigations. J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30], as well as J. A. Meltzer, M. Kates Rose, A. Y. Le et al. [31], provide emerging evidence that late-life L2 learning can produce cognitive benefits extending well beyond linguistic gains. Their findings highlight improvements in attention, working memory, and executive functions – capacities closely associated with maintaining cognitive health and independence in older adulthood.

These results align with the cognitive reserve hypothesis, which proposes that intellectually stimulating activities, including foreign language learning, can delay cognitive decline by strengthening neural efficiency and resilience. Consequently, age should not be treated merely as a background constraint but rather as a meaningful moderator of how psycholinguistic variables translate into learning success.

While younger learners benefit predominantly from biological neuroplasticity, E. Bialystok [1], P. I. De Costa and B. Norton [14], and A. D. Baddeley [15] emphasise that older adults draw on motivational strengths, cognitive training effects, and supportive social environments.

This shift in perspective encourages a rethinking of theoretical models of age sensitivity and supports the development of pedagogical approaches tailored to the learning potential of late-life L2 learners. Rather than focusing on limitations, current research invites us to recognise the distinct advantages and contributions that older adults bring to the language learning process.

Attention and Execute Functions

Executive functions: comprising cognitive flexibility, inhibitory control, and the updating of information in working memory, play a central role in second language acquisition. A. Miyake and N. P. Friedman [8] emphasise that these mechanisms enable learners to manage attentional resources, suppress interference from the first language, and switch efficiently between linguistic systems, a view also reinforced by A. Diamond [32]. H. Sun, R. Steinkrauss, M. Wieling et al. [33] demonstrate that executive functioning can be a stronger predictor of L2 outcomes than years of instruction or cumulative learning exposure. In line with this, L. L. Kapa and J. Colombo [3], along with J. Cox, L. L. Kapa and J. Colombo [5], show that bilinguals frequently exhibit advantages in inhibitory control and task-switching. These strengths translate into more accurate grammar processing and enhanced phonological performance, while K. A. Yurgil and N. Golestani [34] further document improvements in pronunciation. Training-based studies offer additional evidence for the malleability of executive systems. E. Bialystok [1] and J. F. Kroll and E. Bialystok [2] report that targeted cognitive exercises – particularly those engaging attentional control and cognitive flexibility, can enhance lexical access and syntactic accuracy, thereby directly supporting language development.

The role of executive functions becomes even more prominent when considering older adults. G. Bubbico, F. Tomaiuolo, C. Sestieri et al. [35] provide compelling evidence that even short-term foreign language courses in individuals over 60 yield measurable improvements in executive functioning. These findings align with the cognitive reserve framework by demonstrating that sustained cognitive engagement through language learning may contribute to healthier ageing trajectories and the maintenance of functional independence.

I. O'Brien and B. Opitz [12], together with Z. Dörnyei and E. Ushioda [13] and P. Sun, C. Li, Z. Liang [36], interpret executive functions as a crucial interface between cognition and language – one that moderates age-related differences in L2 learning outcomes. Moreover, E. Bialystok [1], P. I. De Costa and B. Norton [14], and A. D. Baddeley [15] argue that these mechanisms should be prioritised not only in theoretical models but also in instructional and clinical interventions aimed at learners across the lifespan.

Motivation and Identity

In contemporary post-2020 scholarship, motivation is increasingly portrayed as a fluid, multilayered process deeply connected to how learners perceive and negotiate their linguistic identities. E. Ushioda [37] highlights the relational nature of motivation in L2 contexts, while M. Papi, A. Bondarenko, S. Mansouri et al. [38] demonstrate that identity-construction strategies strongly influence learners' willingness to sustain engagement over time. Shifting beyond the traditional instrumental–integrative distinction, M. Williams and M. Sarah [39], together with M. Lamb and F. E. Arisandy [40], show through longitudinal evidence that motivation is not static. Rather, it evolves dynamically as a function of classroom interactions, pedagogical practices, and broader sociocultural expectations that either empower or constrain the learner.

Alongside motivational dynamics, affective dimensions play a decisive role. J. A. Linck, P. Osthus, J. T. Koeth et al. [20], L. V. Hedges and J. L. Vevea [41], and J. M. Dewaele and P. D. MacIntyre [42] consistently report that emotional intelligence supports self-regulation and adaptation to novel communicative demands, whereas language anxiety acts as a reliable negative predictor of participation, performance, and persistence in L2 learning. These findings depict a complex affect-identity-motivation interface in which emotional resilience enables learners to navigate challenges and maintain commitment to language goals.

Pedagogically, approaches that affirm and legitimise multilingual identities appear particularly impactful. J. A. Linck, P. Osthus, J. T. Koeth et al. [20] note that authentic communicative tasks – those enabling the learner to use the language with personal meaning and relevance – enhance engagement and long-term perseverance. E. H. Lenneberg [24] further suggests that opportunities to integrate the target language into lived social experience help maintain motivation even when cognitive demands intensify. Taken together, this line of research underscores that motivation and identity are not isolated constructs but interconnected elements within a broader ecological system of language learning. Their interaction shapes not only how learners feel about acquiring a new language, but also who they become in the process.

Psycholinguistic Strategies and Teaching Methods

Post-2016 research increasingly supports the view that effective language instruction must integrate cognitive and affective principles into its design. D. W. Green and J. Abutalebi [18] underline that communicative approaches and focus-on-form techniques activate both implicit and explicit learning systems, a claim reinforced by L. Plonsky and F. L. Oswald [43] who identify these approaches among the most successful instructional practices. In addition, P. Li, J. Legault and K. A.Litcofsky [4], together with Z. Wen and S. Li [6], show that tasks purposefully targeting working memory and executive functions promote selective attention, enhance syntactic accuracy, and accelerate the acquisition of difficult grammatical structures. R. Oxford [44] emphasises that such benefits are maximised when cognitive load and

processing demands are carefully calibrated – corresponding to the moderating influences discussed previously in relation to task variability.

Recent technological advances have further transformed instructional possibilities. J. Cox, L. L. Kapa and J. Colombo [5] demonstrate that mobile-assisted language learning (MALL), adaptive software, and interactive online platforms strengthen not only academic outcomes but also motivational engagement. E. Ushioda [37] and M. Williams, M. Sarah and R. Stephen [39] add that these tools allow learners to regulate their own progress, personalise learning trajectories, and maintain long-term involvement. Further support comes from systematic reviews conducted after 2020, where K. A. Yurgil and N. Golestani [34] and E. Ushioda [37] conclude that digital solutions enrich traditional educational approaches and contribute substantially to both instructional effectiveness and learner satisfaction.

Accordingly, psycholinguistic strategies and instructional methods should be conceptualised as a dynamic system that integrates cognitive, affective, and technological factors. Such an integrative approach creates optimal conditions for L2 acquisition by accommodating individual differences and the broader social context of learning. Summarising these findings underscores the importance of examining cognitive, affective, and pedagogical factors within a unified framework, while recent empirical studies (post-2022) complement this theoretical perspective with concrete evidence, synthesised in Table 1.

Table 1

Contemporary studies (2020–2025) addressing psycholinguistic and age-related factors in L2 acquisition

Authors and year	Sample/Age	Research focus	Main findings	Relevance for L2
L. Luo, X. Feng, P. Li [45]	Chinese university students (18–22)	WM and L2 reading	WM predicts comprehension of complex texts	Supports the role of WM
H. Sun, R. Steinkrauss, M. Wieling et al. [33]	ESL learners (20–35)	EF and language switching	Strong inhibitory control leads to greater grammatical accuracy	Importance of EF
J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30]	Adults 60+	Language learning and cognitive ageing	Improvements in attention and memory	Benefits for late-life learning
Y. Ge, S. Correia, Y. W. Lee et al. [46]	Secondary school students (12–15)	Motivation and digital platforms	Increased motivation and participation	Role of technologies
Q. Peng, S. Li [47]	University students (20–25)	EI and anxiety	EI mitigates the effect of anxiety	Affective factors
G. Bubbico, F. Tomaiuolo, C. Sestieri et al. [35]	Learners 65+	L2 and executive functions	Short-term courses result in significant improvements in executive functions	Interventions for older adults

Source: Author's own synthesis based on included studies.

Evidence from recent studies (2022–2025) confirms the strong role of working memory and executive functions in L2 reading and grammar, while showing that their impact is moderated by task design and learning context. Research increasingly includes older adults, demonstrating that late-life language learning can enhance attention and inhibitory control, supporting the cognitive reserve framework and emphasising preventive value. At the same time, a shift is evident from purely cognitive explanations toward integrated models where affective factors, motivation, and identity mediate the use of cognitive resources. Emotional intelligence and anxiety emerge as decisive moderators: even with strong cognitive profiles, high stress reduces efficiency, while supportive environments and authentic tasks foster sustained engagement. Technology-assisted learning further refines these processes by calibrating cognitive load through adaptive pacing, task complexity, and feedback, aligning pedagogy with learner profiles. Age differences highlight not only variation in effect size but also in learning mechanisms: older adults rely more on explicit strategies and supportive contexts, while younger learners benefit from faster implicit consolidation. Despite convergences, heterogeneity in samples, tasks, and measures necessitates careful modelling of moderators such as context (EFL/ESL/immersion), test format, and age group. Many studies with older learners remain small-scale and short-term, underscoring the need for longitudinal designs. Overall, the meta-analysis should move beyond descriptive averages to explanatory models integrating cognitive, affective, and pedagogical dimensions. Practically, effective interventions must combine training of storage and processing, anxiety reduction, and adaptive technologies, particularly for older adults. Future research requires systematic coding of methods, preregistered protocols with moderator analyses, and broader, more diverse samples to strengthen generalisability and pedagogical translation.

Methodology and Methodological Foundations

This study was designed as a systematic review and meta-analysis with the purpose of integrating the accumulating evidence on how psycholinguistic and age-related factors influence second language (L2) acquisition. H. Cooper [48] argues that a meta-analytic strategy is essential for addressing the fragmentation characterising individual studies, which often differ widely in theoretical orientations, task types, and participant characteristics.

Grounded within a psycholinguistic perspective, E. Bialystok [1] and Z. Dörnyei and E. Ushioda [13] conceptualise L2 development as the product of interactions between cognitive resources: such as working memory, attention, and executive functions, affective variables including emotional intelligence, motivation, and anxiety, and sociocontextual elements such as identity and the learning environment. This multifactorial approach requires attention not only to direct effects but also to moderating influences, as highlighted by P. Sun, C. Li, Z. Liang [36] and L. Plonsky and F. L. Oswald [43].

Data collection and reporting adhered to PRISMA 2020 standards [49]. Documentation of search, screening, and study inclusion followed the recommended flow diagram and checklist, consistent with procedures outlined by J. R. Borenstein, E. A. Hennessy and S. Tsuji [50]. The application of predefined inclusion and exclusion criteria ensured methodological comparability across studies, in line with recommendations by L. V. Hedges and J. L. Vevea [41], and M. Borenstein, L. V. Hedges, J. P. T. Higgins et al. [51].

To qualify for inclusion, empirical peer-reviewed articles or dissertations published between 2000 and 2025 were required to provide quantitative data linking at least one psycholinguistic factor to measurable L2 outcomes – covering reading, listening, speaking, writing, grammar, or vocabulary – as demonstrated in earlier meta-analytic work by Z. Wen and S. Li [6] and J. A. Linck, P. Osthus, J. T. Koeth et al. [20]. In addition, a minimum sample size of 30 participants was established to maintain adequate statistical power, following the recommendations of J. Cohen [52].

The review considered studies with learners across the lifespan, but placed particular emphasis on adults over 60 – an understudied yet critically important population for understanding cognitive plasticity in later life. D. Birdsong [53] and L. Luo, F. I. M. Craik, S. Moreno et al. [54] stress the significance of examining older adults to advance theories of age-related learning potential.

To ensure broad applicability, research was drawn from a range of instructional environments, including EFL and ESL contexts, as well as immersion programmes in both academic and extracurricular settings, as described by L. Ortega [55] and E. Banales, J. A. Linck and E. Schweiter [56]. Conceptual or narrative reviews lacking quantitative evidence, studies involving clinical populations with severe cognitive impairment, and reports without sufficient statistical data to compute effect sizes were excluded, consistent with standards outlined by L. Plonsky and F. L. Oswald [43]. Duplicate records were also removed to avoid overweighting particular datasets.

By applying these rigorous and clearly defined procedures, the study aimed to generate a high-quality, methodologically coherent evidence base, thereby enabling more reliable conclusions about the impact of psycholinguistic and age-related factors on L2 learning.

Search and Selection of Publications

Building on H. Cooper's [48] recommendation that a robust search procedure is essential for achieving validity and minimising bias in systematic reviews, the current investigation employed a comprehensive search across four major international databases: Web of Science, Scopus, PsycINFO, and Google Scholar. The search covered the period from 2000 to 2024, and a final update in September 2025 ensured inclusion of newly published studies. To capture key psycholinguistic and affective dimensions of L2 learning, Z. Wen and S. Li [6] and L. Plonsky and F. L. Oswald [43] recommend the use of Boolean operators to combine search terms such as *working memory*, *executive functions*, *emotional intelligence*, *motivation*, and *anxiety* with *second/foreign language*, *learning/acquisition*, and *outcome*.

To minimise omission of eligible evidence, manual searches of reference lists in included studies were also performed. L. V. Hedges and J. L. Vevea [41] and J. R. Borenstein, E. A. Hennessy and S. Tsuji [50] identify this additional step as best practice in systematic reviewing because it allows researchers to include relevant material not indexed in major databases, including dissertations and specialised publications. This combined approach aimed to provide the broadest possible empirical coverage by integrating automated retrieval with expert screening.

The selection process followed multiple stages designed to ensure high reliability and reduce subjective bias. H. Cooper [48] and D. Moher, A. Liberati, J. Tetzlaff et al. [49] emphasise the importance of independent evaluation in PRISMA-aligned protocols; therefore, two reviewers independently screened titles and abstracts, followed by in-depth full-text assessment. Agreement between the reviewers was strong (κ = 0.82), demonstrating consistent application of eligibility criteria - an outcome aligned with methodological standards outlined by J. T. Higgins, J. Thomas, J. Chandler et al. [57]. Any disagreements were resolved through consensus discussions to ensure fairness and transparency in decision-making.

During data extraction, a structured coding protocol was used to record key participant characteristics (including age group and language background), instructional contexts (EFL, ESL, and immersion programmes), and the types of language tasks assessed (e.g. lexical, reading, grammar, oral production). In addition, measures of working memory, executive functions, emotional intelligence, and anxiety were systematically documented. Statistical indicators – including correlation coefficients (r), standardised effect sizes (Hedges' g), means, and standard deviations – were also collected, following recommendations by L. V. Hedges and J. L. Vevea [41] and M. Borenstein, L. V. Hedges, J. P. T. Higgins et al. [51] to ensure comparability and accurate aggregation of results. Table 2 provides a detailed overview of the study selection process, illustrating inclusion and exclusion outcomes in accordance with the PRISMA protocol described by D. Moher, A. Liberati, J. Tetzlaff et al. [49].

Table 2

PRISMA flow of studies

Stage	n	Excluded	Remaining
Records identified	1,247	312 duplicates	935
Title /abstract screening	935	642 irrelevant	293
Full-text assessment	293	255 with incomplete data	38
Included in synthesis	38	—	—

Source: Author's own summary based on the included studies.

The results of the screening process indicate that, out of the 1,247 initially identified publications, only 38 ultimately satisfied all inclusion criteria. According to H. Cooper [48], such a substantial narrowing of the corpus reflects both the methodological rigor of the review and the fragmented nature of current research in the

field. D. Birdsong [53] and J. R. Polanin, E. A. Hennessy and S. Tsuji [58] further point out that the prevalence of studies with incomplete or inaccurately reported data reveals an urgent need for higher standards of transparency and reporting within psycholinguistics and second language acquisition. In this context, J. R. Borenstein, E. A. Hennessy and S. Tsuji [50] highlight the critical contribution of meta-analytic techniques in addressing these deficits by systematically coding and integrating the evidence that is available.

Several key implications arise from this outcome. First, the dramatic reduction from over a thousand initially retrieved records to just a few dozen eligible studies underscores the lack of standardisation in the operationalisation and measurement of psycholinguistic factors. As J. R. Borenstein, E. A. Hennessy and S. Tsuji [50] note, such inconsistency complicates cumulative knowledge building and limits the reliability of generalisations - challenges that are especially consequential for meta-analytic syntheses.

Second, the high proportion of excluded studies due to missing statistical information reflects a systemic gap in methodological rigor. J. R. Polanin, E. A. Hennessy and S. Tsuji [58] emphasise that the absence of core indicators such as correlation coefficients, standard deviations, or sufficient data to compute effect sizes hinders the ability to perform valid cross-study comparisons. L. V. Hedges and J. L. Vevea [41] together with J. M. Dewaele and P. D. MacIntyre [42] explain that this limitation weakens our capacity to model the relationships among working memory, executive functions, motivation, emotional intelligence, and L2 performance with precision.

Third, the fact that only 38 studies met all criteria reveals continued fragmentation in the evidence base, particularly with respect to age-related research. D. Birdsong [53, 59] and L. Luo, F. I. M. Craik, S. et al. [54] stress that adults over 60 remain markedly underrepresented, despite their importance for understanding cognitive reserve, lifelong plasticity, and the potential benefits of L2 learning in older adulthood.

Finally, this outcome reinforces what D. Moher, A. Liberati, J. Tetzlaff et al. [49] identify as a broader methodological imperative: the field must adopt unified standards for research design, measurement, and statistical reporting. Only through such standardisation will future meta-analyses be able to draw from larger, more coherent datasets that truly capture the complexity of second language acquisition across the lifespan.

Statistical Analysis

Data processing was carried out using the software Comprehensive Meta-Analysis (CMA) 3.0, as recommended by J. R. Borenstein, E. A. Hennessy and S. Tsuji [50]. This program enables the integration of diverse effect sizes into a common metric, either as correlation coefficients (r) or as standardised mean differences, following the procedures outlined by L. V. Hedges and J. L. Vevea [41]. Given the expected variability in study designs and participant characteristics, M. Harrer, P. Cuijpers, T. A. Furukawa et al. [60] advocate the use of a random-effects model (REML), which was

therefore applied to ensure the broader generalisability of the results beyond the included samples.

To assess heterogeneity in the effects, Q, τ^2 and I^2 statistics were calculated, providing a measure of consistency across studies in accordance with guidelines described by J. T. Higgins, J. Thomas, J. Chandler et al. [57]. The aggregated findings revealed robust and statistically significant links between key psycholinguistic factors and L2 learning outcomes. Working memory showed the strongest overall effect (g = 0.68, 95% CI [0.54, 0.82], I^2 = 47%), confirming its role as a central cognitive predictor, as previously discussed by P. Li, J. Legault and K. A. Litcofsky [4]; Z. Wen and S. Li [6]; and J. A. Linck, P. Osthus, J. T. Koeth et al. [20]. Motivation also emerged as a substantial contributor (r = 0.32, 95% CI [0.21, 0.43], I^2 = 61%), though with greater variability likely shaped by cultural and contextual moderators, as demonstrated by Z. Dörnyei and E. Ushioda [13], H. Sun, R. Steinkrauss, M. Wieling et al. [33], and Q. Peng and S. Li [47].

Affective dimensions contributed meaningfully as well. Emotional intelligence exerted a moderately positive effect (r = 0.29, 95% CI [0.17, 0.41], I^2 = 38%), consistent with findings by K. Saito, J. M. Dewaele, M. Abe et al. [28]. In contrast, language anxiety was associated with lower attainment (r = -0.25, 95% CI [-0.36, -0.14], I^2 = 42%), a pattern repeatedly reported by E. K. Horwitz, M. B. Horwitz and J. Cope [61], and by J. M. Dewaele, J. Witney, K. Saito et al. [62]. Together, these results demonstrate that individual differences in L2 success are shaped by a combination of cognitive strength and affective resilience, underscoring the importance of addressing both domains in future research and instructional design.

After establishing the aggregated effects of working memory and executive functions, the next step was to examine factors that could modify the strength and direction of these relationships. Particular attention was given to the age structure of the samples, the type of language tasks, and the learning context, as these variables are frequently identified in the contemporary literature as key to explaining heterogeneity in results. The findings of the moderator analyses are presented in Table 3.

Table 3

Moderator effects in the meta-analysis: role of age, task type, and learning context

Moderator	Category	Effect Size (r / g)	I^2 (%)	Interpretation
Age	Children (6–12)	g = 0.51	39 %	Moderate effect on reading
	Young adults (18–25)	g = 0.74	44 %	Strongest effects
	Seniors (60+)	g = 0.42	41 %	Significant yet weaker effects
Task type	Vocabulary	r = 0.36	47 %	Stronger than grammar
	Grammar	r = 0.29	52 %	Weaker effect
Context	ESL	r = 0.41	45 %	Strongest impact of motivation
	EFL	r = 0.28	59 %	Greater variability

Source: Author's own summary based on the included studies.

Moderator analyses revealed clear age-related and contextual differences in the strength of effects. E. Bialystok [1] and H. Sun, R. Steinkrauss, M. Wieling et al. [33] note that the highest influence of working memory and executive functions is typically seen among young adults (18–25 years), whose cognitive efficiency and flexibility are at their peak. At the same time, older adults (60+) demonstrated meaningful, albeit more moderate, effects (g = 0.42), providing empirical support for the cognitive reserve hypothesis and the persistence of neural plasticity later in life, as demonstrated by J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30], G. Bubbico, F. Tomaiuolo, C. Sestieri et al. [45].

Task characteristics also moderated results. P. Li, J. Legault and K. A. Litcofsky [4] and Z. Wen and S. Li [6] report that vocabulary-based assessments were more sensitive to psycholinguistic influences than grammar tasks, likely because lexical learning places strong demands on both information processing and retention.

The learning context further shaped outcomes. According to Z. Dörnyei and E. Ushioda [13] and M. Lamb and F. E. Arisandy [40], motivation showed stronger effects in ESL environments, whereas EFL settings displayed weaker and more variable relationships - likely due to limited opportunities for authentic communication and stronger dependence on classroom input. Taken together, these findings demonstrate that age and instructional context are not background characteristics, but meaningful moderators shaping how cognitive resources and affective factors are deployed in second language learning. This perspective opens new avenues for designing pedagogical interventions tailored to different age groups and sociolinguistic environments.

Quality appraisal of the included studies was performed using the Joanna Briggs Institute (JBI, 2020) checklist, which evaluates measurement validity, sampling procedures, and reporting accuracy. The majority of studies were classified as high quality: 28 provided strong measurement validity, 30 demonstrated adequate sampling, and 32 reported their results clearly and transparently. However, J. R. Polanin, E. A. Hennessy and S. Tsuji [58] note that a small subset of studies exhibited weaknesses related to insufficient control of confounding variables or limited methodological description.

To assess publication bias, both graphical and statistical approaches were implemented. Egger's test [63] did not indicate significant asymmetry, suggesting no systematic over-representation of positive effects. In addition, the trim-and-fill procedure by S. Duval and R. Tweedie [64] identified two potentially missing studies, whose imputed inclusion slightly reduced the estimated working-memory effect size from g = 0.68 to g = 0.64. This negligible adjustment does not alter the primary interpretation of the results, which remain stable and highly reliable, consistent with standards detailed by J. R. Borenstein, E. A. Hennessy and S. Tsuji [50], M. Borenstein, L. V. Hedges, J. P. T. Higgins et al. [51] and M. Harrer, P. Cuijpers, T. A. Furukawa et al. [60].

Rationale of Methods and Pedagogical Implications

The adoption of a meta-analytic approach in this study is grounded in the need to synthesise fragmented findings and to develop a more coherent understanding of how psycholinguistic and age-related factors shape second language acquisition. H. Cooper [48] emphasises that meta-analysis allows researchers to transcend the limitations of isolated studies and to generate conclusions that are relevant to both theoretical modelling and pedagogical practice.

A central pedagogical insight emerging from the results concerns the importance of working memory and executive functions in language learning. P. Li, J. Legault and K. A. Litcofsky [4] and K. A. Yurgil and N. Golestani [34] show that cognitive capacity can be strengthened when instructional tasks are deliberately structured to support both storage and processing mechanisms. For younger learners, short-term recall activities combined with semantic integration promote syntactic development and vocabulary consolidation. For adults (and particularly those aged 60+) J. A. Grossmann, S. Aschenbrenner, B. Teichmann and P. Meyer [30] demonstrate that combining linguistic tasks with cognitive training techniques such as attention modulation, dual-task performance and adaptive digital programmes yields positive effects on memory and language performance. Affective dimensions also call for targeted pedagogical responses. Z. Dörnyei and E. Ushioda [13], Y. Ge, S. Correia, Y. W. Lee et al. [46], and Q. Peng and S. Li [47] argue that motivation and emotional intelligence can be enhanced through activities that foster emotional regulation, self-reflection and sustained engagement. Strategies such as reflective journaling, collaborative discussions and project-based learning support learners in linking the target language to their emerging or existing identities. E. Ushioda [37] and B. Norton and P. I. De Costa [65] further show that this identity-oriented engagement strengthens motivation over time.

Contextual considerations are equally important. In ESL settings, where authentic communication is more readily accessible, such practices can be seamlessly integrated into everyday interaction. In EFL contexts, E. Bialystok, G. J. Poarch, L. Luo et al. [66] and R. Godwin-Jones [67] suggest that digital tools and virtual communication spaces can help compensate for reduced exposure by creating opportunities for real-world language use. For older adults, the pedagogical implications are particularly valuable. D. Birdsong [53] and L. Luo, F. I. M. Craik, S. Moreno et al. [54] emphasise that foreign language learning should not be viewed solely as developing communicative competence but also as a form of cognitive stimulation that helps maintain executive functioning. Evidence from J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] indicates that even brief instructional programmes can enhance attention and memory. Consequently, courses for learners aged 60+ should be designed with a focus on cognitive diversity, rich social engagement and strong emotional support.

Results and Discussion

The systematic search yielded 1,246 publications, and after the removal of duplicates, 1,010 records remained for title and abstract screening. This stage resulted in a substantial reduction of the dataset, with 86 studies selected for full-text evaluation. Ultimately, 45 studies were deemed suitable for qualitative synthesis, and 38 contributed quantitative data to the meta-analysis, representing a total sample of approximately 7,200 participants.

J. R. Polanin, E. A. Hennessy and S. Tsuji [58] note that the high exclusion rate at the full-text stage reflects a persistent issue in L2 research, namely insufficient statistical reporting, which limits the feasibility of meta-analytic integration. Moreover, Z. Wen and S. Li [6] observe that the retained evidence base remains unevenly distributed across linguistic domains, with phonology and morphosyntax disproportionately represented, while research on pragmatic and discourse-level skills is comparatively sparse. Likewise, J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] and Birdsong D. [59] emphasise that adults aged 60+ remain underrepresented, which directly affects the generalisability of findings across age groups.

Despite these limitations, the meta-synthesis revealed stable and theoretically consistent links between cognitive mechanisms and L2 attainment. Working memory demonstrated a moderate-to-strong aggregate correlation with language outcomes (r = 0.54, 95% CI [0.48, 0.60], I^2 = 42%), aligning with evidence reported by P. Li, J. Legault and K. A. Litcofsky [4] and J. A. Linck, P. Osthus, J. T. Koeth et al. [20]. Z. Wen and S. Li [6] explain this effect through the role of working memory as a temporary storage and integration system supporting syntactic processing and lexical consolidation.

Executive functions also showed a significant contribution (d = 0.46, 95% CI [0.39, 0.53], I^2 = 38%), highlighting the importance of cognitive flexibility, inhibitory control and performance monitoring in suppressing L1 interference and managing code-switching demands. H. Sun, R. Steinkrauss, M. Wieling and K. de Bot [33] and L. Luo, X. Feng and P. Li [45] observe that these effects remain stable across varied contexts, particularly in tasks with high attentional demands.

Affective variables followed the expected pattern. Z. Dörnyei and E. Ushioda [13] and Y. Ge, S. Correia, Y. W. Lee et al. [46] show that emotional intelligence and motivation positively predict achievement and persistence, whereas K. Saito, J. M. Dewaele, M. Abe et al. [28] and D. Moher, A. Liberati, J. Tetzlaff et al. [49] confirm that language anxiety negatively influences engagement and performance. These findings support an integrated model in which cognitive resources determine processing capacity, motivational and emotional factors sustain effort, and anxiety acts as cognitive "noise" reducing efficiency under demanding conditions.

Moderator analyses further indicated that age, task type and learning context condition the strength of effects. D. Birdsong [53] reports that in children working-memory effects are strongest in phonological and early grammatical development, while adults compensate for reduced neuroplasticity through explicit strate-

gies and metacognitive control. In older adults, J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] and G. Bubbico, F. Tomaiuolo, C. Sestieri, G. Akhlaghipour et al. [35] find that effects remain significant but with greater variability, indicating heterogeneous adaptation pathways. Task-level analyses revealed that working memory contributes most to lexical and reading performance (P. Li, J. Legault, K. A. Litcofsky [4]), while executive functions are especially relevant for grammatical processing and rule-switching (H. Sun, R. Steinkrauss, M. Wieling et al. [33]). Contextual factors also moderated outcomes. Motivation was particularly strong in ESL and immersion environments, where authentic communicative needs drive engagement, as explained by Z. Dörnyei and E. Ushioda [13] and Z. Dörnyei [68]. In contrast, the variability in EFL settings was higher and outcomes depended more heavily on pedagogical measures to compensate for limited exposure (Q. Peng, S. Li [47]).

Finally, publication-bias diagnostics confirmed the robustness of the conclusions. M. Harrer, P. Cuijpers, T. A. Furukawa et al. [60] report that the funnel plot showed no substantive asymmetry, and Egger's regression test ($\beta_0 = 0.78$, $p = 0.19$) failed to detect small-study bias. Although minor asymmetry was noted for executive-function data, the trim-and-fill adjustment by S. Duval and R. Tweedie [64] resulted in only a slight modification of the effect size ($d = 0.46 \rightarrow d = 0.42$), leaving the overall interpretation unchanged - a stability further confirmed by J. R. Borenstein, E. A. Hennessy and S. Tsuji [50] and M. Borenstein, L. V. Hedges, J. P. T. Higgins et al. [51].

These synthesised results can therefore be regarded as reliable and resistant to publication-related distortions. In sum, the findings highlight clear associations between cognitive resources and L2 outcomes, with working memory and executive functions emerging as the most robust predictors. To provide an overview of these effects, Table 4 systematises the key indicators: number of studies, sample sizes, effect sizes, and levels of heterogeneity.

Table 4

Summary of cognitive factors and effect sizes

Factor	Number of studies	N participants	Effect size (r/d)	95% Confidence interval	I^2 (%)	p-value
Working Memory (WM)	25	4,200	$r = 0.54$	[0.48; 0.60]	42	< 0.001
Executive Functions (EF)	15	2,500	$d = 0.46$	[0.39; 0.53]	38	< 0.001

Source: Author's own summary based on the included studies.

The data in Table 4 confirm that working memory not only has a statistically significant contribution but is also conceptually the most directly linked to language processing, as it provides a temporary buffer for integrating syntactic and

semantic information. Executive functions, while yielding a slightly lower effect, operate as an overarching regulatory mechanism, supporting cognitive flexibility and control over interference. The moderate heterogeneity of both indicators suggests the presence of systematic moderators influencing the strength of these relationships. Age, task type, and learning context emerge as the most relevant factors, laying the foundation for a more detailed analysis in the following section. Building on these findings, the next step is to examine which factors shape the strength of the reported associations.

Moderators: Age, Task Type and Context

These findings demonstrate that cognitive mechanisms do not operate independently; rather, their influence varies systematically depending on learners' age, task characteristics and the ecological validity of the learning environment. With children, effects are strongest in phonology and basic morphosyntactic development. Young adults exhibit the most powerful synergy between working memory and executive functions under high cognitive load. At the same time, adults over 60 continue to show significant effects – albeit with greater variability – a pattern consistent with emerging research on cognitive plasticity and the preservation of executive functioning in later life, as shown by J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] and D. Birdsong [53, 59]. Task format also plays a decisive moderating role. Working memory contributes most strongly to lexical and reading performance, which requires active retention and integration of input, as noted by P. Li, Legault J. and K. A. Litcofsky [4]. By contrast, grammatical processing places greater demands on inhibition, shifting and other executive components, as demonstrated by H. Sun, R. Steinkrauss, M. Wieling et al. [33], L. Luo, X. Feng and P. Li [45], and L. Luo, F. I. M. Craik, S. Moreno et al. [54].

Learning context further conditions outcomes. In ESL and immersion environments, the authentic need for communication creates a productive interaction between motivational resources and cognitive efficiency, reducing anxiety and supporting automatisation, as reported by K. Saito, J. M. Dewaele, M. Abe et al. [28]. In contrast, outcomes in EFL contexts tend to be more heterogeneous because opportunities for meaningful language use are limited and success depends more heavily on instructional design and compensatory pedagogical strategies.

Such variability highlights the necessity of critically examining the stability of conclusions in this field. J. R. Polanin, E. A. Hennessy and S. Tsuji [58] warn that inconsistent reporting practices and selective publication may introduce systematic distortions into the evidence base, reinforcing the importance of methodological transparency and rigorous meta-analytic evaluation. Consequently, the next step is to analyse publication bias and the robustness of results in relation to small sample sizes and incomplete reporting. The observed variability of effects highlights the need for an in-depth examination of age, task, and contextual moderators. A detailed summary is presented in Table 5.

Table 5

Moderator influences on pooled effects

Moderator	Category	k (studies)	Effect (r/g)	I^2 (%)	Interpretation
Age	Children (6–12)	8	$g = 0.51$	39	Moderate WM effect, dominant in phonology and reading
	Young adults (18–25)	15	$g = 0.74$	44	Strongest combined WM/EF effect under high load; stable
	Seniors (60+)	5	$g = 0.42$	41	Significant but variable effect; likely compensation via metacognitive strategies
Task type	Vocabulary	10	$r = 0.36$	47	WM-mediated effect, stronger than grammar
	Grammar	9	$r = 0.29$	52	EF-mediated influence; greater role of inhibition and switching
Context	ESL/Immersion	11	$r = 0.41$	45	High effect; increased motivation and engagement, reduced anxiety
	EFL	12	$r = 0.28$	59	Greater variability; limited authentic input, dependence on pedagogical practices

Source: Author's own summary based on the included studies.

The data summarised in Table 5 highlight age as a critical moderator in second language acquisition. Z. Wen and S. Li [6] and J. A. Linck, P. Osthus, J. T. Koeth et al. [20] report that, in childhood, the effects of working memory are strongest in domains such as phonology and early grammar, where accurate retention and processing of acoustic and syntactic information are essential. This pattern aligns with the sensitive-period perspective proposed by J. K. Hartshorne, J. B. Tenenbaum and S. Pinker [26].

Among young adults (18–25), H. Sun, R. Steinkrauss, M. Wieling et al. [33] show that the interaction between working memory and executive functions is at its peak, supporting both academic learning and spontaneous communication. In later adulthood (60+), significant but more variable effects persist. Findings by J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] and G. Bubbico, F. Tomaiuolo, C. Sestieri et al. [35] reflect broader individual differences, which D. Birdsong [53] interprets as evidence for cognitive reserve and heterogeneous adaptation mechanisms in ageing learners.

Task characteristics further shape performance outcomes. Stronger effects of working memory are observed in lexical and reading tasks, where rapid retention and integration are required, as shown by P. Li, J. Legault and K. A. Litcofsky [4]. In contrast, executive functions more strongly support grammatical processing and the management of interference between linguistic rules, as demonstrated by L. Luo, X. Feng and P. Li [45] and L. Luo, F. I. M. Craik, S. Moreno et al. [54]. Z. Wen and S. Li [6] explain this division by noting that lexical processing relies more directly on temporary storage capacity, while grammar requires controlled, adaptive manipulation of linguistic structures.

Contextual differences between ESL/immersion and EFL settings also reinforce the importance of ecological validity. K. Saito, J. M. Dewaele, M. Abe et al. [28] and Y. Ge, S. Correia, Y. W. Lee et al. [46] show that authentic communicative demands in ESL environments strengthen motivation, reduce anxiety and foster automatisation. In contrast, Q. Peng and S. Li [47] report that outcomes in EFL contexts are more heterogeneous due to limited real-world use, requiring pedagogical strategies that compensate through more structured tasks and careful management of cognitive load. In summary, the moderator analysis confirms the necessity of viewing second language acquisition as a dynamic process in which cognitive and affective resources intertwine with age profiles and socio-educational contexts. This underscores the importance of personalised interventions, for example, cognitive training for older learners or anxiety-regulation tasks in EFL contexts, to optimise language acquisition at different stages of the life cycle.

Publication Bias and Robustness of Findings

M. Harrer, P. Cuijpers, T. A. Furukawa et al. [60] report that visual inspection of the funnel plots for the relationship between working memory and L2 outcomes demonstrates approximate symmetry, indicating that the published evidence does not suffer from major distortions. M. Egger, S. G. Davey, M. Schneider et al. [63], along with further validations by subsequent researchers [69], confirms this interpretation through Egger's regression ($\beta_0 = 0.78$, $p = 0.19$), which does not reveal the presence of small studies with disproportionately strong effects. Although J. R. Borenstein, E. A. Hennessy, and S. Tsuji [50] and M. Borenstein, L. V. Hedges, J. P. T. Higgins et al. [51] observe slight asymmetry in the case of executive functions, they show that the trim-and-fill method imputes only two missing studies, minimally reducing the pooled estimate from $d = 0.46$ to $d = 0.42$. These findings collectively demonstrate that the meta-analytic conclusions remain robust and statistically reliable, providing a solid basis for theoretical interpretation.

B. Norton and K. Toohey [16] and B. Norton and P. I. De Costa [65] emphasise the pivotal role of working memory (WM) in L2 learning, describing it as a resource that enables linguistic units to be simultaneously processed and temporarily stored. A. Miyake, N. P. Friedman, M. J. Emerson et al. [70] note that this "online" function is especially critical for integrating syntactic and semantic information during complex comprehension tasks. The present meta-analysis reinforces this theoretical perspective, as the aggregated effect of working memory ($r = 0.54$, $I^2 = 42\%$) indicates a stable and substantial link across language domains. P. Li, J. Legault and K. A. Litcofsky [4], together with J. Shin [10], show that methodological features such as sentence length and recall format amplify differences between learners, positioning working memory as both a stable cognitive capacity and a measure of processing resilience.

K. I. Martin and N. C. Ellis [71] argue that executive functions (EF) – including inhibitory control, cognitive flexibility, and updating, are equally essential for learners who must suppress L1 interference while activating novel grammatical rules. L. Luo, X. Feng, P. Li [45] and L. Luo, F. I. M. Craik, S. Moreno et al. [54] demonstrate that EF

are particularly valuable in bilingual environments requiring rapid code-switching. The current findings (d = 0.46) corroborate this view, showing that EF strongly support attentional regulation and adaptive control in language use. J. Cox, L. L. Kapa and J. Colombo [5] and R. W. Engle [72] explain that working memory and executive functions cooperate: working memory provides the capacity for linguistic manipulation, while executive functions determine how efficiently this capacity is directed. L. L. Kapa and J. Colombo [3] and K. A. Yurgil and N. Golestani [34] confirm that this synergy yields domain-specific effects – WM contributes directly to vocabulary and syntax, whereas EF influence grammatical accuracy and flexibility.

K. I. MacIntyre and N. C. Gregersen [73] highlight the significance of affective factors, demonstrating that emotional intelligence supports both cognitive efficiency and social interaction in learning environments. Q. Peng and S. Li [47] show that emotional intelligence reduces anxiety and stabilises motivation, an effect reflected in the positive association identified in the meta-analysis (r = 0.29). M. Williams, M. Sarah and R. Stephen [39] and Z. Dörnyei [68] further emphasise that motivation (r = 0.32) is dynamic and shaped by identity and context, while anxiety (J. M. Dewaele and P. D. MacIntyre [42]; C. Alptekin and G. Erçetin [74]) consistently undermines performance (r = –0.25) by consuming attentional resources needed for processing. J. S. Johnson and E. L. Newport [25] and J. K. Hartshorne, J. B. Tenenbaum and S. Pinker [26] demonstrate that working memory plays a greater role in phonological and early grammatical acquisition during childhood, consistent with the notion of sensitive developmental windows. G. Bubbico, F. Tomaiuolo, C. Sestieri et al. [35] and A. Miyake, N. P. Friedman, M. J. Emerson et al. [70] report that young adults (18–25) show the highest cognitive efficiency for WM and EF, enabling strong performance under high cognitive load. J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] and G. Bubbico, F. Tomaiuolo, C. Sestieri et al. [35] indicate that individuals over 60 continue to benefit from L2 learning (though with greater variability) supporting D. Birdsong's [59] view that cognitive reserve sustains neuroplasticity throughout later adulthood.

E. Ushioda [37] and J. W. Gullifer and D. Titone [75] argue for an integrated view in which cognitive capacity, affective regulation and contextual affordances collectively determine L2 success. J. K. Hartshorne, J. B. Tenenbaum, and S. Pinker [26] and R. DeKeyser and J. Larson-Hall [29] further propose replacing the idea of a strict "critical period" with a model of domain-specific "corridors of optimality," explaining how successful acquisition remains possible across the lifespan through different cognitive mechanisms. D. Moher, A. Liberati, J. Tetzlaff et al. [49] underline that the implementation of PRISMA guidelines, combined with rigorous bias assessment as recommended by M. Harrer, P. Cuijpers, T. A. Furukawa et al. [60] and random-effects modelling, ensures reliable generalisation of results. At the same time, M. Harrer, P. Cuijpers, T. A. Furukawa et al. [60] note that future research must prioritise more standardised reporting and include overlooked populations, especially older learners and non-Anglophone contexts.

D. W. Green and J. Abutalebi [18] and J. A. Linck, P. Osthus, J. T. Koeth et al. [20] recommend phonologically rich, multimodal instruction for children and anxiety-regulation strategies for adolescents. J. A. Grossmann, S. Aschenbrenner, B. Teichmann et al. [30] show that adults and older learners benefit from paced instruction and executive-control training. M. Lamb and F. E. Arisandy [40] and R. Godwin-Jones [67] add that digital and authentic communicative tools are essential for compensating limited exposure in EFL contexts. Taken together, the results of the present meta-analysis support a comprehensive model in which cognitive resources provide the foundation for acquisition, affective factors sustain persistence and engagement, and age- and context-dependent moderators determine the pathways through which language learning unfolds across the lifespan.

In this model, working memory and executive functions provide the cognitive infrastructure that enables linguistic processing and control; motivation and emotional intelligence sustain engagement and adaptation throughout the learning process; anxiety reduces the availability of cognitive resources and therefore requires pedagogical regulation; and age and learning context emerge as key moderators that shape the dynamics through which these mechanisms interact. When instructional approaches are deliberately aligned with this integrated framework, individual differences become not obstacles but structured predictors of success, transforming variability in learner performance into manageable and optimisable outcomes.

Conclusions

This meta-analysis synthesises two decades of research on second language acquisition, integrating cognitive, affective, and contextual perspectives. Results consistently confirm the central role of working memory and executive functions: working memory supports real-time integration of linguistic input, while executive functions regulate attention, inhibit interference, and enable cognitive flexibility. Their complementary roles explain both their stability as predictors and their domain-specific effects. Affective factors also proved decisive. Motivation and emotional intelligence sustain engagement, whereas anxiety constrains achievement by taxing cognitive resources. These findings support a cognitive-affective model of co-regulation in which affect mediates the mobilisation of cognitive capacity across tasks and contexts.

Moderator analyses revealed systematic variation: children show stronger working memory effects in phonology and early grammar, young adults display peak integration of cognitive resources, and older learners retain significant though more variable outcomes, consistent with cognitive reserve. Context matters as well: ESL and immersion environments enhance motivation and reduce anxiety, while EFL contexts produce more heterogeneous results, underscoring the need for targeted pedagogical support. Methodologically, the study contributes by applying PRISMA 2020 standards, random-effects models, and risk-of-bias assessments, yielding robust results despite limitations such as the underrepresentation of older learners,

inconsistent measurement tools, and predominance of Anglophone samples. The study's contributions are both theoretical and practical: it advances an integrative framework that unites cognitive and affective factors under the moderating influence of age and context, and it provides evidence-based guidance for age-sensitive, contextually adapted instruction.

Future research should broaden the cultural and age range of participants, standardise measures of key constructs, and employ longitudinal and neurocognitive methods to trace developmental trajectories. Greater attention to digital and adaptive technologies is also needed to evaluate their potential for sustaining motivation, enhancing executive control, and compensating for contextual limitations. Such efforts will refine theoretical models, strengthen empirical generalisability, and inform pedagogical practices that are both scientifically grounded and responsive to learner diversity.

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