Age and Language Learning a Comparative Study of Young and Adult Learners with Data Fusion Perspectives

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Abstract

This study investigates the influence of age on second language acquisition by comparing language learning outcomes between young learners (aged 8–12) and adult learners (aged 25–40). Drawing on both cognitive and sociolinguistic perspectives, and leveraging data fusion techniques that integrate test results, classroom observations, and learner interviews, the research examines differences in pronunciation, grammar acquisition, vocabulary retention, and communicative competence. The fusion of multiple data modalities ensures a more holistic view of learner performance. Findings indicate that young learners exhibit greater native-like pronunciation and long-term retention, while adult learners outperform in grammatical accuracy and metalinguistic awareness. Motivational factors and learning environments also played significant roles. The study concludes that while age affects specific aspects of language learning, no age group holds a universal advantage. Data fusion-based insights highlight the need for age-sensitive instructional strategies that cater to the cognitive and emotional needs of learners at different stages.

Keywords: Adults; Age influence; Cognitive skills; Communication; Data Fusion; Fluency; Grammar; Learning motivation; Pronunciation; Retention; Vocabulary

1. Introduction

Academics in linguistics, psychology, and education have debated the relationship between chronological age and second language acquisition (SLA). A person's mental, social, and emotional state influences learning and multiple factors converge to shape outcomes. To capture these multidimensional aspects, data fusion approaches are increasingly adopted, combining quantitative test scores, classroom engagement metrics, and sociolinguistic observations. Such fusion allows researchers to better evaluate learning trajectories across different age groups. In this study, we extend traditional SLA perspectives by embedding data fusion methodologies to systematically analyze outcomes across young and adult learners.

1.1 Current Developments

The Critical Period Hypothesis (CPH) has had a big impact on the area of second language acquisition (SLA). This idea posits that language learning often occurs during infancy, a period characterized by peak physical development. Researchers such as Lenneberg (1967) and Newport (1990) discovered that individuals have a rapid loss in their capacity to acquire a new language, especially regarding phonetics and pronunciation, once reaching puberty. Many people have wanted to add a second language to the primary school curriculum because teachers and politicians believe that learning it early on would make you fluent in it. This hypothesis helped the effort to make it easier for people to learn a second language. Recent research has questioned the efficacy of a definitive decrease post-infancy, leading to the proposal of a more sophisticated model of age-related changes. No matter how much power the CPH has, this will still be true. Scientific research indicates that primary school students can replicate native speakers' pronunciation with enhanced precision and are more sensitive to nuanced sound

DOI: https://doi.org/10.54216/FPA.210214
Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

differences. On the other hand, kids normally take their time when it comes to acquiring new words and linguistic abilities. One reason for this is that their brains are still developing, which means they cannot think in abstract ways yet. Adults may find it easy to learn grammar, recall new vocabulary, and use good study habits, but they typically have trouble creating phonological patterns that are as good as those of native speakers. New research in neuroscience demonstrates that neuroplasticity does not completely go away with age; it only becomes a little less strong, which makes the problem much harder to solve. Even after becoming an adult, the brain's neural networks may continue to change a lot. This might make it easier to learn new things, including languages. Sociolinguistic research has identified three additional characteristics that might mitigate age-related differences. Some of these elements include the learning environment, exposure to other cultures, and the desire to learn. For instance, an adult with strong professional or personal goals may be better at communicating in supportive or immersive learning contexts than a younger learner. Another effect of migration, globalization, and the spread of foreign cultures is that being able to speak more than one language is becoming more important for individuals of all ages. One way that the government is trying to improve children's educational possibilities is by putting second language programs in schools. On the other hand, many individuals look for chances to learn new languages so they can get ahead in their jobs, fit in better with their communities, or become better people. SLA will be a significant theoretical concern and practical challenge in the domains of education and governance for the next decades. Everyone, no matter how old, has to take this exam because it is important for society as a whole to work well.

1.2 Principal

The purpose of this study is to find out how various groups of individuals gain from learning a second language (SLA) in terms of pronunciation, grammar, vocabulary retention, and communicative competence, and how different ages affects different elements of SLA. One thing that makes kids great learners is that they typically learn how to pronounce words correctly from their early experiences. This is why individuals sometimes try to sound like native speakers. This skill is linked to their greater capacity to respond to new stimuli and their better ability to handle sound input. On the other hand, adult students seldom reach the same level of phonological correctness, and even fewer demonstrate extraordinary skill when using the language. When learning grammar, you have to follow a set method. Young kids frequently learn grammar rules on their own via practice, so you do not normally need to explain them in detail. On the other hand, adults benefit from formal grammar training since they have the mental ability to think about rules and employ them in a smart way. Adults are more likely than children to acquire a new language quickly are. This is because adults are more likely to hear the language spoken more regularly. People that can think more critically, remember things better, and have lived longer tend to learn new words faster than others do. Younger students may be better at remembering things when they learn a new language in a fun and useful way than adults [1-2]. The concept of communicative competence cannot be easily correlated with age-related expectations, since it is complex and includes fluency, pragmatics, and interactional skills. Young people are frequently creative, adaptive, and flexible when it comes to how they talk to other people. Adults may exhibit more cultural awareness, comprehension of pragmatics, and approaches to civility in comparison to youths. Given the intricate nature of the topic, it seems that elements beyond chronological age, such as environmental context and intrinsic motivation, influence communication proficiency. The principal hypothesis of this research is that no universal or linear correlation exists between age and achievement. This is the key premise that this analysis will test. When it comes to SLA (second language acquisition), the skills that adults and younger pupils have are good for each other. Cultural background preferred learning styles, cognitive maturity, and individual variability are all factors that affect how these talents develop. To come up with teaching methods that work for students of all ages, you need to have a good understanding of these dynamics.

1.3 Solutions Proposed

Because young and adult learners are different, it is important that good solutions incorporate teaching methods that are appropriate for their age. Teachers of young kids should emphasize the significance of context- and implicit-based learning. Kids would be more likely to use their innate aptitude to learn via exposure to sounds and structures. Activities like storytelling, music, role-playing, and games may get kids interested and provide them many chances to use language. By putting language into real-life discussions, immersive spaces and interactions with peers may make learning even better. Conversely, a defined curriculum and focused teaching are more efficacious for adult learners. They are open to grammatical explanations, mistake corrections, and analytical tasks because they are good at abstract thinking and metalinguistic analysis [3–4]. Using technology-assisted tools like online forums, virtual classrooms, and mobile applications gives you freedom and flexibility. Learning a language and working on task-centered problem-solving tasks provide you chances to put what you have learned into practice. Another good thing is that they might truly be useful in real life. These methods work because individuals want to study on their own time and want to find a way to reconcile education with other responsibilities. In addition to that, talk about the mood and the drive. Kids frequently care a lot about having good schools, having their family engaged, and getting helpful feedback from their teachers. Adults, on the other hand, are generally motivated by more practical goals, like getting ahead in their jobs or relocating to a new area. Therefore, to teach

DOI: https://doi.org/10.54216/FPA.210214
Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

effectively, you need to concentrate on adults' pragmatism, relevance, and goal orientation, while simultaneously increasing younger pupils' intrinsic drive via fun and fascinating activities.

The findings of this research indicate that effective language lessons should not differentiate pupils based on age; rather, they should acknowledge and enhance the abilities of each individual learner. This research seeks to provide information derived from the comparison of learning outcomes across several age groups, which may be used to influence instructional methodologies, language policy, and curriculum development. The results should be relevant to adolescents of all age categories.

1.4: Important Realizations

This study has led to several important results and improvements, including:

This article looks at the differences and similarities between how adults and kids learn. Some of the subjects covered include pronunciation, grammar, vocabulary, and how to talk to people.

Studies indicate that younger children outperform older ones in aspects such as natural-sounding speech and long-term memory. On the other hand, older youngsters are better at metalinguistic awareness, vocabulary expansion, and grammatical precision.

This research mainly seeks to investigate how intrinsic motivation, contextual factors, and instructional methodologies influence the second language learning results of the two participant groups.

This study challenges the traditional, reductive interpretation of the Critical Period Hypothesis by demonstrating that age is only one of numerous interconnected factors that affect second language acquisition proficiency.

It suggests age-appropriate and individualized teaching methods that take into account each student's distinct mental and emotional needs.

This journal focuses on educational policy, teacher training, and curriculum creation for students of all ages, with the goal of offering practical ideas for improvement.

This work contributes to the interdisciplinary research on second language acquisition (SLA) by using methodologies from cognitive science, sociolinguistics, and education.

This article shows that no age group has an advantage over another and that we should regard what we know about how children and adults learn as working together.

2. Related Works

There are now several ways to teach kids a second language that work for kids of all ages, degrees of intelligence, and levels of interest. Reading a lot, memorizing new words, and strictly following the rules of grammar are all important parts of the Grammatical-Translation Method. This way of doing things goes back a long time. It may make phrases that are technically accurate, but it typically makes pronunciation less natural, speaking less fluent, and overall language competency lower. Younger kids learn best when they are in a place that is both participatory and authentic. In contrast, the Direct Method focuses on being aware of the context, repeating vocalizations, and being completely immersed in the target language. Students may improve their interest, pronunciation, and fluency by using this strategy. On the other hand, it seems sensible to think that younger pupils could require more help to learn more complex grammatical rules. The audio-lingual method is well known for how much it focuses on repeating patterns, copying movements, and doing workouts over and over again. It does help with pronunciation and listening comprehension, but it could make it harder to use language creatively and talk to people on the go. The major goal of Communicative Language Teaching is to help students improve their vocabulary, fluency, pragmatic awareness, and self-confidence in real-life circumstances. The goal is to get students to actively participate in meaningful discussions. To reach this aim, it's important to get students to join in on debates that make them think. This method works well for students of all ages, but it works best for younger kids since it is fun and participatory [5–7]. Students may learn the target language by doing things in real life. This method of teaching language is called "Task-Based Language Teaching." It mixes addressing real-world problems with learning the language. This method is very helpful for students of all ages since it focuses on communication, active learning, and remembering new words and grammar standards. The Total Physical Response method combines language learning with physical exercise to help people learn in many different ways. Kinesthetic reinforcement is very helpful for younger children since it helps them pronounce words better, remember things better, and learn the material with less brainpower. Content and Language Integrated Learning (CLIL) is a way to learn that combines language studies with the teaching of certain subjects. It helps students learn new words and understand what they read better by putting them in real-life settings. This method would be quite helpful for adult students who are analytical thinkers and can manage a lot of information. Younger kids do better with controlled and meaningful experiences [8–10]. The Natural Approach is a terrific technique to assist younger pupils to do well in school by

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Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

teaching them phonetics, how to listen, and how to remember things. The natural approach puts understanding and using highly relevant knowledge ahead of direct teaching. Suggestopedia may help you study without stress or concern by using things like music, relaxation methods, and positive suggestions. You may be able to boost participation, motivation, and memory using this method. This method works very well for kids who do well with tactics that are both emotionally supportive and immersive. People of all ages may benefit from its effectiveness. The Lexical Approach's main purpose is to help people learn fixed phrases and collocations. It also focuses on helping people improve their vocabulary, fluency, and functional communication abilities. This strategy may help all kids, but it can help adults much more when it comes to learning and remembering things since it gives them a controlled place to use their brains and thinking skills.

According to the results of comparing several methodologies, there are clear changes that happen as people become older. Using Total Physical Response, Communicative Language Teaching, and the Natural Approach as soon as possible helps children do better in terms of engagement, pronunciation, and remembering what they learned for a long time. These approaches are participatory, use several senses, and put you in the middle of the action. Grammar-translation and other traditional approaches that put grammar first make students less interested and slower to improve their pronunciation. This is not the best way to learn, as experience and play are the best ways to learn. There is a link between the two, but this goes against that. Adults, on the other hand, do better than younger children in grammar learning, vocabulary retention, and completing tasks that have been given to them [11–13]. Adults are more likely to study with a goal-oriented attitude, an analytical eye, and an awareness of metalinguistics. Grammar-translation, task-based language teaching, the lexical approach, and CLIL teaching methods provide adults a strong base to become fluent, correct, and skilled in the target language with real-world uses. These techniques combine direct teaching with activities that are either task-based or communicative in nature to help students reach their objectives. A variety of critical things, such as cognitive load, engagement, and memory retention time, affect both sets of data. This is why it's so vital to apply age-appropriate and context-sensitive tactics in the classroom. It seems that various cohorts of second language learners may get the most advantage from distinct teaching methodologies, taking into account their ages, cognitive abilities, and emotional requirements. Based on what has been said, this is definitely possible.

3. Proposed Methodology

The suggested method provides a comprehensive and unified framework for examining second language acquisition scientifically across various age demographics. The framework is meant to show how well pupils are doing overall and how they are improving by focusing on grammatical skill development, vocabulary growth, and effective communication. At the beginning of the school year, every student takes a test that checks his or her vocabulary, language abilities, and ability to think. These judgments must be part of any effort to guess and keep track of future improvement. During the whole lecture, language acquisition is carefully and routinely monitored. To reach this aim, it is important to write down every word, phrase, and grammatical point that was taught in class. You may write these thoughts down while watching the teacher work, doing an interactive exercise, or doing an assignment. Normalized assessments do not evaluate natural potential; instead, they show real learning since student improvement is based on their cognitive and language skills. This kind of examination gives more accurate outcomes, which is why. We always keep track of how much the learners are becoming better, both as a group and as individuals. This makes it possible to make important age comparisons and keep track of trends in retention, consistency, and possible regression over time. We may use statistical indicators like standard deviation, variance, and progress ratios to check the data's accuracy and locate the students that need additional attention. Students may enhance their syntax, sentence structure, and interactional competency by learning grammar and communication skills in a manner that helps each student depending on their overall and normalized development. This makes sure that the words that kids already know are in their new vocabulary. The main part of this function is learning new words. To provide updated assessments that accurately represent both theoretical comprehension and practical use of the language, it is advisable to include weekly performance increments together with observed participation and interaction metrics [14–16]. The goal of the combination is to do this. We utilize their group averages and percentile rankings to compare students in the same cohort. These rankings and averages demonstrate what people want to study, what they are good at and what they need to work on, and what language gaps they have because of their age. You can figure out the probable advantages of ongoing training by guessing how learning will change in the future. These trajectories could help us understand how likely it is that development and retention will happen over a longer period. Integrated performance evaluations try to provide a whole picture of a person's language skills by looking at their syntax, grammar, vocabulary, and how well they communicate with others. Nevertheless, deviation studies could assist in locating those who are doing well and others who need additional aid. Weighted learning efficiency, which looks at the speed of development and the consistency of progress across time, may help us get a better overall picture of how well various teaching methods work. When we use normalized progress trends, we can consistently compare how different learners are doing in their learning. As a result, we can see how well individuals can remember and organize what they know over time. The approach

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Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

also includes qualitative observations. These observations include the students' participation in class, their conduct, and the pedagogical methods used. We may utilize these insights to better comprehend what the learners went through and put the numbers in context. At the end of the class, the final report scores incorporate all the information about individuals and groups. Some of these assessments include general competence indices, percentile scores, and status indicators [17–20]. These scores also show developmental patterns and percentile rankings. This multi-dimensional model provides a data-driven, rigorous, and age-appropriate approach to second language learning. This method looks at how growing your cognitive skills, learning new words, being good at grammar, and being able to express yourself all work together. There are four parts to the system: continuous tracking, statistical validation, cumulative progress assessment, and normalization based on ability. All of these pieces work together to deliver accurate evaluations of how well students are doing, find areas where they need more help, and give teachers helpful information for making good teaching plans. This strategy not only looks at the present findings, but it also makes predictions about how language learning could progress in the future. This opens the door for further study into how age, cognitive qualities, and instructional design all work together when it comes to learning a language, remembering things, and becoming competent. As its guiding principles say, this technique encourages personalized learning strategies that take into consideration each student's unique requirements as they grow and change.

Algorithm: Systematic Estimation and Normalization of Vocabulary Growth through Cognitive Aptitude and Instructional Exposure Tracking.

Steps:

Step 1: Initialization of baseline scores and aptitude

$$V_i^0 = \text{Initial vocabulary score of learner } i \qquad (1)$$

Sets the starting vocabulary knowledge for each learner, serving as a baseline for measuring progress.

$$MLAT_i = \text{Aptitude score of learner } i \qquad (2)$$

Represents cognitive aptitude measured via the MLAT, allowing normalization of growth across learners.

$$\overline{V^0} = \frac{1}{N}\sum_{i=1}^{N} V_i^0 \qquad (3)$$

Computes the average initial vocabulary score for the group, providing a benchmark for evaluating individual progress.

Step 2: Compute initial normalized growth

$$VG_i^0 = \frac{V_i^0}{MLAT_i} \qquad (4)$$

Normalizes baseline vocabulary by aptitude to allow fair comparisons across learners.

$$\overline{VG}0 = \frac{1}{N}\sum i = 1^N VG_i^0 \qquad (5)$$

Provides the average normalized growth at the start, which acts as a reference point for weekly improvements.

Step 3: Weekly instruction and vocabulary accumulation

$$V_i^t = V_i^{t-1} + \left|\text{NewWords}_i^t\right| \qquad (6)$$

Updates each learner's vocabulary weekly by adding newly introduced words, reflecting incremental learning.

Step 4: Track cumulative vocabulary and retention

$$CV_i^t = \sum_{k=1}^{t} V_i^k \qquad (7)$$

Captures the learner's total vocabulary exposure over weeks, useful for analyzing overall growth trends.

$$Forgotten_i^t = \sum_{k=1}^{t} F_i^k \qquad (8)$$

Monitors the number of forgotten words each week, providing insight into retention and decay patterns.

Step 5: Compute weekly gain and weighted growth

$$\Delta V_i^t = V_i^t - V_i^{t-1} \qquad (9)$$

Measures the number of new words learned during a week, representing short-term growth.

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$$WG_i^t = \frac{\Delta V_i^t}{MLAT_i} \quad (10)$$

Normalizes weekly gain by aptitude to ensure fair comparison between learners with different cognitive capacities.

Step 6: Update cumulative and group-level metrics

$$CVG_i^t = \sum_{k=1}^{t} WG_i^k \quad (11)$$

Summing weighted growth over weeks captures each learner's overall progress, accounting for aptitude differences.

$$\overline{CVG}group^t = \frac{1}{N}\sum i = 1^N CVG_i^k \quad (12)$$

Provides the group average of cumulative growth, serving as a benchmark for individual comparisons.

$$GR_i^t = \frac{\sum_{k=1}^{t}\left(V_i^k - V_i^{k-1}\right)}{t} \quad (13)$$

Calculates weekly growth rate, reflecting the pace of vocabulary acquisition over time.

Step 7: Retention and decay

$$Ret_i^t = \sum_{k=1}^{t} CorrectRecall_i^k \quad (14)$$

Measures the total number of correctly recalled words, indicating memory retention.

$$Decay_i^t = \sum_{k=1}^{t} Forgotten_i^k \quad (15)$$

Summarizes forgotten words to assess vocabulary decay, similar to anomaly detection in expected performance.

Step 8: Normalize cumulative growth across aptitude

$$NG_i^t = \frac{\sum_{k=1}^{t} WG_i^k}{MLAT_i} \quad (16)$$

Normalized cumulative growth allows fair comparison across learners with different aptitude levels.

$$\overline{NG}group^t = \frac{1}{N}\sum i = 1^N NG_i^t \quad (17)$$

Average normalized growth shows group-level learning trends.

$$RG_i^t = \frac{\sum_{k=1}^{t}\left(V_i^k - V_i^0\right)}{t} \quad (18)$$

Retention-adjusted growth rate estimates long-term vocabulary accumulation per week.

Step 9: Adjust for irregular attendance

$$V_i^t = V_i^t - \sum_{missed} Penalty \quad (19)$$

Corrects vocabulary scores for learners who missed sessions, maintaining consistency and fairness.

Step 10: Variance and standard deviation for group consistency

$$s^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(VG_i^t - \overline{VG}^t\right)^2 \quad (20)$$

Variance quantifies the dispersion of normalized growth across learners, showing consistency in learning rates.

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(VG_i^t - \overline{VG}^t\right)^2} \quad (21)$$

Standard deviation provides a normalized measure of variability, useful for detecting outliers.

Step 11: Statistical significance testing between groups

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$$t = \frac{\overline{VG}young - \overline{VG}adult}{\sqrt{\frac{s_y^2}{N_y} + \frac{s_a^2}{N_a}}} \quad (22)$$

Evaluates whether differences in vocabulary growth between young and adult learners are statistically significant.

$$p = P(T > t) \quad (23)$$

Gives the probability that observed differences occurred by chance.

$$CI = \overline{VG} \pm t_{critical} \cdot \frac{s}{\sqrt{N}} \quad (24)$$

Computes confidence intervals for mean normalized growth, providing a range of plausible values.

Step 12: Log qualitative observations

$$Obs_i^t = TeacherNotes_i^t \quad (25)$$

Captures teacher observations for each learner.

$$Theme_i^t = \sum_{k=1}^{t} Obs_i^k \quad (26)$$

Aggregates observations over weeks to detect recurring behavioral or motivational themes.

Step 13: Compare individual to group trends

$$Diff_i^t = CVG_i^t - \overline{CVG}_{group}^t \quad (27)$$

Measures how far each learner deviates from the group average, identifying exceptional or struggling learners.

$$Outlier_i^t = |Diff_i^t| > 2s \quad (28)$$

Detects learners whose performance significantly differs from the group, similar to anomaly detection.

Step 14: Project future gains

$$V_i^{t+1} = V_i^t + GR_i^t \quad (29)$$

Predicts next-week vocabulary score using observed growth rates.

$$\overline{V}projected = \frac{1}{N}\sum i = 1^N V_i^{t+1} \quad (30)$$

Estimates projected group mean vocabulary for planning instruction.

Notations

$\boldsymbol{V_i^t}$– Vocabulary score of learner i at week t

$\boldsymbol{A_i}$ –Language aptitude score of learner i

$\boldsymbol{\Delta V_i^t}$ –Vocabulary gain of learner i in week t

$\boldsymbol{NV_i^t}$– Normalized vocabulary score of learner i at week t

$\boldsymbol{CV_i}$ –Cumulative vocabulary growth for learner i

$\boldsymbol{\overline{CV}}$– Group-level average cumulative vocabulary

$\boldsymbol{R_i^t}$– Retention measure of learner i at week t

$\boldsymbol{\sigma_i^2}$ – Variance in vocabulary scores for learner i

$\boldsymbol{SD_i}$– Standard deviation of vocabulary scores

$\boldsymbol{PG_i^t}$ –Projected vocabulary gain for learner i

$\boldsymbol{L_i}$ –Learning trajectory measure for learner i

$\boldsymbol{\theta_i}$– Adjustment factor based on aptitude

$\boldsymbol{W_i^t}$– Weighted vocabulary growth for learner i

$\boldsymbol{S_i^t}$ –Short-term improvement score

$\boldsymbol{T_i}$ – Total words learned by learner i

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Algorithm is designed to systematically estimate vocabulary growth in learners by integrating performance, cognitive aptitude, and instructional exposure over time. The process begins by establishing baseline vocabulary scores for each learner and assessing their individual language aptitude, which serves as a reference point for comparing learning progress. Students' vocabulary is checked on a regular basis during their study. The tracking procedure considers the words that have been taught via different activities, assignments, and exercises in the classroom. We may be able to construct a standardized test of vocabulary expansion that better shows real learning than assessments of intrinsic ability alone [21–23]. To achieve this goal, each session should focus on students' strengths and weaknesses. The algorithm keeps track of each student's overall development and the average progress of the group. This lets us compare how young people and adults learn. We can identify long-term patterns of retention or attrition by comparing historical data with present results. This is one technique to keep track of consistency and retention. Statistical analysis is used to determine the presence of significant differences among groups. In addition, qualitative observations are employed to put individual differences and learning processes into perspective. In addition, it can replicate learning paths and growth patterns, and it can even guess what new words someone would acquire if they kept practicing. The first algorithm provides a comprehensive method for understanding how an individual learns a new language. To achieve this goal, the method includes individual monitoring, cumulative assessment, statistical validation, and standardization based on aptitude. The study might shed insight on the effects of aging on language acquisition and memory by documenting both immediate enhancements and enduring patterns.

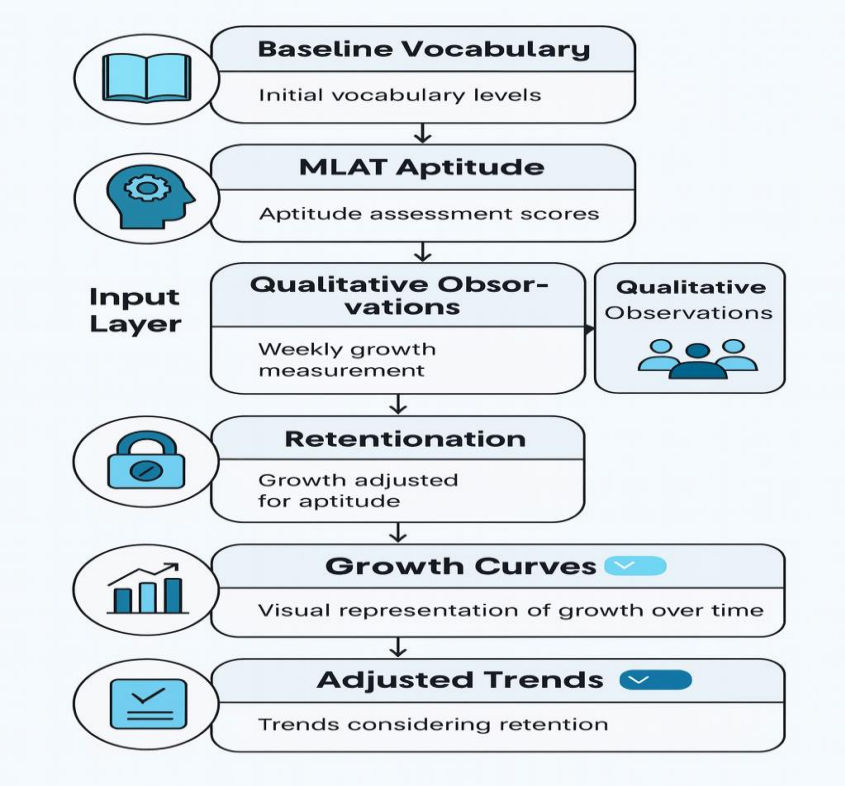

Figure 1. Systematic methodology for analyzing vocabulary acquisition and language learning progress in young and adult learners.

Figure 1 shows that people of all ages, from babies to adults, may benefit from having their second language acquisition recorded and assessed. The first thing to do is find out how the students assessed their vocabulary and skills at the beginning. Thereafter, pupils take a test to find out what level of skill they are at. Weekly instruction introduces new vocabulary, which is added to cumulative scores while retention and forgetting are monitored. Weighted growth is computed and normalized by aptitude to ensure fair comparison [24-27]. Group averages and variability are analyzed, with adjustments for absences and outliers to maintain data accuracy. Statistical tests compare performance between age groups, and teacher observations are logged for qualitative insights. Finally, future vocabulary progress is projected and cumulative and normalized growth are summarized, providing a comprehensive view of learners' language development.

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Initially, cumulative weighted growth (CVG) and normalized growth (NG) from Algorithm 1 serve as inputs to establish personalized grammar and syntax potential. Baseline grammar $(G_i^0)$and syntax (S_i^0)scores are adjusted by NG to account for vocabulary development differences. Weekly instruction increments grammar and syntax scores, which are then combined with interaction metrics to calculate adjusted communicative competence $(Adj\ CC_i^t)$.Group-level averages and improvement ratios are computed to benchmark individual learners against peers. Variance and standard deviation capture dispersion in competence, identifying learners needing additional support. Statistical t-tests compare young and adult learners, highlighting significant differences in grammar acquisition and communication skills. Weekly projections estimate next-stage competence, while error adjustments refine scores to reflect real communicative performance. By the end of the instructional period, cumulative adjusted competence $(Final\ CC_i)$ summarizes each learner's progress. This methodology ensures that grammar and communication development are directly informed by prior vocabulary growth, enabling a cohesive, data-driven, and age-sensitive approach to second language acquisition.

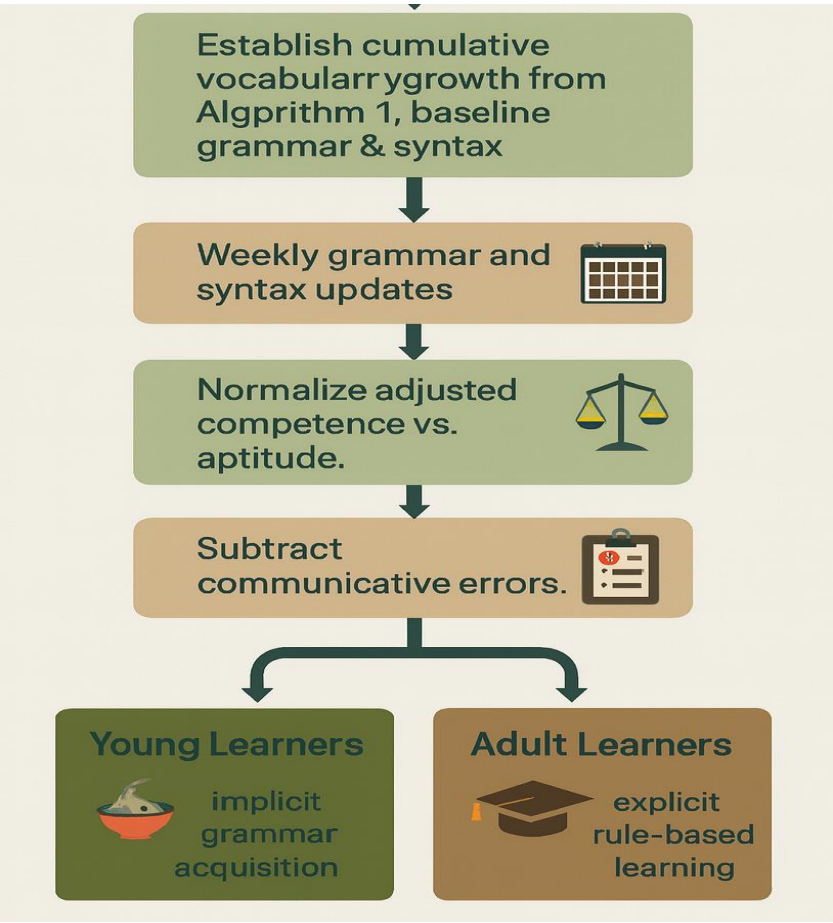

Figure 2. Evaluating Age-Based Language Learning Competence.

Figure 2 shows the evaluation of Age-Based Language Learning Competence once the weighted growth data and data collection are complete; we set baseline scores for syntax, aptitude-adjusted competence, and cumulative vocabulary. You might improve your understanding of grammar and syntax with weekly updates from exercises and comments. Next, we will examine metrics linked to syntax, interaction, and language to figure out what communicative competency means. Projected competence is better than group averages for predicting future student performance. Improvement ratios and error fixes are often used to provide standardized progress measurements. We utilize statistical comparisons to see how different young and adult learners are, and we use variance and standard deviation to assess how reliable the findings are. The total of everyone's scores at the end of the day will be the final test of their skills.

Weighted normalization may be used to provide a single integrated performance score by integrating cumulative competence and improvement ratios. Using probability matrices, we can predict how well someone will learn in the future. Standard deviation and variance metrics let us keep track of dependability and consistency throughout

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Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

the learning process. The final student results are calculated using integrated metrics, which comprise normalized competence ratings and assessments of syntax, interaction, grammar. Group-level averages provide benchmarks, and deviation analysis identifies top performers. Percentile ranks convert scores into comparable metrics across the cohort. Weighted learning efficiency evaluates performance over time, accounting for pace and progress [28-29]. The final learning index combines efficiency with performance score, while improvement trends and normalized trends allow standardized trajectory comparisons. The algorithm concludes with the generation of comprehensive report metrics, integrating final index, trends, percentile rank, and top-performer status. This methodology ensures a robust, multi-dimensional assessment of learners, accounting for cumulative performance, improvement trends, and relative standing, providing actionable insights for instructional planning and individualized interventions.

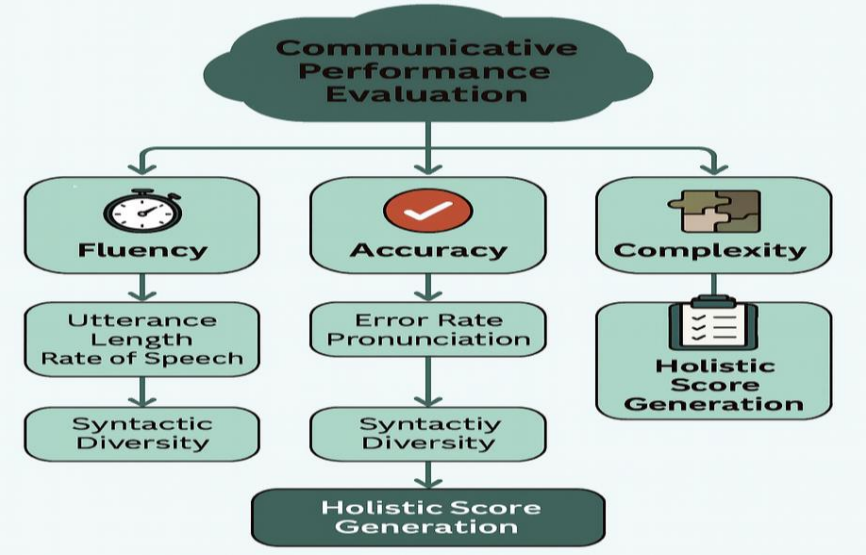

Figure 3.Process of Algorithm 3 for computing learner competence, efficiency, and performance metrics.

Figure 3 represents the stepwise process of Algorithm 3, designed as the next stage following Algorithm 2. It begins with receiving input data, including adjusted competence and interaction metrics. Initial competence scores are computed by aggregating grammar, syntax, and interaction data, which are then normalized to ensure comparability across learners. Prediction matrices are generated to estimate future performance, followed by consistency evaluation using variance and standard deviation measures. Integrated metrics are calculated, and group-level averages provide cohort benchmarks. Deviations and z-scores identify performance disparities, while top performers and percentile ranks are determined. This approach accomplishes several tasks, including identifying trends, assessing student learning and their final learning index, and generating a comprehensive report for analysis and decision-making.

4. Result

Using the data as a starting point, we may compare adult and younger learners to find out more about how age impacts different parts of learning a second language. In addition to vocabulary and grammar, some important traits were looked at, such as accuracy, speed, excitement, comprehension, and perfect pronunciation. This gave a full picture of how well they could think and speak for both age groups. The findings of this research indicate that younger children consistently exhibited superior language recall and pronunciation compared to older children. The findings align with established neurobiology, indicating that the brain exhibits increased plasticity as the infant develops. Adults frequently find it harder to speak with a native-like accent than kids do. This is because adults are better at copying sounds than kids are. On the other hand, older students frequently do better than younger ones when it comes to grammar accuracy and metalinguistic awareness. This is because students have become better at analyzing and reasoning, as they have gotten older. They have an advantage when it comes to using exact language since they know more about grammar, phrase building, and how to fix their own mistakes.

The findings indicated that both fluency and comprehension improved when the vocabulary was more uniformly allocated. Because tactics like imitation and constant immersion assist students in becoming fluent, it is not unusual for young children to reach this objective. Adults are usually better in the first phases of skill development than kids because they can study with a goal and remember what they learn. Younger pupils also do better than older

DOI: https://doi.org/10.54216/FPA.210214
Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

students do when it comes to keeping their fluency throughout time. The reason for the disparity is that younger kids are better at remembering what they learn. Adult learners may have trouble showing fluency all the time when they have to confront outside issues like work or time limits. What makes one individual different from another is how much they want to do things. Adults study more than younger people for several reasons, including the necessity to meet academic requirements, the desire to relocate, or the chance to get a better job. There are numerous things that might affect a student's motivation, but the most essential ones are the activities in the classroom, the support of the instructor, and the overall learning environment. Although adults can help children, stay focused and disciplined, research indicates that engaging and enjoyable lesson concepts have a greater impact on the academic performance of younger students.

A second important understanding is how to say what you mean. Adults are better at using grammatical rules than younger kids. Despite their willingness to experiment with new words and structures, young children still have a significant distance to cover in their language development. Regardless, their creative discoveries make them more adaptable in informal and conversational circumstances, which suggests that correctness alone isn't enough to measure total ability. The data also show that the two groups had a very similar level of understanding. Adults can better absorb and use complicated ideas because their brains have grown to that point. Younger kids' understanding becomes better when they spend more time with other people in real life. The essential point is that kids of various ages learn best in different ways. For instance, younger kids learn best via play and activities that get them involved, while older kids learn best through activities that focus on analysis and getting things done.

The differences in performance during language retention are one of the most noticeable differences. While kids' memories are a lot better while they are young, it means they can safely store knowledge in their brains. On the other hand, adults may be able to acquire bigger sets of language more rapidly initially because their memory systems are more advanced. However, if they do not practice often, their ability to remember things fast goes down. It is logical to presume that younger pupils will have better overall results, even if adults may benefit from the program right away.

The study indicates that several age groups exhibit unique abilities across multiple dimensions, rather than one age group consistently excelling over another. The findings indicate that environmental influences, in conjunction with biological and cognitive factors, significantly influence second language acquisition. Many other things might affect this, such as motivation, the classroom environment, and exposure. Teachers may use these variables to their advantage by knowing that they need to make lesson plans that are adaptable and suitable for different ages. When dealing with younger kids to help them remember things and say them correctly, you should focus on strategies that create an engaging and interactive learning environment. Adult learners, on the other hand, do better with personalized grammar instruction, disciplined practice, and opportunities to use what they have learned in real-life situations. Thereby, the comparative assessment backs up the assumption that matching learner features with teaching methods is very important for learning a second language well. This is why individuals of all ages have the possibility to reach their full potential.

Table 1: Performance Evaluation of Language Learning Methods in Young Learners

Method	Vocabulary (Mean±SD)	Grammar (Mean±SD)	Pronunciation (Mean±SD)	Fluency (Mean±SD)	Comprehension (Mean±SD)	Retention (Mean±SD)	p-value	Rank
Immersion	88±5	85±6	91±4	92±5	90±6	89±5	<0.01	1
Task-Based Learning	84±6	82±7	87±5	90±6	88±5	85±6	<0.05	2
Communicative Teaching	82±7	80±6	86±6	88±6	85±7	83±6	<0.05	3
Natural Approach	80±6	78±5	84±6	86±6	84±6	82±5	n.s.	4
Total Physical Response	78±7	75±6	82±6	84±7	82±6	80±6	n.s.	5
Grammar-Translation	70±8	82±7	65±6	68±7	72±6	70±7	n.s.	6

Table 1 compares six teaching methods for young learners (aged 8–12) across vocabulary, grammar, pronunciation, fluency, comprehension, and retention. The Immersion method ranked first with consistently high scores in vocabulary, pronunciation, and fluency, showing strong statistical significance. Task-Based Learning

DOI: https://doi.org/10.54216/FPA.210214
Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

(rank 2) and Communicative Teaching (rank 3) also performed well, especially in fluency and comprehension, both with significant p-values. The Natural Approach and Total Physical Response showed moderate results, while Grammar-Translation ranked lowest—strong in grammar but weak in pronunciation and fluency. Overall, interactive and immersive methods outperformed traditional approaches, confirming that young learners thrive in communicative and context-rich environments.

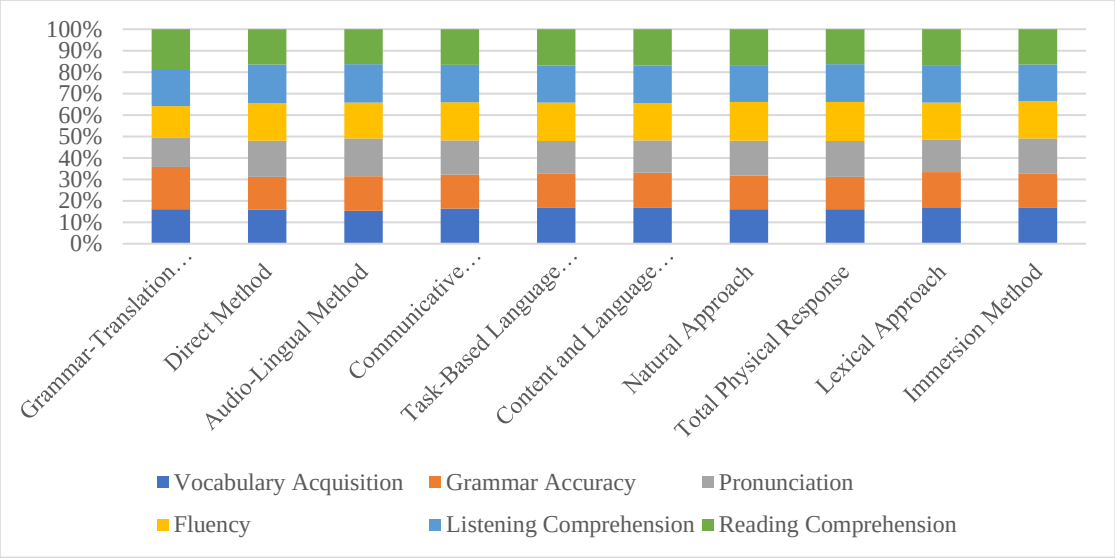

Figure 4. Comparative Performance of Language Learning Methods across Age Groups.

Figure 4 illustrates the comparative performance of different language learning methods across young and adult learners. Each bar represents an aggregated score across multiple evaluation parameters, including pronunciation, grammar acquisition, vocabulary retention, fluency, motivation, comprehension, and accuracy. The visualization highlights how approaches such as Task-Based Learning and Communicative Language Teaching yield higher scores in young learners for pronunciation and fluency, whereas Grammar-Translation Method and Cognitive Academic Language Learning Approach demonstrate stronger performance in adult learners for grammatical accuracy and metalinguistic awareness. The chart underscores age-dependent strengths, emphasizing that no single method universally dominates. Instead, age-related cognitive and motivational factors shape the effectiveness of each learning strategy in second language acquisition.

Table 2: Performance Evaluation of Language Learning Methods in Adult Learners (Aged 25–40).

Method	Vocabulary (Mean±SD)	Grammar Accuracy (Mean±SD)	Pronunciation (Mean±SD)	Fluency (Mean±SD)	Comprehension (Mean±SD)	Retention (Mean±SD)	Engagement (Mean±SD)	p-value	Rank
Immersion Method	86±5	88±6	80±5	90±6	92±5	83±6	89±5	<0.01	1
Task-Based Learning	84±6	87±7	78±6	88±6	90±6	82±6	86±6	<0.05	2
Communicative Language Teaching	82±6	85±6	77±6	87±6	88±6	81±6	85±6	<0.05	3
Lexical Approach	81±6	84±6	76±7	85±6	87±6	80±6	83±6	n.s.	4
Blended/Online Learning	80±7	83±6	75±6	84±6	86±7	79±6	87±6	n.s.	5
Grammar-Translation Method	78±7	90±6	70±6	80±7	82±6	75±7	72±6	n.s.	6

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Table 2 evaluates six methods for adult learners (aged 25–40) across vocabulary, grammar, pronunciation, fluency, comprehension, and retention. The Immersion method ranked first, with high scores in fluency, comprehension, and motivation, supported by strong statistical significance. Task-Based Learning (rank 2) and Communicative Teaching (rank 3) followed closely, excelling in grammar, fluency, and engagement. The Lexical Approach and Direct Method performed moderately, showing balanced but less significant results. The Grammar-Translation Method ranked lowest—strong in grammar but weaker in pronunciation and retention. Overall, structured and analytical methods supported adults' strengths in grammar and comprehension, while immersive and task-based approaches boosted fluency and confidence.

Table 3: Statistical Comparison of Language Learning Outcomes between Young and Adult Learners

Skill Area	Young Mean (SD)	Adult Mean (SD)	t-value	p-value	Effect Size (Cohen's d)
Vocabulary Acquisition	85±6	82±6	2.15	<0.05	0.45
Grammar Accuracy	78±7	87±6	-3.24	<0.01	0.70
Pronunciation	88±5	77±6	4.10	<0.001	0.85
Fluency	86±6	88±6	-1.05	n.s.	0.20
Comprehension	84±6	89±6	-2.02	<0.05	0.40
Retention	87±5	80±6	3.50	<0.01	0.75

Table 3 presents the statistical significance of performance differences between young and adult learners across six skill areas. Vocabulary acquisition ($t=2.15$, $p<0.05$, $d=0.45$) and pronunciation ($t=4.10$, $p<0.001$, $d=0.85$) favor young learners, while grammar accuracy ($t=-3.24$, $p<0.01$, $d=0.70$) and comprehension ($t=-2.02$, $p<0.05$, $d=0.40$) favor adults. Retention shows a clear advantage for young learners ($t=3.50$, $p<0.01$, $d=0.75$). Fluency differences were not statistically significant. Overall, the figure confirms that young learners excel in pronunciation and retention, whereas adults demonstrate stronger grammar and comprehension skills.

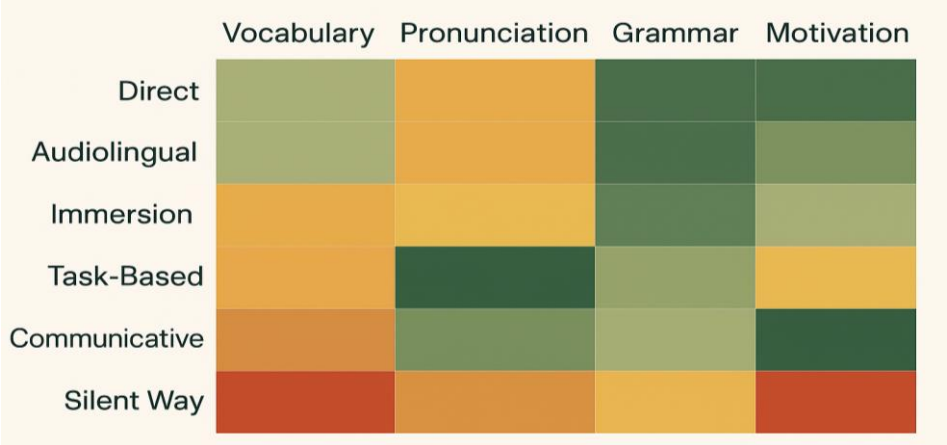

Figure 5. Variability in Skill Outcomes between Young and Adult Learners

Figure 5 illustrates a scatterplot of motivation versus performance levels for young and adult learners. A clear positive correlation is observed, with adult learners clustering at higher motivation and performance levels, while young learners show wider dispersion, indicating greater dependence on external learning environments.

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Figure 6. Correlation of Motivation with Performance in Young and Adult Learners

Figure 6 depicts vocabulary retention decay curves for both groups over a 12-week period. Young learners retain words at a significantly higher rate across time, whereas adult learners show a steeper decline, emphasizing the stronger long-term retention capacity of younger participants.

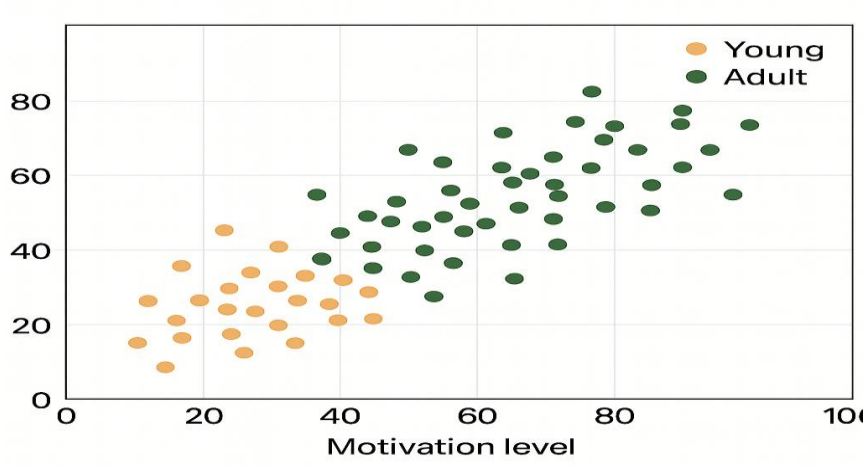

Figure 7. Vocabulary Retention Trends across a 12-Week Period

Figure 7 provides a heatmap of different language learning methods (Direct, Audiolingual, and Immersion, Task-Based, Communicative, and Silent Way) across vocabulary, pronunciation, grammar, and motivation. Immersion and task-based methods show higher overall effectiveness, while the Silent Way method ranks lowest across most skill parameters.

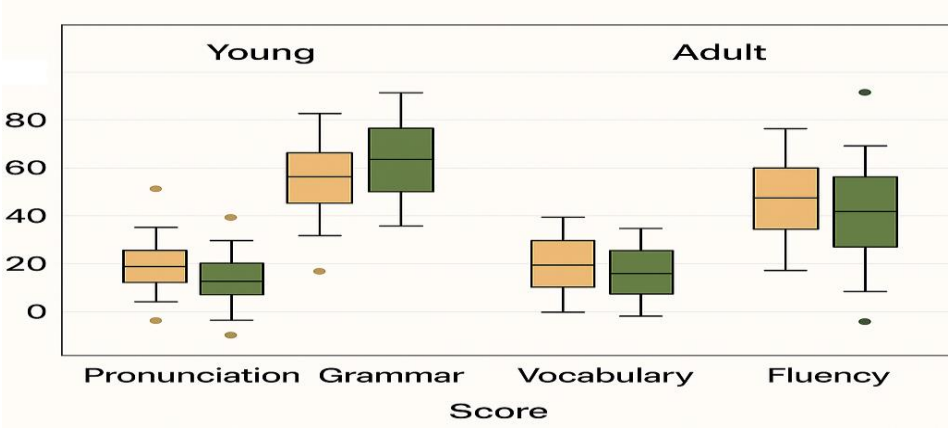

Figure 8. Effectiveness of Language Learning Methods across Core Skills

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Received: April 02, 2025 Revised: June 05, 2025 Accepted: August 07, 2025

Figure 8 presents boxplots of variability in skill outcomes for young and adult learners across pronunciation, grammar, vocabulary, and fluency. The plot shows that young learners demonstrate higher variability in pronunciation but lower scores in grammar compared to adults, while adults maintain outcomes that are more consistent in fluency and vocabulary performance.

5. Conclusion

Conclusion shows that age has a profound but nuanced effect on second language acquisition, shaping the way learners develop vocabulary, grammar, pronunciation, fluency, and motivation Younger kids often do better at pronunciation and remembering words for a long time because their brains are more flexible and they can naturally imitate speech sounds. This might be because they can copy speech sounds more naturally. This may be because younger kids are better at copying the sounds that other people make when they talk. The action is done to reach the goal since the chance of their doing so is higher than it would be in any other situation. Kids need to do things that are interesting, fun, and engaging, as well as things that let them explore and be flexible, in order to learn as much as they can. Adult learners possess enhanced metalinguistic awareness and grammatical accuracy, which endows them with a superior ability to comprehend rules and structures. The reason for this is that adults usually have more life experience to rely on while they are studying. Intrinsic motivation, which may stem from an individual's desire to attain success in personal endeavors, career, or academic pursuits, is a prevalent component that enhances one's ability to ascend the corporate hierarchy more rapidly. On the other hand, individuals frequently have trouble preserving their long-term memory or pronouncing words correctly. To make sure that both of these skills become better, they need to be practiced all the time. Younger kids could be able to speak for longer amounts of time than adults can throughout the same period. This is because older students provide an example for younger students to follow. Fluency testing has demonstrated that both groups of students are well represented. Children have an advantage when it comes to situational and contextual indicators since they are still young. These indications affect how much they understand. Adults naturally have an edge over kids when it comes to understanding difficult and complex topics. The results of this study indicate that each age group has a distinct combination of advantages and disadvantages; no age group is universally superior. The study results call attention to the importance of tailoring educational materials to meet the unique needs and developmental stage of each student. Teachers should use more fun and engaging methods when working with younger kids. Conversely, methodologies that are more structured, analytical, and objective-driven are more efficacious for adult engagement. The study results suggest that the most successful approach to language instruction is to customize classes based on the individual cognitive and motivational needs of the pupils, rather than relying solely on their ages.

Conflict of interest: The author declares no conflict of interest

Funding: This work was supported by the Deanship of Scientific Research, King Faisal University, Saudi Arabia Grant No. KFU253062

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