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Neurological and Cognitive Factors Shaping Second Language Acquisition: A Systematic Review

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Abstract
The process of second language acquisition (SLA) is subject to various neurological and cognitive factors, including the age of the learner, brain plasticity, memory, and executive function. The flexibility of the neural networks that characterizes young learners allows them to acquire a native-like fluency, while adult learners attain a reasonable level of L2 proficiency if particular cognitive strategies are deployed. The current review scrutinizes adults' SLA from the perspective of psycholinguistics, bilingualism, and cognitive neuroscience. A qualitative investigation was carried out to reveal SLA related themes discussed by academic articles in PubMed, WoS, and Scopus between 2001 and 2024. The study incorporated aspects such as the learner's memory function, adaptation to phonology, age, stimulus, intelligence, cognitive processing, and L2 anxiety. This review demonstrates that the differences in neural stimulation and bilingual brain processes influence SLA. The evidence illustrates that young learners are more naturally and cognitively equipped to acquire the L2 effectively, but Adult learners can enhance their acquisition of L2 by adopting certain cognitive strategies. Understanding the cognitive and neural factors that influence SLA aids in improving proficiency. The conclusions are meant to positively impact multilingual education, shaping the teaching process, policy making, and SLA academic research.

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Introduction

Multilingualism is rising with the increased number of people speaking multiple languages. This changing tendency is apparent in Teens and young adults. Second language acquisition (SLA) is approached as the process of learning a non-native language. SLA processes differently in adults and youngsters. L2 acquisition follows different trends than native language acquisition due to different teaching patterns (Ortega & Iberri-Shea, 2005).

The acquisition of a non-native language arises from an amalgamation that gathers mental abilities, brain arrangements, and the age of the learners with environmental elements that shape the process. Human beings acquire language subconsciously during early childhood by absorbing grammar rules through communication and extended language exposure (Christiansen & Chater, 2008). When learning L2, adults depend mainly on explicit methods of teaching and grammar memorization because they need clear instructions. Whereas SLA functions through the interplay of memory networks, executive control, and brain pattern adaptation (Gkintoni et al., 2025; Xie & Wang, 2024). Researchers put joint efforts into understanding how L2 learning differs among individuals. SLA theories identified that the language acquired differs across different learners because of many factors. This is also associated with the abilities of humans to listen, speak, read, and write. The extensive research efforts have failed to solve the challenges associated with this field (Gallo et al., 2025; Xie & Wang, 2024). Bilingualism leads to specific brain changes. Furthermore, MacIntyre (2003) suggests that Statistical research indicates that motivation, L2 anxiety, and strategies of teaching and learning a foreign language create significant emotional factors that impact language learning. Various theories about SLA explore distinct mental components, brain mechanics, and environmental elements. The Critical Period Hypothesis (CPH) is an intrinsic idea associating the brain's plasticity with young-aged learners and neural constraints that older-aged learners face (Gunderson, 2020).

The learner's capability to process and preserve linguistic material of the L2 becomes intricate because of the limited dimension of the working memory, cognitive overload, and L1 interference (Phan & Ho, 2019). Regular and proficient acquisition of language occurs instinctively in a particular period according to CHP, illustrating that neuroplastic aptitudes start to weaken after the period of puberty, leading to the sophistication of the process of acquiring the L2. Neurolinguistics research highlights the gains of genetic progress in childhood during the stage of language learning as opposed to adult learners who chiefly hinge on overt memory-based learning approaches while attempting to master the L2 (Grey, 2013; Harsiwi, 2025). Deploying the CPH perspective to assess the achievement of adult learners reveals that they can attain a higher level of mastery in lexis and composition if they are intensively exposed to language use and practice (Pongotak, 2024). Furthermore, the Connectionist Model suggests that the process of acquiring a second language is governed by an interactive pattern of recognition that

evolves through frequent social interactions (MacWhinney & Chang, 2013). All the previously mentioned models are based on neural network studies that illustrate that L2 acquisition progresses following pattern recognition. In fact, Williams (2020) confirmed that continued encounters with L2 practice and drills enhance not only competence and performance in the second language but also aid in strengthening neural routes and cognitive plasticity.

Undeniably, second language mastery incorporates cognitive and neural processes. Communication or language skills, talent, and intelligence are intrinsic factors that contribute to cognitive progress. Moreover, the working memory is the chief dynamic aspect that regulates SLA since it allows the learners to preserve and amend language material for a particular context and period. Students acquiring L2 experience improved syntax processing ability and better vocabulary retention following increased working memory capacity (Begum et al., 2025; Luque & Morgan-Short, 2021; Phan & Ho, 2019).

The ability of brain restructuring, known as neuroplasticity or neural plasticity, affects the SLA processing. Sensory brain input results show that compared with monolingual speakers, bilingual subjects have more dense grey matter in the areas of their brains associated with language processing. Additionally, bilinguals demonstrate increased neural functioning in regions like the prefrontal cortex of the brain that are associated with better problem-solving and cognitive flexibility. (Stocco et al., 2014). According to cognitive load theory, too many cognitive tasks hamper SLA when students need to process advanced grammar rules with new vocabulary. The reduction of cognitive overload during language acquisition is supported through scaffolded learning combined with immersion because these strategies provide systematic, meaningful information (Hao & Othman, 2021).

New findings in cognitive neuroscience also indicate the possibility that bilingualism improves cognitive control processes that allow multitasking and concentration. According to the latest sources, bilingualism allows an individual to maintain a higher mental flexibility, meaning that they can simply switch activities to require less force and, therefore, learn more languages more easily (Abdumuxtorova & Rayimaliyeva, 2025). Moreover, the information at hand indicates that bilingualism might keep the brain in a fresh condition that is mentally robust, postpones cognitive ageing, and would not lead to any neurodegenerative disabilities like dementia and Alzheimer's disease (Bialystok, 2021).

It is important to point out, however, that recent findings have shown that an extension of the cognitive strategy to include chunking and rehearsal can lead to improved second language acquisition (SLA), especially where retention is difficult for elderly learners (Wang & Christiansen, 2024). Then, alongside them, modern language instruction tools, e.g., spaced repetitions and interactive technology, can be utilized to place age pressure,

produce learning complexities, and direction in a more constructive syntactic and phonics accumulation.

Psycholinguistics research further examines the relationship between bilingualism, cognitive development, and language processing mechanisms. Bilingual people excel at controlling their minds in situations that test their switching ability and their ability to control impulses (Babazade, 2025; Bruni, 2023). Babazade (2025) and Woumans et al. (2015) revealed that bilingual speakers were found to delay age-related cognitive deterioration; put differently, individuals who are able to speak more than one language have the ability to delay neurodegenerative conditions such as Alzheimer's.

Multiple explanations based on theory exist, yet researchers disagree on how neuroplasticity, working memory, and executive function work for language learning. There has been much research on SLA, but still little is known about the cognitive, neurological, and psycholinguistic processes that underlie them. This research calls for a systematic review to synthesize the different evidence from studies and compare approaches of SLA through the cognitive neuroscience perspective. The research follows the protocols of qualitative thematic analysis to categorize recurrent arrangements and reveal gaps in the literature, aiding in acquiring scientifically-grounded action points for language learning and multilingual education.

Research Objectives

This research methodically scrutinizes L2 acquisition at both the neurological and the cognitive levels. The investigation of the L2 is carried out based on evidence derived from psycholinguistics, cognitive neuroscience, and the bilingual educational sector. The existing literature has investigated these issues in separate manner and independent from each other, leading to a scarcity of integrative analysis that joins all aspects that have an effect on SLA, such as the emotional, cognitive, and neurological factors, predominantly in late-stage learners. This research attempts to address this unexplored area by assessing the instinctively happening cognitive mechanisms in language learning, considering the role of memory and executive control. Furthermore, this research navigates the brain-based indications associated with how bilingual individuals use language and investigates the manner in which brain plasticity can aid or limit L2 acquisition. Moreover, this systematic review evaluates the psychological and emotional factors that make the learners anxious, motivated, or encounter cognitive constraints while embarking on the SLA journey; in fact, these issues are scarcely navigated by neurolinguistics reviews.

Through the synthesis of interdisciplinary evidence, this systematic review provides an intrinsic clarification for the intersected aspects that impact SLA. The results of this research have as an objective the enhancement of scientifically grounded teaching practices and improving multilingual educational programs that support scientific accomplishment and long-term language retention.

Methodology

The Process of Systematic Review

The current research deploys a systematic review method to scrutinize second language acquisition across the domains of psycholinguistics, bilingual education, and cognitive neuroscience. The systematic review is conducted by means of a phased process to guarantee clarity, precision, and reproducibility.

Database Framework and Search Procedure

An all-inclusive academic source retrieval has been employed through the use of academic indexing platforms. The academic databases that feed the current systematic review are PubMed, Scopus, PsycINFO, ERIC, Web of Science, and Google Scholar. While retrieving material that is related to this research the researchers use MeSH terminology with unrestrained vocabulary comprising phrases and lexis such as "bilingualism," "working memory," "second language acquisition," "cognitive load," "adult language learning," "motivation and anxiety in SLA," and "neuroplasticity," to enhance the precision and the scope of the research and data retrieval, Boolean connectors were used especially (AND, OR) along with Truncation to achieve data refinement.

Inclusion and Exclusion Criteria

Studies published in peer-reviewed journals between 2001 and 2024 were included in this review. Studies that focused on the cognitive, neurological, or psycholinguistic dimensions of SLA were considered. In addition, studies that investigated bilingualism or second language learning among adolescents or adult populations were also included. Only studies published in the English language were considered for inclusion.

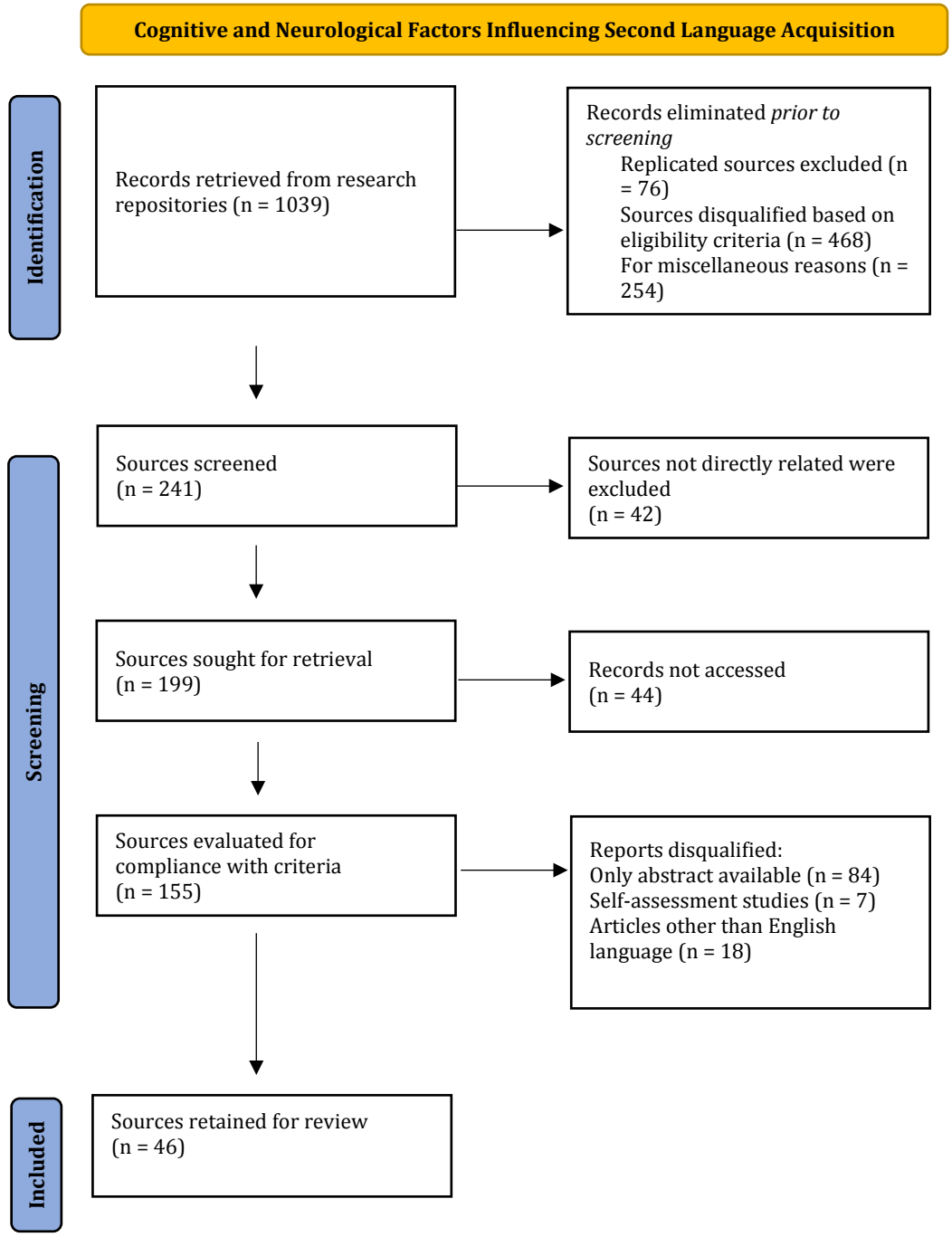
Research that is centered on first language acquisition was excluded; additionally, other research was also excluded, such as editorials, opinion pieces, or purely conceptual frameworks, or did not address any of the core cognitive, psychological, or neurological factors relevant to SLA. Self-assessment studies about language acquisition were not considered. Furthermore, studies published in languages other than English were excluded.

Screening and Selection Process

The academic source retrieval led to the identification of 1,039 initial records. Out of the total records, only 46 academic works fulfil the outlined criteria and have been qualified to be part of the final systematic review, after a full-text reading that was preceded by an abstract and title screening. Furthermore, PRISMA guidelines were applied strictly during the section stage, guaranteeing clarity and reproducibility. To uphold transparency, a PRISMA flow chart is deployed to illustrate selection choices based on the exclusion and inclusion criteria (Figure 1). Moreover, any occurring disagreement between research reviewers has been fixed by means of conversation and accord.

Figure 1

PRISMA Flow Diagram Elucidating the Research Selection Process



Data Extraction and Thematic Synthesis

The included second language acquisition sources were scrutinized by means of qualitative thematic analysis, leading to the extraction of significant data. A structured data extraction table is deployed to document the included studies' type of academic work, sample type, year of publication, author (s), focus topic, and key results. The application of thematic analysis aided in arranging the results into key themes comprising cognition, neural plasticity, phonology, age, and psychological factors.

Results

All details documenting data abstraction are outlined in Appendix 1, including the thematic grouping. The investigation of the extracted sources led to the identification of numerous neurological and cognitive themes influencing SLA. The findings are arranged into major themes according to their cognitive abilities, neural processes, phonological operations, age-dependent outcomes, and psychological dynamics. Table 1 showcases the deduced thematic results.

Table 1

Summary of Key Cognitive, Neurological, and Psychological Factors Influencing SLA

Key Theme	Findings	Description
Cognition	Memory Systems Involvement	Declarative memory (hippocampus) is crucial for vocabulary learning, while procedural memory (basal ganglia) supports grammar acquisition.
	Cognitive Control & Executive Functions	Bilinguals exhibit enhanced executive control (prefrontal cortex), leading to better task-switching, working memory, and conflict resolution.
	Cognitive Techniques	Deep processing, metacognitive reflection, and multimodal learning enhance retention and comprehension. Improved brain activity synchronized with metacognitive training.
Neural Plasticity	Brain Adaptation	L2 acquisition depends on the cognitive function to formulate and rearrange learning circuits in learners of a young age, in particular. This is proved with the increased concentration of grey matter in bilingual speakers in the left inferior parietal cortex.
	Early vs. Late Learners	Young learners of a second language show a more active neural arrangement, illustrated by a significant integrity in white matter and a robust supremacy of the left hemisphere. Language learners of old age are more dependent on broader neural network activation that engages both hemispheres of the brain to counterbalance the reduction of neuroplasticity.
	Delayed Brain Disease Effects	Older second-language learners show a boosted cognitive reserve. Therefore, researchers have linked the delay of the occurrence of Alzheimer's and other neurodegenerative illnesses to the act of learning new languages.
Phonology	Hemispheric Specialization	First language (L1) is typically left-lateralized, but L2 activation depends on proficiency and age of acquisition, with early bilinguals showing bilateral activation.
Age	The brain's prime time for language acquisition, also known as the Critical Period Hypothesis/CPH)	Represents an ideal opportunity to learn a language, with reduced neuroplasticity after puberty, affecting pronunciation and syntax acquisition.
Psychological Factors	Impact of Psychological Factors and Cognitive Load in SLA	SLA is shaped by motivation, attitude, intelligence, anxiety, and cognitive techniques, which influence success.
	Motivation	Affects the pace and efficacy of language learning. Motivation is distinguished as integrative (cultural interest) and instrumental (pragmatic).

	Neuroimaging links motivation to activity in the ventral striatum and prefrontal cortex.
Attitude	Learners' beliefs about the target language and its speakers influence language acquisition. Positive attitudes correlate with higher proficiency.
Intelligence	The multiple intelligences model suggests linguistic and logical-mathematical intelligence strongly affect SLA in academic settings.
Anxiety	High anxiety (e.g., Foreign Language Anxiety) impairs language retention and spontaneous speech. Moderate anxiety may enhance learning. Neuroimaging shows that anxiety-related amygdala activation reduces working memory for SLA.

Discussion

Being determined by multidimensional processes that are cognitive, neurologic, and psychological makes L2 acquisition multilayered. With the advances of cognitive neuroscience and psycholinguistics in the past few decades, second language acquisition researchers have been focusing more on how learners', especially adults', L2 learning is processed. This review focuses on the impact of brain plasticity, memory systems, executive functions (EF), phonology awareness, and affective factors in second language acquisition (SLA) at different ages, with special emphasis on adult learning.

To identify and investigate the neurological and cognitive processes involved in adult SLA is the chief objective of this systematic review, whereas the principal goal was to fill the knowledge gap about the role of neuroplasticity, phonological processing, and executive functions in L2 acquisition. By combining data from peer-reviewed literature between 2001 and 2024 from various databases (Web of Science, PubMed, and Scopus), the research sought to give an integrative perspective of SLA underpinned by neuroimaging data and cognitive studies.

Neuroplasticity in SLA

Neuroplasticity is the brain's capacity for reorganization, which is essential to acquiring L2 learning. Starting the journey of learning a second language at a particular age considerably impacts the learners' cognitive progression and the arrangement of their synaptic networks. Based on the principles of the CPH approach, the opportunity for L2 learners to acquire a native-like language use weakens once they start getting older, because their brain neuroplasticity begins to diminish (Harsiwi, 2025; Singleton & Lesniewska, 2024). Individuals who start acquiring two languages simultaneously prior to the period of puberty display a significant neural activity in the left hemisphere regarding both their mother tongue and the second language.

Learners who were exposed to second language acquisition at early stages of their lives benefit from a significant integration of their brains. Wattendorf et al. (2014) suggest that the use of fMRI demonstrates that bilinguals of early age have the ability to use the two hemispheres of the brain while processing languages; however, late age bilinguals chiefly show activity in the left hemisphere during language processing. These ideas were later

confirmed by bishop et al. (2021). Moreover, individuals who begin acquiring L2 at a late stage of their lives demonstrate an augmented activation of the prefrontal zones of the brain, which is connected to goal-directed cognition (Liu & Cao, 2016). Therefore, these differences between early age and late age regarding L2 acquisition and brain function suggest that being exposed to L2 at a young age aids in processing language in a native-like manner, while learning the L2 at an old age requires the individuals to be more intentionally engaged in the learning procedure.

Involvement of Brain Regions in SLA

Numerous significant zones of the brain partake in SLA, including the basal ganglia, Inferior Frontal Gyrus (IFG), hippocampus, and Wernicke's area. Broca's zone, also known as the IFG, is vital for the formulation of syntax and speaking. According to Abutalebi (2008), the IFG is highly active in late-stage learners because of the intensified cognitive effort required from them to produce meanings using the second language. Furthermore, adult learners are also faced with the constraints of pressurizing the Wernicke's area to show a more effective understanding of language and meaning integration (Park et al., 2012; Van Heuven & Dijkstra, 2010). While early learners' dependency on the Basal ganglia is limited, late-age learners illustrate a more significant reliance on it, since it aids in procedural memory that is indispensable for acquiring language configurations (Diego Balaguer & Rodríguez Fornells, 2010; Erçetin & Alptekin, 2013).

Bilingual speakers of different age categories depend on the active deployment of the hippocampus as a crucial brain area that is essential in retaining and enhancing terminology (Gallo et al., 2025; Lieberman, 2016; Merkl, 2006). Moreover, according to Desai et al. (2008) both categories of learners show a hyper activity in the superior temporal gyrus (STG), while Zhang et al. (2023) suggested that not only the temporal gyrus that is necessary in phonological processing but also other brain zones such as Heschl's gyrus, angular gyrus (AG), supramarginal gyrus (SMG), and posterior superior temporal sulcus (pSTS), additionally these brain zones are also essential in acoustic memory, diction and meaning analysis. The increased usage of different areas of the brain while producing speech in the L2 aligns with Yum and Law's (2021) findings that suggest that the more second language learners advance in their mastery of the L2, the more their left hemisphere becomes more active.

Indeed, L2 acquisition stimulates two major neural circuits, namely the dorsal stream that is responsible for connecting IFG and STG through the arcuate fasciculus, aiding the phonological memory and the production of speaking, and the ventral stream that is in charge of joining STS and MTG to IFG; this latter helps in mapping phoneme-to-meaning and terminological access (López-Barroso & de Diego-Balaguer, 2017). AoA or the age of acquisition considerably impacts the previously mentioned mechanisms since young learners exhibit a very effective and automated processing of the left-lateralized, whereas late age learners of SLA depend on other brain zones to achieve effectiveness in leaning

the L2 such as the prefrontal cortex and the right hemisphere, Demir (2020) even linked this mechanism to the deep rooted L1 system in the cognitive system of the late learners, suggesting that these learners are always suffering from difficulties while producing phonemes because of the deep-seated L1 system of phonology. Yet, neuroplasticity continues in old age, leading to the enhancement of phonology via drill. Furthermore, HVPT or the procedures of High-Variability Phonetic Training supports the production of phonemes in adults through involving the ventral and dorsal stream systems in an effective and active manner that replicates native speakers speech production (Alotaibi et al., 2023), in fact those mechanisms are in line with the Flege's Speech Learning Model which demonstrates the importance of the association of the act producing and perceiving L2 phonology.

Age-Related Effects and Brain Plasticity in SLA

SLA acquisition is contingent on various neurological and cognitive procedures that have been the core issue of significant academic publications that approached the topic from the angle of diverse age categories. The influence of the age of the learners in SLA is related to CPH, which speculates that physiologically speaking, there is a period of time related to the age of the learners in which the individual can benefit the most from the learning process and achieve maximum acquisition of the L2. Contemporary academic publications illustrate that while early age learners can acquire native-like mastery of the second language when it comes to grammar and pronunciation, late age individuals have the ability to achieve potentially the same mastery, especially if their experience-reliant brain neuroplasticity is considered. The influence of age-associated alteration on second language learning and the part that neuroplasticity plays in easing the process of learning after the period of childhood are going to be investigated in the section below.

The Age-Related Variations in SLA

According to Singleton and Leśniewska (2024). The learners' age is a decisive aspect that shapes L2 learning; they assert that the commonly accepted claim is that young learners acquire foreign languages faster and more effectively than mature learners. This claim is validated by most of the academic works that this review investigates. The CPH, a pillar topic in research about second language learning, indicates that there should be a clear and predefined biological period in which it is advisable to start learning languages; that period, according to CPH, is the optimal phase for language acquisition, and it ends at puberty. Beyond this period, the individual learner will have difficulties and constraints in learning the second language due to the changes that occur in the brain's neuroplasticity (Lucio, 2020; Shabbir et al., 2025). Furthermore, the studies composing the corpus of this systematic review demonstrate that beginning the process of learning the second language at an early age leads to improved pronunciation skills and boosts grammatical and lexical abilities (Flege et al., 2006; Hopp & Schmid, 2013; Tahta et al., 1981). Yet, recent academic research opposes the belief that early age learners are more efficient in SLA. Hakuta et al. (2003) indicate that the preconception that a second language is better acquired in childhood is unrealistic, since, according to their study,

children show more talent in native-like pronunciation, but their performance in grammar is unreliable. While adult learners, though their pronunciation is not as perfect as that of young learners, still demonstrate an advanced grammatical proficiency (Hakuta et al., 2003; Muñoz & Singleton, 2011).

In fact, research carried out in real situations in classrooms rejects the CPH hypothesis. In structured classroom contexts, late-age learners achieve more than young learners, especially regarding morphology and syntax, though the general success is typically displayed by youngsters. It becomes apparent then that even if the trajectory of learning is not affected by when the learning begins, the achieved progress is age-dependent. For instance, mature learners achieve a mastery of lexis and grammar at a fast pace in comparison to other learners; however, children reach a much higher rate of competence in grammar and lexis in the long run as a direct result of continued contact with the L2 through education (Caldwell-Harris & MacWhinney, 2023; Hough, 2005).

More recent studies suggest that the brains of young learners are more prepared to acquire phonetics and other linguistic components of a language system. Newborns younger than 12 months can identify phonemes universally between languages, although this capacity diminishes as experience diminishes (Kuhl, 2009). Late L2 learning shows different brain neural patterns than early language learners, as measured by fMRI tests, which suggest reliance on declarative memory over procedural memory mechanisms for understanding grammar (Birdsong, 2018; Ullman, 2006). Granena (2016) discovered in his research on SLA age changes that older learners experience reduced implicit learning skills but succeed with explicit learning procedures, which provide enhanced support to adult learners, showing that age-related changes affect learning methods rather than preventing progress completely (Granena, 2016).

According to cognitive theories, the techniques that children and adults use to learn differ considerably. Adult language acquisition relies on the direct use of linguistic normalcy, although children learn language primarily through communication without recognizing underlying grammatical rules. Affective aspects and children who influence learning tend to be more motivated since they want to belong socially. Researchers in SLA want to learn when the optimal period exists for language acquisition. Every age segment brings specific learning benefits and difficulties to the table. Starting L2 acquisition depends on individual situations and variables that emerge in personal life. Educators must use specific teaching approaches matching each age group's characteristics when students of different ages learn languages (Lyster, 2007).

Neural Plasticity and SLA Throughout the Lifespan

Although early learners benefit from developmental plasticity, evidence indicates that adults exhibit significant experience-driven plasticity, facilitating SLA (Xia & Wang, 2025). Neuroimaging evidence indicates that bilingual individuals exhibit a higher concentration of grey matter in the left side of the inferior parietal cortex in comparison

to monolingual individuals; this observation is confirmed regardless of the age at which they started the process of learning the L2 (Abutalebi et al., 2015). The evidence derived from studies that focus on language learning and neural processes suggests that bilingual people have a brain that is operationally improved by the second language, even if they are adults. Transmission of language knowledge modifies brain structures during any stage of cognitive development. According to research that contrasted brain structures between controls and bilingual speakers in aging populations, bilingual elderly participants demonstrated higher grey matter density in LIPL and RIPL regions of their brains.

Whether individual learners start acquiring the L2 at an early age or later in their lives, this has nothing to do with the density of the grey matter in their brains. In fact, the competence and performance in L2 is linked to the grey matter density in brain zones called the left inferior parietal lobule, whereas the time frame of being exposed to the learning process of the second language is associated with the density of the grey matter in the right inferior parietal lobule (Abutalebi et al., 2015). Furthermore, Heidlmayr (2015) discovered that bilingual individuals activate the prefrontal cortex to signpost a shift from automatic language learning associated with children to an enhanced cognitive mechanism, suggesting full control and awareness of the learning process that is linked to adults.

The impact of age on SLA exists as a combination of various factors instead of producing complete effects. Young beginners show better pronunciation and long-term retention skills, but structured education enables older students and adults to reach advanced proficiency levels, mainly in grammar and vocabulary acquisition. According to research, three multimodal imaging techniques that are task-based fMRI (functional Magnetic Resonance Imaging), rs-fMRI (resting-state functional Magnetic Resonance Imaging),and sMRI (structural Magnetic Resonance Imaging) were deployed to scrutinize the neural plasticity in Chinese individuals with a bilingual background and whose level of performance and competence in the mastery of the second language differ. Individuals who are less competent in the second language exhibit higher brain activity in zones of IFG (Inferior Frontal Gyrus) and insula, cerebellum, and other cognitive areas such as ACC (Anterior Cingulate Cortex) and IPL (Inferior Parietal Lobule); furthermore, less fluency in L2 also triggers brain activity in visual-processing zones such as calcarine gyri and fusiform. Individuals who have higher mastery of the second language exhibit an augmented brain motion in the right and left fusiform gyrus, indicating the intrinsic part of both the orthographic and visual procedures and the immensity of the cognitive control. According to Wang et al. (2020), the right fusiform gyrus is a core sign that illustrates second language competence for Chinese language speakers, simultaneously exhibiting its importance for the native language and the second language handling. Moreover, Gallo and Abutalebi (2024) confirm that bilingual individuals demonstrate distinguished executive functioning and cognitive flexibility that is caused by a sustained

engagement with the second language, resulting in lifelong alterations in the functions of the brains of bilingual individuals. Additionally, Antoniou et al. (2013) confirm Gallo and Abutalebi's (2024) findings and add that late age learners of L2 demonstrate a greater resistance to diseases that are associated with old age and mental deterioration, such as Alzheimer's and Parkinson's, in the sense that bilingualism plays the role of a fence that blocks the neuro-deteriorating procedures.

Phonetic Acquisition and Neural Adaptations in Late L2 Learners

The deterioration of plasticity in auditory abilities results in posing difficulties for adult learners of SLA to improve their accent and pronunciation. According to the research conducted by Flege (2019), the period prior to puberty is a post-critical time frame for the acquisition of phonetic skills. Second language learners face challenges in attaining a level that is near that of the native speakers regarding pronunciation because their native language's phonological rules have already been deeply rooted in their brains. However, if adults are to be exposed to enhanced and progressive phonological exercise, they may activate neurological plasticity, allowing them to reach a level in phonetics that is close enough to the natives as suggested by findings deriving from fMRI scans of the STG (Moore et al., 2025; Whelan et al., 2021). According to Munoz (2021), if an individual adult is subject to a specific kind of phonetic drills of different levels of difficulty, neuroplasticity can be activated, leading to improvement in perceiving and producing vowels in the L2. Furthermore, contemporary studies carried out on the topic of neural plasticity indicate that SLA has revealed anatomical variances in the brains of people who are bilingual that do not exist in monolingual brains. To confirm this idea, Yang et al. (2024) inspected cognitive differences in students who are originally from India but live in China. The brains of the Indian students who learnt to speak Chinese were compared to those who did not speak Chinese. MRI scan and analysis uncovered a noticeable volume of grey matter in the zone named lingual gyrus in students who speak Chinese (Yang et al., 2024).

The research of Yan et al. (2024) confirms findings by Liu et al. (2021), these later revealed that leaners of studied Chinese as a second language have a greater volume of grey matter that they associated with correctness in identifying Chinese characters, the grey matter that Liu et al. (2021) discovered was located in the fusiform gyri and the left lingual, indicating that second language learning triggers neural plasticity not only in brain regions that are linked to second language but also the zones that are associated with the native language also. To say more, the evidence from Yan et al. (2024) and Liu et al. (2021) goes hand in hand with other findings that suggest individual learners use different reading ways while studying phonology. Dong et al. (2022) concluded that learners who preferred the lexical pathway (whole-word phonology mapping) showed better performance, which used less neural activation, and hence apparently more efficient neural processing. These findings do have any explanation according to most studies included in this review, especially in relation to the critical period mentioned earlier; however, they aid in clarifying how continuous drill and exposure to the

phonology of the second language can reshape not only the perception of the L2 but also the brain of the learners.

Cognitive Control's Function and the Working Memory

Age-dependent effects in language learning processes are associated with working memory's ability and cognitive control. According to Mackey and Sachs (2012) that the variability of inhibitory control and the intentional switching predictive of the SLA performance, is majorly among the elderly learners (Mackey & Sachs, 2012). Since a better working memory capacity permits, bilinguals have a superior level of grammatical processing, another supportive fact to prove the hypothesis that older students use the cognitive control system as a useful tool to compensate (Gkintoni et al., 2025). Many studies indicate that bilinguals exhibit more efficient working memory processes than monolinguals, which may allow them to better produce and understand language (Begum et al., 2025; Bialystok et al., 2008; Keijzer & Schmid, 2016). Moreover, Bialystok et al. (2004) also illustrated that speakers of more than one language show greater management of cognitive control, giving the instance of Simon tasks. The study of Bialystok et al. (2004) demonstrated that bilinguals are more advanced than monolinguals in these types of tasks. Furthermore, Bialystok et al. (2004) and Gkintoni et al. (2025) even indicated that bilingualism has many positive outcomes on adults, among which they hint at the counteraction of the effects of old age, such as the deterioration of executive functions of the human brain. Grundy et al. (2017) set forth the fact that multilinguals are more activated by the brain region that coding keeps tracking conflicts and resorts to language switching the anterior cingulate area, and there is some evidence that high-level thinking is required to achieve L2 proficiency, especially in late learners whose brain has to suppress the interference of the L1 language (Grundy et al., 2017).

Recent studies also emphasize such cognitive benefits of extended L2 engagement. Research suggested that lifetime bilingualism postpones the beginning of the appearance of symptoms associated with Alzheimer's, thereby amplifying the characteristic of forming a neuroprotective layer to guard the human brain. The cognitive resilience enhanced by bilingualism serves the bilingual individual by delaying the occurrence of most of the neurodegenerative ailments in general and their indicators in particular. Studies linked to working memory, cognitive control, and SLA have shown that bilingualism leads to fostering the human brain and protecting it from diseases such as Huntington's disease, Parkinson's disease, and multiple sclerosis. Cognitive reserve strength is associated with the level of bilingualism, which offers a longer-lasting resilience to cognitive decline. At least the protective impact of bilingualism against the disease in such conditions as Alzheimer's or Parkinson's is proven unconditionally, but the impact against such diseases as multiple sclerosis is more unstable, and more longitudinal research should confirm all levels of outcomes (Babazade, 2025; Gold, 2015; Kampfl, 2024).

Moreover, Markiewicz et al. (2024) found that the neuroplasticity of aging bilinguals reduces the health of language white matter to the extent that continued L2 use can maintain neuronal performance. This paper highlights the fact that lifelong bilingualism can provide neural defense against cognitive and social cognitive impairment, namely, the theory of mind (ToM) skills. Before the L2 AoA (L2 age of acquisition), older-aged bilinguals were associated with increased cortical volume and structural density in the brain's zones that are linked to language learning, as well as greater surface area. The researchers concluded that the structural brain associations between bilingual young adults and older adults regarding the L2 AoA were similar, but the correlation between L2AoA and ToM performance was stronger in older adults. It suggests that such loss of theory-of-mind ability during the normal aging process may be buffered by early acquisition of bilingualism (Li et al., 2024). These results support an emerging trend that SLA is not fixed and is instead driven by changing brain systems. The ability to acquire L2 is lifelong, provided learners adopt adequate learning strategies, immersion situations, and cognitive training.

Impact of Psychological Factors and Cognitive Load in SLA

Language learning is ominously impacted by cognitive and psychological aspects, including attitudes, motivation, anxiety, intelligence, and cognitive tactics (Larsen-Freeman, 2014). Integrative motivation that is centered on culture and communal language and instrumental motivation which is linked to profession purposes significantly influence achievements in second language learning (Khasinah, 2014; Otajonova, 2025), these claims are validated by various approaches including the Self-Determination that accentuates the pivotal part that motivation occupy in lifelong education (Deci & Ryan, 1980; Ten Cate et al., 2011) and the theory of Motivational Self System that focuses on the impact of collective and individual distinctiveness on the individual learner dealing with the L2 (Kwon, 2022). Moreover, Rohan et al. (2021) Motivation as a factor in SLA plays the role of a stimulator that activates the human brain's routes, most importantly the prefrontal cortex and ventral striatum. Additionally, motivation has the ability to foster gamification as a learning tactic through visualizing lessons and creating dynamism in the classroom environment (Moore & Blackmon, 2022). In parallel with motivation, the attitudes of the learners regarding cultural phenomena and language learning that are determined by pre-existing knowledge and didactic models occupy an immense part in assessing achievement (Horwitz, 2020).

Gardner's Multiple Intelligence Model contributed to language learning, especially when it comes to intelligence in general and logical-mathematical and linguistic in particular. However, that model has not influenced the social side of language education (Gardner & Hatch, 1989; Messick, 1992). On the other hand anxiety can be perceived at two levels, the first one is mild anxiety and it is the kind that can positively affect leaners via motivating them to achieve mastery of the second language, the second level is that of extreme anxiety which an anxiety that leaners develop from foreign languages (Boukranaa et al., 2024), this kind of psychological problems shape the working memory

of the learners and affect their achievement in class is caused by hippocampal suppression and amygdala overactivation (Ng, 2023). There are many instances of anxiety that are based on classroom environment, such as teachers' behavior, tests and examinations, and competitive actions between learners; however, helpful and friendly classroom management skills have the ability to decrease the adverse influence of classroom anxiety (Boukranaa et al., 2024; Tsiplakides & Keramida, 2009). Regarding cognitive strategies, there are many tactics through which they can aid in learning the L2, including metacognitive reflection and deep processing. These strategies, according to Rominger et al. (2022), support executive control and enhance neural routes. Furthermore, Karamova (2024) indicated that SLA programs and models that are based on audio-visual strategies and kinesthetic tactics, such as hands-on, Movement-based learning, and the touch-and-move approach, have been shown to reinforce a greater safeguarding of mental adaptability.

This systematic review's major addition and primary advantage is its strategy of following an interdisciplinary framework that includes linguistics, psychology, and neural physiology to investigate second language learning. Furthermore, the review offers an amalgamation of findings based on the investigation of results from EEG, fMRI, and DTI to achieve academic rigor and systematic deductions which opposed to other SLA research that has a limited focus, this review provides experts and readers interested in the domain of SLA with an all-inclusive systematic conclusions of how cognition and psychology influence the process of language learning.

Nevertheless, there are limitations that can be tackled in future research. Firstly, this research is a review of the existing literature that is dependent on neural imaging, which may hinder its generalizability to the actual context or classroom learning environment. Secondly, it is not based on authentic statistical figures. Thirdly, the influence of culture and the domain of linguistics were not investigated extensively; therefore, the outcomes may face constraints while attempting to apply them to learners from different backgrounds.

Conclusion

While embarking on the journey of learning a second language, individuals may encounter many aspects that affect the learning process. The influences that affect SLA are diverse, among which are phonology, cognition, psychology, culture, and social perceptions. An effective SLA must rely on motivation since this latter shapes how learners perceive the learning process at the psychological level. Based on the reviewed studies, there is a great dependency on three cognitive components regarding SLA, namely working memory, metacognitive strategies, and executive control. In association with preceding experiences, profound knowledge significantly improves information storage. Multimodal approaches to learning enhance the way students learn a foreign language. This review identifies that the acquisition of native-like pronunciation structure among students depends heavily on age due to their exceptional phonological

flexibility and implicit learning abilities, leading to better pronunciation skills. In adult L2 learners, in addition to self-perception, strong learning methods help them become fluent speakers even if they experience phonological difficulties.

Regarding brain-based modifications, the ability to speak multiple languages modifies neural pathways and causes structural changes in different brain regions in bilinguals, leading to improved decision-making ability and delayed signs of cognitive decline. Thus demonstrating the enduring benefits of language study. Psychosocial factors, like anxiety along with personality aspects, create substantial effects on individuals' learning of L2. Anxiety moderately increases cognitive function, which can boost performance, but increased nervousness levels generally lead to impairments in language and speech. Outward-oriented personalities and highly sympathetic learners can communicate quickly and express themselves. However, practice and structured study techniques lead introverted students to gain better language competence. The adjustability of human brains allows perpetual language learning, demonstrating why immersive educational methods, positive reward systems, and personalized instructional techniques are crucial for achieving success in acquiring L2.

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Ahmed Boukranaa: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project Administration, Funding Acquisition

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Ethics Declarations

World Medical Association (WMA) Declaration of Helsinki–Ethical Principles for Medical Research Involving Human Participants

This study adhered to the ethical principles of the World Medical Association (WMA) Declaration of Helsinki. As a systematic review based on previously published studies and publicly available data, it did not involve human participants. Ethical approval and informed consent were therefore not required.

Competing Interests

The authors of this study acknowledge that they have no conflict of interest to declare.

Data Availability

All data associated with this study are included in the manuscript.

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Appendix

Appendix 1

Extracted Data and Themes Identified in the Corpus Included in the Review

S. No.	Author(s), Year	Title	Type of Research	Sample	Focus Area	Key Findings	Key Theme
1.	(Abutalebi, 2008)	Neural aspects of second language representation and language control	Review	Bilingual adults	Language control and neural representation	Bilingual language control involves the basal ganglia and anterior cingulate cortex; bilingualism alters neural mechanisms of language processing.	Neural Mechanisms
2.	(Abutalebi et al., 2015)	The neuroprotective effects of bilingualism upon the inferior parietal lobule: a structural neuroimaging study in aging Chinese bilinguals	Experimental study	Aging Chinese bilinguals	Bilingualism and cognitive reserve	Mastering more than one language has a neural protective impact on the inferior parietal lobule in aging populations.	Neural Mechanisms
3.	(Alotaibi et al., 2023)	Rapid neural changes during novel speech-sound learning: An fMRI and DTI study	Experimental study	Twenty native English-speaking adults and 26 individuals who use their right hand in daily tasks participated in the study.	Neural adaptation in speech learning	Behavioral improvements in perception and production were observed post-training. fMRI and DTI revealed increased activity and structural (LIFG) and connectivity with (LIPL), indicating rapid neural adaptation within 3 hours of training.	Neural Mechanisms
4.	(Antoniou et al., 2013)	Foreign language training as cognitive therapy for age-related cognitive decline: A hypothesis for future research	Review	-	Bilingualism as cognitive therapy	Bilingualism is suggested as a shield to protect individuals from diseases linked to old age, especially deterioration in cognition. Since learning languages in old age creates a cognitive reserve by engaging brain regions vulnerable to aging.	Age-Related Effects
5.	(Bialystok et al., 2008)	Cognitive control and lexical access in	Experimental study	Participants were between 20 and 68	The study focused on SLA components linked to lexical	Participants of a young age had greater scores than older	Cognitive Functions

		younger and older bilinguals		years; they all spoke one or two languages; no multilingual speakers were in the group composed of 96 individuals.	retrieval, executive control, and Working memory in participants of different ages.	participants in most of the tasks of the study. Bilinguals showed better executive control, particularly under high lexical competition.	
6.	(Bialystok et al., 2004)	Bilingualism, aging, and cognitive control: evidence from the Simon task	Experimental study	40 participants: 20 middle-aged adults (30-54 years) and 20 older adults (60-88 years). Some groups were composed of Canadian monolinguals, and others were composed of Indian bilinguals.	Cognitive control in bilingualism	Bilingualism was linked to enhanced cognitive control and reduced Simon effect costs, with older bilinguals showing the greatest advantage regarding executive processing and working memory tasks.	Cognitive Functions
7.	(Birdsong, 2018)	Plasticity, variability and age in second language acquisition and bilingualism	Review	-	Plasticity, variability, and age in SLA	Age conditions plasticity and individual variation in L2 acquisition, but does not fully explain non-nativelike outcomes; bilingualism, dominance shifts, and experiential factors also significantly shape L2 attainment across the lifespan.	Age-Related Effects
8.	(Bishop et al., 2021)	Cerebral lateralisation of first and second languages in bilinguals assessed using functional transcranial Doppler ultrasound	Experimental study	First study: 24 participants: First languages (L1) were German (14) and French (10), and the second language (L2) was English Second study: 25 participants: L1 was Japanese and L2 was English	Lateralized brain function in L1 and L2	Fluent bilinguals show strong concordance in cerebral lateralisation for both native language and second language, without a substantial impact of age of acquisition on lateralisation patterns. .	Neural Mechanisms
9.	(Caldwell-Harris & MacWhinney, 2023)	Age effects in second language acquisition: Expanding the emergentist account	Theoretical Review	-	Age effects, emergentist theory, SLA variability	Argues that age is neither necessary nor sufficient for explaining non-nativelike outcomes in SLA; proposes that age effects reflect an interaction of exposure, cognition,	Age-Related Effects

						motivation, and neuroplasticity within an emergentist framework.	
10.	(Christiansen & Chater, 2008)	Language as shaped by the brain	Theoretical review	-	Evolution of language, learning mechanisms, Universal Grammar (UG)	Argues that UG could not have evolved biologically due to language's rapid change over time. Proposes that languages adapt to human cognitive and learning constraints, rather than being shaped by innate linguistic mechanisms.	Cognitive Functions
11.	(Desai et al., 2008)	Left posterior temporal regions are sensitive to auditory categorization	Experimental study	28 healthy Adults	Auditory categorization and neural sensitivity	Categorical perception of speech sounds activates the STS and SMG; activation is driven by phonetic categorization rather than acoustic differences, indicating learned phoneme category representations.	Phonological Processes
12.	(Diego Balaguer & Rodríguez Fornells, 2010)	Contributions to the functional neuroanatomy of morphosyntactic processing in L2	Review	-	Morphosyntactic processing in L2	L2 morphosyntactic acquisition involves dynamic neural network engagement, shifting from posterior to anterior brain regions over time; executive functions, age of acquisition, learning strategies, and L1–L2 similarity significantly influence processing and individual variation.	Neural Mechanisms
13.	(Dong et al., 2022)	Individuals' preference on reading pathways influences the involvement of neural pathways in phonological learning	Original Research	25 Chinese learners	Neural pathways in phonological learning	Individuals who prefer the lexical (addressed) reading pathway perform better and show less neural activation in related brain areas (e.g., orbitofrontal cortex, right pars triangularis) when learning new characters via that same pathway.	Phonological Processes
14.	(Erçetin & Alptekin, 2013)	The explicit/implicit knowledge distinction and working memory: Implications for second-language	Original Research	51 students from a Turkish university that uses English as a medium of instruction.	Working memory and L2 reading	Higher working memory capacity significantly enhances inference generation and reading comprehension in L2 learners, indicating that working memory has a significant part in	Cognitive Functions

		reading comprehension				differentiating between overt and covert linguistic knowledge.	
15.	(Flege, 2019)	A non-critical period for second-language learning	Review	-	Critical period and L2 learning	Adult learners, under certain conditions, can achieve native-like pronunciation, underscoring the plasticity of phonological acquisition beyond early childhood.	Age-Related Effects
16.	(Flege et al., 2006)	Degree of foreign accent in English sentences produced by Korean children and adults	Longitudinal study	Old-aged and young–aged learners from Korea and England.	AoA in a second-language speaking country affects the foreign accent.	Age of arrival in a second language-speaking country directly affects the degree of foreign accent; children exhibited more pronounced accents than adults, supporting age-related sensitivity in phonological encoding.	Age-Related Effects
17.	(Gallo & Abutalebi, 2024)	The unique role of bilingualism among cognitive reserve-enhancing factors	Review	-	Dual language proficiency and cognitive reserve	Emphasizes the unique contribution of bilingualism to neural resilience, illustrating its defensive role against cognitive deterioration caused by being old through increased neural flexibility and executive control.	Cognitive Functions
18.	(Gold, 2015)	Lifelong bilingualism and neural reserve against Alzheimer's disease: A review of findings and potential mechanisms	Review	-	Bilingualism, neural reserve, and Alzheimer’s disease	Lifetime dual language proficiency is linked to postponing the beginning of the appearance of diseases such as Alzheimer’s, attributed to enhanced neural reserve and sustained cognitive control mechanisms in bilingual individuals.	Cognitive Functions
19.	(Grundy et al., 2017)	Neural correlates of cognitive processing in monolinguals and bilinguals	Review	-	Cognitive control and bilinguals	Bilinguals demonstrate distinct neural activation patterns during executive control tasks, suggesting enhanced cognitive processing efficiency compared to monolinguals.	Neural Mechanisms
20.	(Hakuta et al., 2003)	Critical evidence: A test of the critical-period hypothesis for	Original Research	2.3 million U.S citizens from Chinese and Spanish linguistic backgrounds. The	Critical period in SLA	Provides statistical evidence against a strict critical period for SLA; language proficiency develops gradually with age,	Age-Related Effects

		second-language acquisition		data was derived from the U.S. Census of 1990.		highlighting continuous rather than categorical effects.	
21.	(Hao & Othman, 2021)	Automation of function assignment in the models of speech production and second language acquisition	Conceptual paper	-	Speech production modeling in SLA	Automation of function assignment may enhance the SLA. Proposed a computational model in which functional assignments within speech production are dynamically mapped in SLA, offering a novel framework for modeling learner output.	Phonological Processes
22.	(Hopp & Schmid, 2013)	Perceived foreign accent in first language attrition and second language acquisition: The impact of age of acquisition and bilingualism	Original Research	Individuals with the German language as their mother tongue living either in Canada or in the Netherlands, and individuals learning the German language as a second language.	Age, perceived foreign accent, and bilingualism	Both native speakers of the German language living in a foreign country and those living in Germany and learning the German language as a second language show the same accent and language fluency, indicating cross-linguistic interference; the study undermined the idea that learning a language from childhood can lead to native-like production and questions the validity of using monolingual standards to assess L2 ultimate attainment.	Age-Related Effects
23.	(Keijzer & Schmid, 2016)	Individual differences in cognitive control advantages of elderly late Dutch-English bilinguals	Original Research	Elderly Dutch-English bilinguals, long-term immigrants in Australia; L1 is Dutch and L2 is English	Cognitive control in aging bilinguals	No consistent group-level bilingual advantage was found in elderly late bilinguals; however, individual variation linked to language use context and education revealed nuanced cognitive benefits, especially in executive control and working memory.	Cognitive Functions
24.	(Khasinah, 2014)	Factors affecting second language acquisition	Review	-	Factors influencing SLA	Internal factors including individual personality, age, motivation, and aptitude and external factors including input quality, and learning context are key determinants of SLA success.	Psychological Variables

25.	(Kuhl, 2009)	Early language acquisition: phonetic and word learning, neural substrates, and a theoretical model Patricia K. Kuhl	Review	-	Early age phonetic learning and brain plasticity	Early language exposure is essential for phonetic learning, as infants exhibit neural specialization for speech sounds, reinforcing the brain's plasticity in early language acquisition.	Phonological Processes
26.	(Li et al., 2024)	Brain gray matter morphometry relates to onset age of bilingualism and theory of mind in young and older adults	Original Research	46 young, and 50 older bilingual adults	AoA, ToM, neural reserve	Early bilinguals exhibit greater GMV in ToM regions, indicating a neuroanatomical link between age of acquisition and social cognitive development.	Age-Related Effects
27.	(Liu et al., 2021)	Structural brain changes with second language learning: A longitudinal voxel-based morphometry study	Longitudinal Study	20 individuals who graduated recently from South China Normal University.	Brain structural changes in SLA	SLA leads to structural brain changes in language-related regions over time, supporting neuroplasticity through adult L2 learning.	Neural Mechanisms
28.	(Liu & Cao, 2016)	L1 and L2 processing in the bilingual brain: A meta-analysis of neuroimaging studies	Systematic synthesis	Neural imaging studies	Native language and second language processing in the bilingual brain.	Systematic synthesis uncovered neural pathway networks for native and second language handling, with differences determined by language ability and task requirements, highlighting neurocognitive divergence between L1 and L2. Second language learners of old age activate more regions in the brain than early age learners.	Neural Mechanisms
29.	(López-Barroso & de Diego-Balaguer, 2017)	Language learning variability within the dorsal and ventral streams as a cue for compensatory mechanisms in aphasia recovery	Brief literature review	-	language learning's neural pathways	Dorsal and ventral neural pathways are differentially engaged in SLA and aphasia recovery, offering a dual-stream framework for understanding compensatory mechanisms in language processing.	Neural Mechanisms
30.	(Luque & Morgan-Short, 2021)	The relationship between cognitive control and second language proficiency	Original Research	28 individual learners of English as a second language with Spanish as a first language.	Cognitive control and L2 proficiency	Enhanced cognitive control is linked to greater fluency in the second language, suggesting that executive function is an indicator of L2 successful mastery.	Cognitive Functions

31.	(Mackey & Sachs, 2012)	Older learners in SLA research: A first look at working memory, feedback, and L2 development	Original Research	Learners of English aged between 65 and 89 of Spanish origin.	Working memory, feedback use	Working memory capacity and explicit feedback use significantly enhance L2 achievement in individual learners of old age, emphasizing cognitive adaptability.	Cognitive Functions
32.	(Markiewicz et al., 2024)	Effects of healthy ageing and bilingualism on attention networks	Original Research	Adult learners who are Monolingual compared to other adults who are bilingual.	Aging, attention, bilingualism	Bilingualism in older adults preserves attention networks more effectively than monolingualism, supporting cognitive resilience through multilingual experience.	Cognitive Functions
33.	(Muñoz & Singleton, 2011)	A critical review of age-related research on L2 ultimate attainment	Scholarly critique	-	AoA and SLA outcomes	AoA significantly influences maximum achievement in SLA, with early starters generally outperforming late learners across proficiency measures.	Age-Related Effects
34.	(Park et al., 2012)	Language lateralisation in late proficient bilinguals: a lexical decision fMRI study	Original Research	8 late proficient bilinguals; L1 was Macedonian and L2 was English	Neural activation, bilingualism	fMRI results reveal that late bilinguals exhibit more bilateral neural activation during L2 lexical processing, suggesting less lateralized language representation compared to L1.	Neural Mechanisms
35.	(Phan & Ho, 2019)	Cognitive Factors in Second Language Acquisition: A Study in The English Language Faculty of Ba Ria Vung Tau University, Viet Nam	Mixed-method Research	Undergraduate English majors	Cognitive factors in SLA	Cognitive style and learner motivation are significant predictors of SLA outcomes, with high-motivation learners demonstrating stronger language performance.	Psychological Variables
36.	(Pongotak, 2024)	A Systematic Review: The Impact of CPH and Age on Second Language Acquisition in EFL Context	Systematic Review	7 empirical studies	Critical Period Hypothesis (CPH), age	Learners of L2 who are very young tend to attain higher rates of success than learners who are comparatively older, supporting claims that suggest that there is a sensitive period for SLA, where early exposure enhances outcomes.	Age-Related Effects
37.	(Singleton & Lesniewska, 2024)	The Role of Age in Second Language Development	Review	--	Age, bilingual development	Argues for a nuanced interpretation of age in SLA, emphasizing that input quality, motivation, and frequency of use	Age-Related Effects

						play pivotal roles alongside biological maturation.	
38.	(Stocco et al., 2014)	Bilingual brain training: A neurobiological framework of how bilingual experience improves executive function	Theoretical framework and review	-	Executive function and bilingualism	Proposes a neurobiological model where bilingualism enhances executive function through plasticity in the front striatal circuitry, supporting cognitive benefits of bilingual experience.	Cognitive Functions
39.	(Tsiplakides & Keramida, 2009)	Helping students overcome foreign language speaking anxiety in the English classroom: theoretical issues and practical recommendations	Classroom-based case study	High school English learners	Anxiety reduction in L2	Recommends practical classroom strategies, such as scaffolding, peer collaboration, and expressive tasks, to alleviate foreign language anxiety and promote communicative confidence.	Psychological Variables
40.	(Van Heuven & Dijkstra, 2010)	Language comprehension in the bilingual brain: fMRI and ERP support for psycholinguistic models	Review	--	L1-L2 processing, neuroimaging	ERP and fMRI evidence supports bilingual language comprehension as a process involving interactive activation across languages, consistent with psycholinguistic models of non-selective access.	Neural Mechanisms
41.	(Wang et al., 2020)	Functional and structural neuroplasticity associated with second language proficiency: An MRI study of Chinese-English bilinguals	Original Research	30 individuals who speak both Chinese and English.	L2 proficiency, brain plasticity	Higher L2 competence is linked to augmented volumes of the gray matter in particular zones of the brain, highlighting experience-dependent neuroplasticity in bilinguals.	Neural Mechanisms
42.	(Wattendorf et al., 2014)	Early bilingualism influences early and subsequently later acquired languages in cortical regions representing control functions	Original Research	Early bilingual adults	Language control, brain regions	Early bilinguals engage control-related cortical areas for both early and later learned languages, indicating shared neural mechanisms for language control.	Neural Mechanisms
43.	(Williams, 2020)	The neuroscience of implicit learning	Conceptual Review	--	Incidental phonological acquisition	Investigates data associating learning in general and language learning in particular to the function of the basal ganglia,	Cognitive Functions

						highlighting the part of understanding rules and principals unconsciously.	
44.	(Xie & Wang, 2024)	The Impact of Cognitive Control Ability on Second Language (English) Writing Performance	Original Research	58 Chinese-English bilinguals	Cognitive control, L2 writing	Cognitive control ability significantly predicts planning and fluency in L2 writing tasks, suggesting executive functioning as a key individual difference variable in SLA.	Cognitive Functions
45.	(Yum & Law, 2021)	N170 reflects visual familiarity and automatic sublexical phonological access in L2 written word processing	Original Research	Readers who are originally speakers of either Japanese, Chinese, or Korean.	L2 orthographic/phonological processing	N170 component reflects early visual word recognition and sound-based lexical retrieval regarding second language learners, indicating automaticity in bilingual reading processes.	Phonological Processes
46.	(Zhang et al., 2023)	Functional preference of the left inferior parietal lobule to second language reading	Original Research	Children of Chinese origin acquiring English.	L2 reading, brain activation	Neural imaging evidence demonstrates that the LIPL is functionally preferred by second language learners during reading tasks.	Phonological Processes