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NEUROLINGUISTIC CHALLENGES IN LEARNING FOREIGN LANGUAGES.

Termez State University
70230101 – Linguistics (English)
1st year master's student
Eshmurodova Muhayyo
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Abstract: Foreign-language learning is constrained not only by exposure and motivation but also by neurobiological limits and tradeoffs in how the brain represents speech, grammar, and meaning. Methods involved a structured narrative review prioritizing meta-analyses, longitudinal neuroimaging/ERP studies, and large-sample behavioral work. Results converge on several quantifiable patterns: grammar-learning ability shows a marked age-related decline after late adolescence in large-sample modeling (estimated turning point ≈ 17.4 years in one widely cited dataset). Age of acquisition effects appear robust even when bilingualism is controlled, with a factorial design study (n=80) reporting major age effects and minimal bilingualism effects on ultimate attainment. Neuroplastic changes occur in adults but often recruit control-related circuitry: a one-year longitudinal structural MRI study of Chinese university students showed gray matter volume reductions in left anterior cingulate cortex and right inferior frontal gyrus, with correlation between age of acquisition and volumetric change (r=0.595). Working memory shows a reliable, small-to-moderate relationship with L2 outcomes across large meta-analyses (ρ≈.255; and r≈.300 for L2 reading). Sleep supports consolidation of newly learned foreign words, including implicit measures; immersive learning environments can modulate this consolidation. The discussion integrates these findings into a practical neurocognitive framework: L2 learning difficulty spikes when phonological category formation, proceduralized grammar, and interference control compete for limited neural and cognitive resources, especially in learners with weaker working memory or reading-language vulnerabilities.

Keywords: second language acquisition; neurolinguistics; neuroplasticity; cognitive control; working memory; age of acquisition; sleep-dependent consolidation; dyslexia; developmental language disorder; fMRI; ERP.

Introduction Neurolinguistic “challenges” in foreign language learning are not excuses for failure; they are predictable constraints imposed by how the brain learns, stores, and controls language. The same learner can be strong in vocabulary but weak in pronunciation, or fluent in conversation but inaccurate in grammar, because different subcomponents rely on partly distinct learning mechanisms and neural circuits. A central implication is that “language ability” is not a single trait: it is an interaction between representational systems (sounds, words, syntax, discourse), memory systems (declarative vs procedural), and control systems that regulate attention and interference.

Age is the most publicly discussed constraint, often framed as a “critical period.” The strongest modern evidence is not that adults cannot learn languages, but that the probability of achieving fully native-like ultimate attainment decreases with later starting age, and that the shape of this decline depends on which component is measured (phonology vs grammar vs lexical knowledge). In a large-sample analysis of grammar-learning ability (with modeling aimed at separating age, age of first exposure, and years of experience), one estimate places the crux of preserved grammar-learning ability around 17.4 years, followed by steady decline. This

is not the only interpretation in the field, but it provides a concrete, testable benchmark for discussing age-related constraints.

Crucially, some debates confound "age of acquisition" with "being bilingual." If native speakers used as controls are monolingual while L2 speakers are bilingual, then differences might reflect bilingualism rather than late learning. A careful factorial design that crossed age of acquisition and bilingualism tested 80 Swedish speakers across phonetic, grammatical, and lexical measures and found consistent age-of-acquisition effects with only limited bilingualism effects—concluding that age of acquisition, not bilingualism per se, was the primary determinant of less-than-native ultimate attainment. For foreign-language education, that means later starting age can raise the difficulty ceiling even when learners are highly motivated and cognitively healthy.

A second major neurolinguistic barrier is interference. When two languages are active, competition emerges at multiple levels: phonology (accent), lexis (false friends), syntax (transfer), and discourse conventions. Managing this competition taxes the brain's cognitive-control architecture. Independent of language, meta-analytic evidence supports a "superordinate cognitive control network" involving dorsolateral prefrontal and anterior cingulate regions, among others, that is engaged when behavior requires conflict monitoring and goal maintenance. Language learning in adults often looks "hard" because it requires both new representations and heavy control demands to overcome entrenched L1 routines.

A third challenge is memory consolidation. Vocabulary and grammar do not become usable simply by exposure; they must be stabilized and integrated into long-term networks. Sleep is one of the best-established biological supports for consolidation. In foreign-language word learning, sleep-dependent gains can show up on explicit recognition and on implicit priming tasks, and the learning environment (e.g., richer sensory experience) can change how strongly consolidation appears on implicit measures. This is a neurolinguistic issue because it links classroom decisions (how learning is structured) to memory systems that operate during offline states.

Finally, individual differences are not noise; they are a core part of the neurolinguistic picture. Working memory is one of the most consistent predictors of L2 processing and proficiency. A major meta-analysis covering 79 samples (3,707 participants; 748 effect sizes) reported a positive association between working memory and L2 outcomes with an estimated population effect size $\rho=.255$. For L2 reading specifically, a meta-analysis of 74 studies (228 correlations) reported $r=.300$ and found that measurement practices in working memory tasks were key moderators. In addition, a meaningful minority of learners face neurodevelopmental vulnerabilities that directly affect language learning: dyslexia prevalence estimates vary by orthography and method, but a large cross-sectional study in Persian-speaking elementary students ($n=1,400$) reported a weighted dyslexia prevalence of 10.40% (95% CI: 9.00–12.05). Developmental language disorder/specific language impairment has also been estimated at 7.4% in an epidemiologic kindergarten study referenced in clinical summaries. These learners are not "lazy"; they face measurable processing constraints that influence foreign-language outcomes.

This paper therefore asks: which neurolinguistic mechanisms repeatedly constrain foreign-language learning, how strong is the evidence, and what principles follow for instruction and support?

Methods

Design. This study is a structured narrative review (not a new experiment). The goal is to synthesize real, published evidence on neurolinguistic constraints in foreign-language learning, prioritizing sources that include quantitative results (meta-analyses, large-sample behavioral analyses, and longitudinal neuroimaging/ERP designs).

Search strategy and sources. Searches targeted combinations of the following terms: second language acquisition; neurolinguistics; fMRI; EEG/ERP; age of acquisition; critical period; cognitive control; anterior cingulate; working memory; meta-analysis; sleep consolidation; dyslexia; developmental language disorder. Priority was given to peer-reviewed journal articles, systematic reviews/meta-analyses, and primary longitudinal neuroimaging studies. Examples of cornerstone sources included: a large-sample modeling paper on age effects in grammar learning, a factorial design study separating age of acquisition from bilingualism, a major working memory meta-analysis, an L2 reading–working memory meta-analysis, longitudinal structural MRI evidence of L2-learning-induced brain changes, sleep-dependent consolidation work using explicit and implicit measures, and prevalence/clinical evidence relevant to neurodevelopmental constraints.

Inclusion criteria. Studies were included if they (a) directly investigated foreign/second language learning or bilingual language control, (b) provided quantitative behavioral or neural outcomes, and (c) used empirical methods (experimental, longitudinal, meta-analytic, or systematic review). For neurodevelopmental conditions, studies were included if they reported prevalence or clearly operationalized reading/language impairment with standardized measures.

Data extraction. From each included source, we extracted: sample characteristics (age, n), design (cross-sectional/longitudinal/meta-analysis), main outcomes (effect sizes, correlations, prevalence, or reported neural changes), and the specific "challenge mechanism" addressed (age plasticity, control/interference, memory consolidation, or individual differences). We did not compute new meta-analytic estimates; instead, we report published effect sizes and statistics as given by the original authors.

Results

1. Age-related constraints: native-likeness vs learnability

The strongest quantitative evidence for age effects comes from large datasets and careful controls. In the large-sample grammar-learning analysis often cited in critical-period discussions, the authors report that grammar-learning ability is "preserved almost to the crux of adulthood (17.4 years old) and then declines steadily." Importantly, the interpretation is not that learning stops after that age, but that the rate/ceiling changes, making full native-likeness less likely without unusually extensive experience.

When bilingualism is controlled more explicitly, age remains a major factor. In Bylund et al. (2021), eighty Swedish speakers were grouped so that age of acquisition and bilingualism were fully crossed (including simultaneous bilinguals and international adoptees). The authors report consistent age-of-acquisition effects across most instruments and minimal standalone effects of bilingualism, supporting the claim that age of acquisition is the primary determinant of less-than-native ultimate attainment. This result matters because it reduces a common alternative explanation: that subtle differences from monolingual natives simply reflect bilingualism.

2. Neuroplasticity exists in adulthood, but it often tracks control and efficiency

Adult learners do show brain changes, but the pattern often suggests optimization and reallocation rather than a simple "more activation is better." A longitudinal voxel-based morphometry study followed Chinese college freshmen majoring in English, scanned twice one year apart. The authors report decreased gray matter volume in the left anterior cingulate cortex and right inferior frontal gyrus after one year of L2 learning, and note that these structural adaptations correlated with changes in language control ability. They also report that age of acquisition significantly predicted volumetric change in the left ACC, with a reported correlation $r=0.595$ (95% CI [0.207, 0.821], $p=0.009$). This is a key neurolinguistic pattern: language learning pressure can reshape control-related regions, and individual experience variables (AoA, proficiency) relate to how the brain adapts.

Relatedly, longitudinal resting-state fMRI work comparing English majors to non-English majors indicates that intensive L2 experience can alter the stability properties of the language control network. The study reports lower stability and higher instability in the language control network for English majors relative to non-English majors, and provides specific stability values (36.11% vs 51.72%) within their network fingerprinting framework. Even if one does not adopt their exact stability metric, the direction is informative: sustained learning experience reshapes control-network dynamics.

3. Cognitive-control burden: why interference feels "mentally expensive"

The cognitive-control explanation for L2 difficulty is not speculative; it aligns with meta-analytic evidence that a domain-general control network (including dorsolateral prefrontal and anterior cingulate regions) supports conflict monitoring and goal-directed behavior. In language contexts, this becomes relevant when learners must inhibit a dominant L1 response, manage competition during lexical access, or monitor grammar choices under time pressure.

Specific bilingual studies show that language proficiency modulates how control networks are recruited. For example, an event-related fMRI study on bilingual translators reports that second-language proficiency modulates the brain language-control network. The neurolinguistic implication is that "difficulty" is partly the cost of control: lower proficiency often requires more monitoring and inhibition to reach the same communicative outcome.

4. Working memory as a recurring bottleneck: Working memory is among the most replicated individual-difference predictors in L2 research. Linck et al. (2014) synthesized 79 samples (3,707 participants; 748 effect sizes) and found that working memory was positively associated with both L2 processing and proficiency outcomes, with an estimated population effect size ρ=.255. The study also reports larger effects for executive-control components of working memory than for pure storage measures, consistent with the idea that L2 learning heavily taxes control.

For reading in a foreign language, In'nami et al. (2022) meta-analyzed 74 studies (228 correlations) and reported a significant, small relationship between working memory and L2 reading (r=.300). Notably, they found that task design (whether working memory was measured in L1 vs L2; and reporting reliability) moderated the relationship more than learner proficiency did. This matters for research and practice: if you measure working memory poorly, you will misunderstand what learners can do.

5. Sleep-dependent consolidation: vocabulary is learned twice—online and offline

Sleep is increasingly treated as part of the language-learning mechanism rather than a lifestyle detail. A controlled study on foreign word learning compared a virtual reality learning environment with a traditional picture-word environment. Participants learned novel words (in Korean) across two days; consolidation was assessed with an explicit recognition task and an implicit primed lexical-decision task. The authors report sleep-dependent consolidation effects in both explicit and implicit measures, but only the primed lexical-decision task showed an influence of learning environment, suggesting better consolidation for words learned via VR. The practical neurolinguistic claim is narrow but strong: richer encoding conditions can change the strength of offline consolidation measured implicitly.

6. Neurodevelopmental risk: dyslexia and language disorder as "hidden" constraints

A major problem in foreign language education is that many students who struggle are treated as unmotivated, when a measurable subset has reading-language vulnerabilities. Dyslexia prevalence varies by language and method, but it is not rare. A cross-sectional study in Persian-speaking students (grades 2–5; n=1,400) reported a weighted dyslexia prevalence of 10.40% (95% CI: 9.00–12.05), with higher rates in boys (14.50%) than girls (6.01%). Because dyslexia involves persistent decoding/word-recognition difficulty, it directly impairs foreign-language

reading and spelling acquisition, especially in orthographies where decoding is a major gateway skill.

Developmental language disorder/specific language impairment is also common. Clinical summaries referencing epidemiologic work report a prevalence estimate of 7.4% (8% boys; 6% girls) among kindergarten children. Since grammar and morphosyntax are described as particularly vulnerable areas in SLI/DLD profiles, foreign language learning that relies on rapid morphosyntactic pattern extraction can become disproportionately hard for these learners even when general intelligence is typical.

Discussion

The evidence above supports a realistic, non-mystical conclusion: foreign-language learning difficulty emerges when the brain must simultaneously build new representations and run heavy control and memory-consolidation operations under time and exposure constraints. The "neurolinguistic challenges" are therefore best described as interacting bottlenecks rather than a single barrier.

Challenge 1: Phonological category formation under entrenched L1 perception

Although this review emphasized sources with explicit statistics, a consistent neurolinguistic theme across L2 phonology research is that learners perceive speech through L1-tuned categories. This makes certain contrasts hard to hear and produce, especially those not phonemic in the L1. The age-of-acquisition findings help explain why: early exposure increases the likelihood that the brain's auditory–motor mappings develop in a more native-like way, while later learners may require more explicit strategies and control support to overcome entrenched mappings. The age-of-acquisition study controlling bilingualism reinforces that timing, not bilingualism itself, drives many ultimate attainment limits.

What follows as a principle is not "adults can't learn pronunciation," but that late learners often need more targeted perceptual training and feedback loops to get comparable category learning. If an educational system ignores this and relies only on reading and vocabulary drills, it is structurally setting learners up for fossilized accent and listening difficulties.

Challenge 2: Grammar as a control-and-proceduralization problem

Grammar learning has at least two phases: explicit knowledge (rules you can state) and proceduralized skill (fast, automatic use). Neurolinguistically, late learners can often acquire explicit rule knowledge but struggle to proceduralize it to native speed. The large-sample grammar-learning analysis implies that the learning system supporting grammar changes with age, with a turning point in late adolescence in their model. That does not prove a single "critical period," but it strongly suggests that adult grammar learning may rely more on compensatory mechanisms (attention, working memory, explicit reasoning) to reach high performance.

The longitudinal structural MRI evidence is consistent with this: control-related regions such as ACC and IFG show measurable structural adaptation after intensive learning, and these changes relate to language control ability. If grammar learning in adults leans heavily on control circuitry, then classrooms that overload students with complex structures without sufficient automatization practice will magnify the bottleneck.

Challenge 3: Interference and the real cost of bilingual control

Interference is not a metaphor; it is a consequence of competition in neural representations. Domain-general control networks involving dorsolateral prefrontal and anterior cingulate structures are well supported by meta-analysis as the machinery for conflict monitoring and goal maintenance. When learners must suppress L1 lexical candidates, inhibit literal translations, or choose among competing syntactic frames, they are effectively running conflict tasks continuously.

Longitudinal work suggests that sustained L2 experience changes control network dynamics—English majors show reduced stability and increased instability in language control networks compared to non-English majors, indicating adaptive reorganization. This also clarifies why foreign language learning can feel "mentally draining": the learner is not just memorizing words; they are building a control system that can manage cross-language competition in real time.

Challenge 4: Memory consolidation limits—learning does not end when class ends
Vocabulary acquisition often looks like a simple mapping problem (word ↔ meaning), but the neurolinguistic reality is that new words must become integrated so they can be accessed quickly and can prime related words. Sleep-dependent consolidation provides one pathway for this integration. Evidence shows sleep-dependent effects on both explicit recognition and implicit priming for newly learned foreign words, and that learning context can modulate implicit consolidation.

A hard implication is that "more homework" is not automatically better if it reduces sleep or increases stress; the brain may lose consolidation opportunities. Equally, teaching methods that enrich encoding (multisensory, context-rich learning) can improve later automaticity, which is precisely what learners experience as "fluency."

Challenge 5: Individual differences are structurally important, not marginal
The working-memory meta-analytic evidence is too large to ignore. A population effect size around ρ=.255 across 3,707 participants means working memory differences reliably relate to L2 outcomes, with executive control playing a particularly strong role. For L2 reading, r=.300 suggests a consistent relationship, but also warns that measurement practices can distort conclusions.

For education, this implies that one-size-fits-all pacing will systematically disadvantage learners with lower working memory capacity, especially on tasks that require simultaneous processing (listening while planning speech; reading complex sentences while tracking discourse). The correct response is not to lower standards, but to design instruction that reduces unnecessary working memory load (clear task goals, chunking, repeated retrieval, and gradual speed-up).

Challenge 6: Neurodevelopmental vulnerabilities can mimic "low motivation"
Dyslexia and DLD/SLI illustrate how neurolinguistic constraints can appear as "poor effort" if teachers are not trained to recognize them. If around one in ten students in a sample meets operational criteria for dyslexia, then a typical classroom will include multiple learners who may struggle severely with decoding-based foreign language instruction. DLD prevalence estimates around 7% in early populations suggest additional learners for whom grammar and morphosyntax are unusually fragile.

The educational principle here is simple: when foreign-language instruction is heavily text-based, these students may need alternative routes (more auditory/oral work, structured phonological support, explicit decoding interventions) to access the same communicative outcomes. Ignoring this is not "rigor"; it is mismeasurement of ability.

Limitations of the evidence base Several limitations should shape how confidently you write conclusions. First, neuroimaging studies often have modest sample sizes; although longitudinal designs are powerful, generalization must be cautious (e.g., the structural MRI study's final sample was 20 participants). Second, "age effects" are sensitive to how proficiency is measured and how exposure is quantified; even large-sample models are debated and can be reanalyzed with different functional forms. Third, meta-analytic effect sizes like r=.300 or ρ=.255 are meaningful but not destiny; they indicate probabilistic constraints, not fixed ceilings.

Conclusion

Neurolinguistic challenges in foreign-language learning are best explained as interacting constraints: age-sensitive plasticity affects the probability of native-like attainment; interference requires cognitive control; memory consolidation depends on offline processes like sleep; and individual differences—especially working memory and reading-language vulnerabilities—shape the pathway each learner can realistically follow. The strongest evidence-based stance is neither pessimistic nor naive: adults and adolescents can learn languages well, but they often do so through heavier reliance on control and explicit learning systems, and they are more vulnerable to overload. The practical lesson for research and instruction is to stop treating "difficulty" as a single trait and instead diagnose the bottleneck: phonological categories, proceduralized grammar, interference control, consolidation opportunities, or neurodevelopmental risk. When the bottleneck is correctly identified, the learner's trajectory becomes far more predictable—and improvable.

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