Iranian Journal of Educational Sociology

Journal Website

Article history:
Received 02 October 2026
Revised 17 February 2026
Accepted 26 February 2026
Initial Published 26 February 2026
Final Publication 20 March 2026

Iranian Journal of Educational Sociology

Volume 9, Issue 1, pp 1-14

Quarterly Iranian Journal of Educational Sociology

E-ISSN: 2645-3460

The Impact of Brain-Based Feedback Strategies on EFL Learners' Speaking Fluency and Accuracy

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Article Info

Article type:
Original Research

How to cite this article:
Jafari Mehr, S., Fatehi Rad, N., & Jalali, V. (2026). The Impact of Brain-Based Feedback Strategies on EFL Learners' Speaking Fluency and Accuracy. *Iranian Journal of Educational Sociology, 9*(1), 1-14.
https://doi.org/10.61838/kman.ijes.1441

ABSTRACT

Purpose: The present study aimed to examine whether brain-based feedback strategies grounded in educational neuroscience principles significantly improve speaking fluency and speaking accuracy among intermediate EFL learners compared with traditional corrective feedback.

Methods and Materials: The study employed a quantitative quasi-experimental design involving sixty adult intermediate EFL learners enrolled in a private language institute. Two intact classes were assigned to an experimental group receiving brain-based feedback and a control group receiving traditional corrective feedback. Participants' proficiency was confirmed using the Oxford Placement Test to ensure group homogeneity. Data were collected through pre-test and post-test speaking tasks consisting of picture description and role-play activities. Speaking performances were audio-recorded, transcribed, and analyzed using temporal fluency measures (speech rate, pausing patterns, and utterance length) and accuracy indices based on error-free clauses and grammatical correctness. An eight-week instructional intervention was implemented in which both groups followed identical materials and lesson plans while differing only in feedback delivery. Statistical analyses included descriptive statistics and mixed-design ANOVA after testing assumptions of normality, homogeneity of variance, and equality of covariance matrices.

Findings: Inferential analyses revealed significant main effects of Time for both speaking fluency and speaking accuracy, indicating overall improvement across participants. More importantly, significant Time × Group interaction effects demonstrated that learners exposed to brain-based feedback achieved substantially greater gains than those receiving traditional feedback. Large effect sizes confirmed that neuroscience-informed feedback practices contributed to accelerated development in speech rate and increased proportions of error-free production. The findings suggest that feedback aligned with attentional capacity, memory consolidation processes, and emotional regulation mechanisms enhances oral performance more effectively than conventional corrective feedback approaches.

Conclusion: The results provide empirical evidence that brain-based feedback strategies constitute an effective pedagogical approach for promoting simultaneous improvement in speaking fluency and accuracy in EFL contexts.

Keywords: *brain-based feedback; speaking fluency; speaking accuracy; EFL learners; corrective feedback; neuroscience-informed pedagogy; oral performance*

1. Introduction

The growing intersection between educational neuroscience and second language acquisition (SLA) has fundamentally reshaped contemporary perspectives on language learning and pedagogy. Traditional language instruction historically relied on linguistic theories and classroom-based observations; however, advances in cognitive neuroscience now provide empirical insights into how the human brain processes, stores, retrieves, and automatizes language knowledge. Research increasingly demonstrates that effective teaching practices must align with neural mechanisms governing attention, memory consolidation, emotional regulation, and cognitive load management (Cearon & de Moraes Feltes, 2020; Gashmardi, 2025). Within foreign language education, this shift has encouraged scholars to reconsider instructional strategies not merely as pedagogical techniques but as cognitively grounded interventions capable of optimizing learning efficiency. Educational neuroscience emphasizes that learning emerges from dynamic interactions among cognitive, affective, and social processes, highlighting the need for teaching approaches that correspond with natural brain functioning (Leisman, 2022; Sousa, 2022). Consequently, brain-based learning (BBL) has gained prominence as an interdisciplinary framework integrating neuroscience findings into classroom practice.

Speaking skill occupies a central position in SLA because it represents the most cognitively demanding and socially interactive dimension of language competence. Unlike receptive skills, speaking requires simultaneous coordination of conceptualization, lexical retrieval, grammatical encoding, monitoring, and articulation under real-time communicative pressure (Renandya & Nguyen, 2022). Modern models of oral proficiency conceptualize speaking fluency as a multidimensional construct involving cognitive fluency, utterance fluency, and perceived communicative effectiveness (Suzuki & Kormos, 2023). Fluency development depends on efficient processing speed and automatized access to linguistic representations, while speaking accuracy reflects learners' ability to control grammatical and lexical forms during production (Révész et al., 2016). Cognitive limitations, particularly restricted attentional resources, strongly influence learners' performance; when cognitive load increases, speech breakdowns, hesitation phenomena, and disfluencies frequently occur (Hutin & Tomas, 2025; Wickens, 2020). Therefore, pedagogical interventions that reduce cognitive overload while reinforcing linguistic accuracy are crucial for fostering balanced oral development.

Corrective feedback (CF) has long been recognized as one of the most influential instructional mechanisms supporting language learning. Extensive SLA research confirms that feedback promotes noticing of linguistic errors and facilitates interlanguage restructuring (Alsolami, 2019; Ellis, 2017). Meta-analytic findings further demonstrate that appropriately delivered feedback enhances long-term language development and improves learner performance across skills (Li & Tan, 2022). Beyond linguistic improvement, feedback also affects learners' psychological states, motivation, and willingness to communicate (Hartono et al., 2022). Learners' attitudes toward corrective feedback vary depending on timing, delivery style, and emotional tone, indicating that feedback effectiveness extends beyond mere correction of errors (Rabani EbrahimiPour, 2023). Studies comparing immediate and delayed feedback suggest that timing plays a decisive role in how learners process corrective input and build self-efficacy (Farmani et al., 2017). Despite these insights, most traditional CF models prioritize linguistic accuracy rather than the cognitive and emotional conditions under which feedback is processed.

Recent developments in neuroscience challenge purely form-focused perspectives on feedback by emphasizing the role of attentional control systems and emotional regulation in learning. Neurocognitive research shows that anxiety and cognitive interference disrupt attentional networks essential for language processing (Eysenck et al., 2023). Emotional neuroscience further demonstrates that supportive learning environments enhance neural readiness for learning by stabilizing affective states and enabling executive functions to operate efficiently (Gkintoni, Antonopoulou, et al., 2023; Gkintoni, Dimakos, et al., 2023). Emotion regulation processes influence working memory capacity, directly affecting learners' ability to process linguistic input and perform complex speaking tasks (Grecucci et al., 2017). From this perspective, feedback that interrupts speech production or generates emotional pressure may hinder fluency even if it promotes error awareness. Brain-based feedback strategies attempt to reconcile this tension by aligning feedback delivery with attentional cycles and emotional safety principles.

Brain-based learning approaches operationalize neuroscience findings into pedagogical practices designed to optimize learning conditions. These approaches emphasize meaningful engagement, supportive emotional climates, multimodal input, and structured repetition consistent with neural learning mechanisms (Jean Paul, 2019; Koşar, 2018). Research demonstrates that BBL environments improve learners' engagement, motivation, and academic achievement across educational contexts (Winantaka et al., 2024). Empirical studies reveal that brain-based instruction enhances vocabulary acquisition, reading comprehension, and language retention by aligning instruction with memory consolidation processes (Al-aajam, 2025; Amini et al., 2024; Rahmani et al., 2025). Similar findings indicate improved reading performance and learner participation when instruction reflects brain-compatible principles (Al Firdaus, 2024). Moreover, investigations conducted in EFL settings confirm that brain-based teaching contributes to speaking skill development and communicative competence (Khalil et al., 2019; Syahbandi, 2018). These results collectively suggest that instructional alignment with neural processes enhances both cognitive and affective learning outcomes.

A key mechanism underlying brain-based instruction is memory consolidation through spaced repetition and retrieval practice. Neuroscience-informed learning research consistently demonstrates that spaced learning strengthens neural connections and supports durable knowledge retention (Kim & Webb, 2022; Noor et al., 2021). Experimental studies across educational domains show that spaced repetition significantly improves learning performance by allowing consolidation cycles to occur between learning episodes (Burel et al., 2024; Jayaram, 2026). In language learning contexts, repeated exposure to patterns at cognitively optimal intervals promotes proceduralization of linguistic knowledge, enabling learners to access language more automatically during communication. Such mechanisms are particularly relevant for speaking accuracy, which depends on stable memory traces and efficient retrieval during real-time speech production.

Theoretical explanations for the effectiveness of brain-based feedback also draw heavily on skill acquisition theory. According to this framework, language learning progresses from declarative knowledge toward automatized procedural competence through practice and feedback cycles (DeKeyser, 2020; Sato, 2023). Fluency development emerges when learners repeatedly practice language under conditions that minimize cognitive interruption, enabling gradual automatization (Segalowitz, 2016). Feedback aligned with cognitive readiness allows learners to integrate corrections without disrupting ongoing speech planning. Additionally, dual attention to form and meaning has been shown to enhance communicative learning outcomes, suggesting that feedback must support accuracy while maintaining communicative flow (Daskan & Yildiz, 2020). Brain-based feedback strategies embody these principles by delaying correction until learners complete their utterances, thereby preserving fluency while reinforcing accuracy.

Another crucial contribution of neuroscience concerns attentional development and executive control. Research on attentional systems highlights that learning occurs most effectively when attentional resources are selectively directed toward relevant stimuli (Rueda, 2024). Speaking tasks place heavy demands on attentional coordination, requiring learners to manage linguistic encoding alongside communicative intentions. Brain-compatible feedback respects these limitations by providing concise, targeted corrections that do not overwhelm working memory. Cognitive neuroscience of language further emphasizes that speech production relies on integrated neural networks coordinating perception, memory, and motor planning (Kemmerer, 2022). When feedback interferes with these networks during active speech, processing efficiency declines, resulting in increased disfluency (Williams, 2022). Therefore, feedback timing and delivery style become critical determinants of oral performance development.

Empirical research increasingly confirms that brain-based instruction positively influences learners' emotional and cognitive engagement. Studies demonstrate improvements in emotional-cognitive outcomes, learner confidence, and motivation within brain-based learning environments (Pezhmanfard et al., 2025; Shahzadi et al., 2024). These affective benefits are particularly significant for speaking activities, which frequently trigger anxiety and fear of negative evaluation. Emotional safety enables learners to allocate cognitive resources more effectively, thereby facilitating both fluency and accuracy development. Furthermore, investigations into brain-based speaking instruction reveal enhanced communicative performance when learners receive instruction consistent with neurocognitive principles (Iranmanesh et al., 2022, 2023). Such findings reinforce the argument that pedagogical effectiveness depends not only on instructional content but also on how learning experiences interact with neural processing systems.

Despite growing evidence supporting brain-based learning, an important gap remains in the literature. Most existing studies focus on general instructional approaches rather than feedback practices, even though feedback constitutes one of the most powerful drivers of language development. While numerous investigations examine types of corrective feedback, few explicitly analyze how neuroscience-informed feedback influences distinct dimensions of oral performance simultaneously. Fluency and accuracy have often been treated as competing outcomes, with improvements in one assumed to occur at the expense of the other. However, contemporary neuroscience perspectives suggest that appropriately timed and emotionally supportive feedback may facilitate concurrent development of both dimensions by optimizing cognitive and affective conditions for learning.

In addition, relatively few experimental studies have systematically compared brain-based feedback with traditional corrective feedback using robust statistical designs capable of capturing developmental change over time. Given the complexity of speaking performance and its dependence on cognitive processing, emotional regulation, and memory consolidation, empirical investigation is required to determine whether brain-based feedback strategies can produce measurable improvements in EFL learners' oral proficiency. Addressing this gap is essential for bridging theoretical advances in educational neuroscience with practical language teaching applications and for providing evidence-based guidance to instructors seeking more effective feedback practices.

Therefore, the aim of the present study is to investigate the impact of brain-based feedback strategies on EFL learners' speaking fluency and speaking accuracy in comparison with traditional corrective feedback.

2. Methods and Materials

2.1. Study Design and Participants

This study adopted a quantitative quasi-experimental design to examine the effects of brain-based feedback on EFL learners' speaking fluency and accuracy. Due to institutional constraints, two intact intermediate classes were assigned to conditions: an experimental group receiving brain-based feedback and a control group receiving traditional CF. Both groups were taught by the same instructor, used identical materials, and completed parallel speaking tasks. The study included a pre-test, an eight-week intervention, and a post-test, enabling comparison of performance changes over time in a natural classroom context.

The study involved about 60 adult EFL learners enrolled in intermediate speaking courses at Tanin Private Language Institute. The participants aged 18 to 25 and including both men and women, reflected the typical learner population in Iranian private institutes. All the learners were administered the Oxford Placement Test to ensure similar proficiency; hence, only those within the B1-B2 range were considered. The sample consisted of two intact classes of approximately 30 students: the experimental and the control. Ethical issues such as voluntary participation, written consent, confidentiality, anonymity and right to withdraw were observed.

2.2. Instruments

2.2.1. Oxford Placement Test (OPT)

The Oxford Placement Test, published by Oxford University Press, was used to determine participants' proficiency level prior to the intervention. The OPT provides reliable assessment aligned with the CEFR and is commonly used to establish group equivalence in EFL research. Only learners within the intermediate range were included.

2.2.2. Speaking Test

Learners' speaking performance was evaluated through two elicited-production tasks: picture-description activities and role-play interactions, both of which are widely used in L2 research for generating spontaneous and naturalistic speech samples. All speaking performances were audio-recorded and subsequently transcribed to enable precise quantitative analysis. Speaking fluency was assessed by examining several temporal measures, including overall speech rate expressed in words per minute, the mean length of utterance runs, and the frequency and duration of pauses, following established procedures in the field. Speaking accuracy was evaluated through indicators such as the proportion of error-free clauses, counts of grammatical errors, and judgments of lexical appropriateness, which together provide a comprehensive measure of linguistic precision (Ellis, 2017). These combined fluency and accuracy measures offer reliable and widely recognized indices of oral performance quality, allowing for robust comparisons of learners' development across the study.

2.2.3. Instructional Material

Both groups received instruction using Collins Speaking for IELTS: Intermediate (Kovacs, 2011). The reasons for choosing this textbook are that it offers structured topic-based speaking activities, lexical support, and communicative tasks. Hence, the textbook is appropriate for systematic speaking instruction. Using the same material in

Iranian Journal of Educational Sociology
E-ISSN: 2645-3460

both groups ensured that differences in outcomes could be attributed to feedback type rather than content.

2.3. Data Collection and Analysis Procedures

Data collection lasted eight weeks and consisted of three stages of pre-test, treatment, and post-test. First, during the pre-test stage, homogeneity among the participants was checked by using the Oxford Placement Test, followed by carrying out the baseline speaking tasks by all the learners, which involved picture description and role-play activities. These were audio-recorded and later analyzed to get preliminary measures of fluency and accuracy to make sure the experimental and control groups were comparable at the beginning of the intervention.

The treatment phase lasted eight weeks, during which both groups attended two 90-minute sessions per week. Although they followed the same lesson plans and engaged in identical speaking tasks, the nature of the feedback they received differed substantially. The experimental class received brain-based feedback based on neuroscience-informed pedagogical principles. In this case, the emphasis was optimally on timing: correcting after learners have finished their utterances, so as not to disrupt cognitive processing; immediate micro-feedback; and spaced repetition of recurring issues. These also included emotionally sensitive practices of using only a supportive tone and avoiding public corrections consistent with affective neuroscience research that emphasizes how emotional display can preserve or destroy working memory capacity. The feedback was multimodal, combining verbal explanations with visual or gestural aids, thus following Dual Coding Theory.

To avoid cognitive overload in working memory, feedback also adhered to memory- and attention-based principles by targeting only key error patterns rather than isolated mistakes (Ellis, 2017). Additionally, the learners were encouraged to self-reflect and self-regulate, such as activities on self-repair and metacognitive awareness raising. Finally, the feedback tried to foster social rapport, drawing on studies indicating that positive interpersonal relationships create trust, reduce anxiety, and make one more willing to communicate (Immordino-Yang, 2016; Immordino-Yang & Damasio, 2007). The six categories of brain-based strategies were consistently used throughout the intervention.

By contrast, the traditional CF in the control group relied primarily on explicit correction, recasts, and occasional metalinguistic comments. This feedback was delivered without especial consideration for emotional tone, timing, multimodality, or cognitive load. To guarantee the treatment fidelity, the teacher received training in both methods of providing feedback, there was random classroom observation, and implementation checklists were carried out so as to make sure that each condition was implemented accordingly.

In the post-test phase, all learners completed the same speaking tasks administered during the pre-test. These performances were again recorded and analyzed for fluency and accuracy. Differences between pre-test and post-test results across both groups provided the basis for evaluating the extent to which brain-based feedback strategies influenced learners' speaking performance.

Data were analysed in SPSS (Version 26). Descriptive statistics were calculated for pre- and post-test speaking fluency and accuracy across groups. Before conducting the main analyses, assumptions of normality (Shapiro–Wilk), homogeneity of variances (Levene's test), and equality of covariance matrices (Box's M test) were checked. For each research question, a mixed-design ANOVA was performed. The Time × Group interaction was used to determine whether brain-based feedback resulted in significantly greater improvement than traditional feedback.

3. Findings and Results

RQ1. To What Extent Do Brain-Based Feedback Strategies Affect EFL Learners' Speaking Fluency?

To address RQ1, Table 1 presents the descriptive statistics for speaking fluency scores across groups and testing times. As shown, both groups improved from pre-test to post-test; however, the experimental group demonstrated a larger gain (105.78 → 126.13 WPM) than the control group (106.22 → 109.69 WPM).

Table 1

Descriptive Statistics for Speaking Fluency by Group and Time

Group		Fluency_Pre	Fluency_Post
Control	Mean	106.220	109.693
	N	30	30
	Std. Deviation	7.7982	8.3673
Experimental	Mean	105.777	126.133
	N	30	30
	Std. Deviation	8.8782	8.8572
Total	Mean	105.998	117.913
	N	60	60
	Std. Deviation	8.2876	11.9032

Before running the mixed-design ANOVA, normality was examined using the Shapiro–Wilk test (Table 2). The results indicated no significant deviations from normality for either group at pre-test or post-test (all $p > .05$), confirming that the normality assumption was satisfied.

Table 2

Shapiro–Wilk Normality Test for Speaking Fluency

	Group	Statistic	df	Sig.
Fluency_Pre_WPM	Control	.967	30	.457
	Experimental	.958	30	.273
Fluency_Post_WPM	Control	.968	30	.497
	Experimental	.990	30	.990

Table 3 shows Box's M test for homogeneity of covariance matrices. The non-significant result (p = .923) indicates that the covariance matrices were equivalent across groups, supporting the suitability of the mixed-design ANOVA.

Table 3

Box's Test of Equality of Covariance Matrices for Speaking Fluency

Box's M	.500
F	.160
df1	3
df2	605520.000
Sig.	.923

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.
a. Design: Intercept + Group
Within Subjects Design: Time

As presented in Table 4, Levene's tests for fluency at pre-test and post-test were non-significant (all $p > .38$), confirming homogeneity of variances between the groups at each time point.

Table 4

Levene's Test of Equality of Error Variancesa for Speaking Fluency

		Levene Statistic	df1	df2	Sig.
Fluency_Pre_WPM	Based on Mean	.726	1	58	.398
	Based on Median	.577	1	58	.451
	Based on Median and with adjusted df	.577	1	57.53	.451
	Based on trimmed mean	.768	1	58	.384
Fluency_Post_WPM	Based on Mean	.001	1	58	.970
	Based on Median	.007	1	58	.932
	Based on Median and with adjusted df	.007	1	55.44	.932
	Based on trimmed mean	.002	1	58	.964

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Group
Within Subjects Design: Time

Table 5 reports the results of the mixed-design ANOVA. A significant main effect of Time was observed, $F(1, 58) = 190.14$, $p < .001$, partial $\eta^2 = .766$, indicating overall improvement in fluency. Most importantly, the Time × Group interaction was also significant, $F(1, 58) = 95.44$, $p < .001$, partial $\eta^2 = .622$, demonstrating that the experimental group improved significantly more than the control group.

Table 5

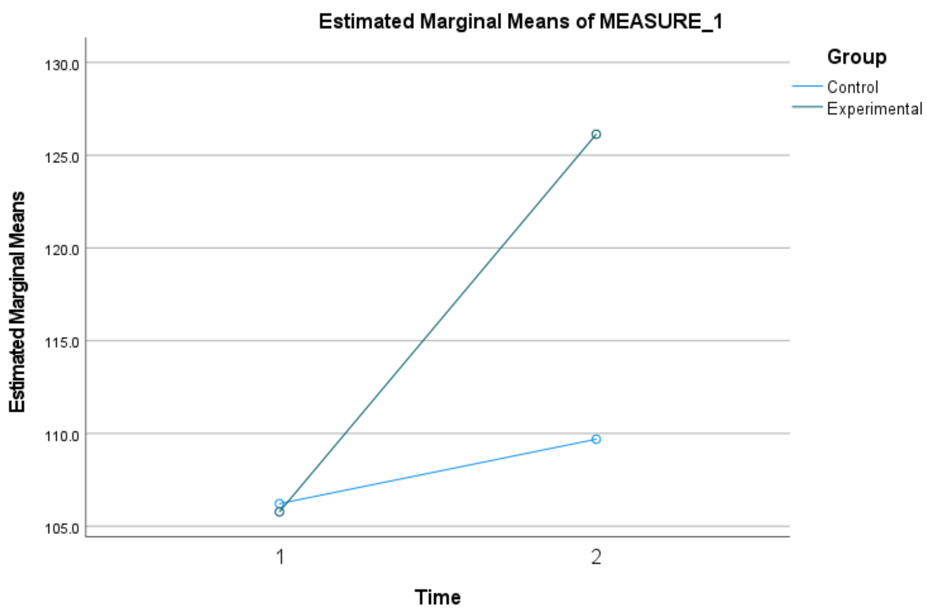
Tests of Within-Subjects Effects for Speaking Fluency (Mixed-Design ANOVA)

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	4259.017	1	4259.017	190.140	.000	.766
	Greenhouse-Geisser	4259.017	1.000	4259.017	190.140	.000	.766
	Huynh-Feldt	4259.017	1.000	4259.017	190.140	.000	.766
	Lower-bound	4259.017	1.000	4259.017	190.140	.000	.766
Time * Group	Sphericity Assumed	2137.852	1	2137.852	95.442	.000	.622
	Greenhouse-Geisser	2137.852	1.000	2137.852	95.442	.000	.622
	Huynh-Feldt	2137.852	1.000	2137.852	95.442	.000	.622
	Lower-bound	2137.852	1.000	2137.852	95.442	.000	.622
Error(Time)	Sphericity Assumed	1299.166	58	22.399			
	Greenhouse-Geisser	1299.166	58.000	22.399			
	Huynh-Feldt	1299.166	58.000	22.399			
	Lower-bound	1299.166	58.000	22.399			

Figure 1 visually illustrates the interaction effect, showing a steep rise in fluency for the experimental group compared to a modest increase for the control group. This graphical pattern confirms the statistical interaction reported in Table 5.

Figure 1

Interaction Profile Plot for Speaking Fluency across Time by Group



RQ2. To What Extent Do Brain-Based Feedback Strategies Affect EFL Learners' Speaking Accuracy?

To address RQ2, Table 6 provides the descriptive statistics for speaking accuracy across groups and testing times. Both groups improved from pre-test to post-test; however, the experimental group showed a substantially larger gain (51.88% → 65.55%) compared to the control group (51.96% → 55.13%).

Table 6

Descriptive Statistics for Speaking Accuracy by Group and Time

Group		Accuracy_Pre	Accuracy_Post
Control	Mean	51.963	55.127
	N	30	30
	Std. Deviation	4.1636	5.1956
Experimental	Mean	51.883	65.550
	N	30	30
	Std. Deviation	5.8824	7.2220
Total	Mean	51.923	60.338
	N	60	60
	Std. Deviation	5.0528	8.1564

Table 7 summarizes the Shapiro–Wilk normality tests. Results showed no significant deviations from normality for most conditions (all $p > .05$), with only a slight deviation for the experimental pre-test score ($p = .048$). Given the robustness of mixed ANOVA with balanced groups, normality was considered acceptable.

Table 7

Shapiro–Wilk Normality Test for Speaking Accuracy

	Group	Statistic	df	Sig.
Accuracy_Pre	Control	.958	30	.271
	Experimental	.930	30	.048
Accuracy_Post	Control	.972	30	.586
	Experimental	.947	30	.138

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

As shown in Table 8, Box's M was non-significant ($p = .263$), indicating that the covariance matrices were equivalent across groups. This confirms that the homogeneity of covariance assumption for mixed-design ANOVA was met.

Table 8

Box's Test of Equality of Covariance Matricesa for Speaking Accuracy

Box's M	4.143
F	1.329
df1	3
df2	605520.000
Sig.	.263

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.
a. Design: Intercept + Group
Within Subjects Design: Time

Levene's tests for both pre-test and post-test accuracy scores were non-significant (all $p > .17$), demonstrating that the assumption of homogeneity of variances was satisfied across groups (Table 9).

Table 9

Levene's Test of Equality of Error Variancesa for Speaking Accuracy

		Levene Statistic	df1	df2	Sig.
Accuracy_Pre	Based on Mean	1.884	1	58	.175
	Based on Median	1.633	1	58	.206
	Based on Median and with adjusted df	1.633	1	49.216	.207
	Based on trimmed mean	1.681	1	58	.200
Accuracy_Post	Based on Mean	1.861	1	58	.178
	Based on Median	1.931	1	58	.170
	Based on Median and with adjusted df	1.931	1	50.242	.171
	Based on trimmed mean	1.871	1	58	.177

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Group

Within Subjects Design: Time

Mixed-design ANOVA results in Table 10 revealed a significant main effect of Time, $F(1, 58) = 267.93$, $p < .001$, partial $\eta^2 = .822$, indicating overall improvement in accuracy. The Time × Group interaction was also significant, $F(1, 58) = 104.35$, $p < .001$, partial $\eta^2 = .643$, showing that the experimental group improved significantly more than the control group.

Table 10

Tests of Within-Subjects Effects for Speaking Accuracy (Mixed-Design ANOVA)

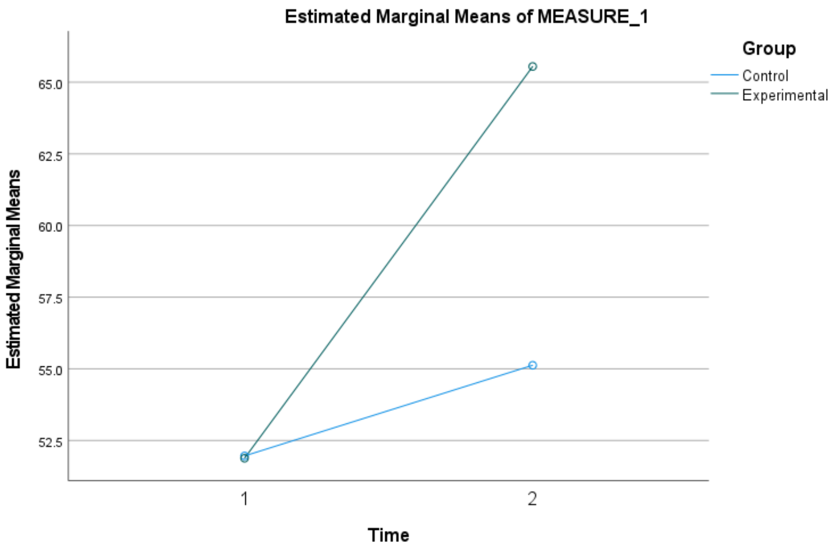
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	2124.367	1	2124.367	267.926	.000	.822
	Greenhouse-Geisser	2124.367	1.000	2124.367	267.926	.000	.822
	Huynh-Feldt	2124.367	1.000	2124.367	267.926	.000	.822
	Lower-bound	2124.367	1.000	2124.367	267.926	.000	.822
Time * Group	Sphericity Assumed	827.400	1	827.400	104.352	.000	.643
	Greenhouse-Geisser	827.400	1.000	827.400	104.352	.000	.643
	Huynh-Feldt	827.400	1.000	827.400	104.352	.000	.643
	Lower-bound	827.400	1.000	827.400	104.352	.000	.643
Error(Time)	Sphericity Assumed	459.878	58	7.929			
	Greenhouse-Geisser	459.878	58.000	7.929			
	Huynh-Feldt	459.878	58.000	7.929			
	Lower-bound	459.878	58.000	7.929			

Figure 2 visually confirms the interaction effect, with a pronounced increase in accuracy for the experimental group relative to the modest improvement observed in the control group.

E-ISSN: 2645-3460

Figure 2

Interaction Profile Plot for Speaking Accuracy across Time by Group



4. Discussion and Conclusion

The present study examined the effectiveness of brain-based feedback strategies on two fundamental dimensions of EFL oral performance, namely speaking fluency and speaking accuracy. The statistical analyses revealed significant improvements across time for both groups, confirming that sustained speaking practice itself contributes to oral development. However, the significant Time × Group interaction effects demonstrated that learners receiving brain-based feedback achieved substantially greater gains than those exposed to traditional corrective feedback. These findings suggest that feedback aligned with cognitive processing mechanisms, emotional regulation principles, and memory consolidation processes provides more optimal conditions for language development than conventional feedback approaches.

The superior gains in speaking fluency observed in the experimental group can be interpreted through cognitive processing theory and attentional resource models. Speaking requires simultaneous coordination of lexical retrieval, syntactic encoding, monitoring, and articulation, all operating under strict limitations of working memory capacity (Wickens, 2020). When corrective feedback interrupts speech production, attentional resources are divided, increasing cognitive load and disrupting temporal speech flow. The present findings align with research demonstrating that elevated cognitive load negatively affects fluency, leading to slower speech and increased hesitation phenomena (Hutin & Tomas, 2025). Brain-based feedback, delivered after learners completed their utterances, likely minimized such interference, allowing uninterrupted message formulation and smoother speech production.

From a neurocognitive perspective, attentional control plays a central role in oral performance. Educational neuroscience research indicates that efficient learning occurs when attention is optimally directed without overload or emotional distraction (Rueda, 2024; Sousa, 2022). The delayed and concise nature of brain-based feedback used in this study appears to have respected these attentional cycles, enabling learners to maintain communicative flow. This explanation is supported by models of oral fluency emphasizing the interaction between cognitive fluency and observable speech performance (Suzuki & Kormos, 2023). By preserving real-time processing resources, brain-based feedback likely facilitated faster retrieval of linguistic forms, which explains the marked increase in speech rate observed among experimental participants.

Skill acquisition theory further clarifies these results. According to this framework, language learning progresses through repeated practice leading to automatization of linguistic knowledge (DeKeyser, 2020; Sato, 2023). Automatization depends on practice conditions that allow learners to perform tasks with minimal disruption. Traditional feedback delivered during production may prevent proceduralization by forcing learners to shift attention from communication to error processing. In contrast, brain-based feedback allowed learners to complete

E-ISSN: 2645-3460

communicative cycles before receiving correction, supporting gradual transition from controlled to automatic performance. Similar observations were reported in studies highlighting the cognitive foundations of fluency development and the role of uninterrupted practice in fostering automatic speech production (Segalowitz, 2016; Williams, 2022).

The fluency findings are also consistent with affective neuroscience explanations. Emotional states significantly influence cognitive efficiency and language performance. Anxiety activates neural systems that impair attentional regulation and working memory functioning (Eysenck et al., 2023). Supportive feedback environments reduce emotional threat and promote willingness to communicate, which enhances speaking performance. Previous investigations have shown that brain-based learning environments increase learner confidence, emotional engagement, and classroom participation (Pezhmanfard et al., 2025; Shahzadi et al., 2024). Emotional neuroscience research similarly emphasizes that positive emotional climates facilitate learning by stabilizing affective regulation mechanisms (Gkintoni, Antonopoulou, et al., 2023; Gkintoni, Dimakos, et al., 2023; Grecucci et al., 2017). Therefore, the fluency gains identified in the experimental group likely reflect the combined influence of reduced anxiety, preserved attentional resources, and improved cognitive efficiency.

Regarding speaking accuracy, the results indicated that both groups improved over time, yet the experimental group achieved significantly greater development. Accuracy improvement depends heavily on learners' ability to notice linguistic forms and store them in long-term memory. Corrective feedback has long been recognized as a mechanism facilitating noticing and interlanguage restructuring (Alsolami, 2019; Ellis, 2017). However, neuroscience research suggests that feedback effectiveness depends on the cognitive conditions under which it is processed rather than merely its linguistic type. Brain-based feedback strategies used in the present study incorporated spacing, repetition, and focused correction, which align with established principles of memory consolidation.

Research on spaced learning demonstrates that information presented at optimal intervals strengthens neural connections and improves retention (Kim & Webb, 2022; Noor et al., 2021). Experimental evidence confirms that spaced repetition enhances learning outcomes across educational domains by allowing consolidation cycles to occur between exposures (Burel et al., 2024; Jayaram, 2026). The repeated pattern-focused corrections implemented in the experimental condition likely reinforced memory traces associated with accurate linguistic forms, enabling learners to retrieve them more efficiently during post-test speaking tasks. Similar improvements in vocabulary retention and language learning outcomes have been reported in brain-based instructional studies within EFL contexts (Al-aajam, 2025; Amini et al., 2024).

Another explanation for improved accuracy relates to attentional readiness during feedback processing. When learners receive feedback during high cognitive load moments, such as mid-utterance, they may fail to process corrections deeply. Brain-based feedback timing ensured that cognitive resources were available for reflection and internalization of linguistic forms. Studies investigating dual focus on form and meaning support this interpretation, demonstrating that balanced attention to communication and linguistic accuracy enhances learning outcomes (Daskan & Yildiz, 2020). Furthermore, learner perceptions of feedback effectiveness have been shown to depend strongly on clarity and emotional tone, reinforcing the importance of supportive delivery methods (Rabani EbrahimiPour, 2023).

The accuracy findings also align with broader research demonstrating the effectiveness of brain-based instruction for language skills. Empirical studies report improvements in speaking, reading, and vocabulary learning when instruction is aligned with neural learning principles (Al Firdaus, 2024; Khalil et al., 2019; Rahmani et al., 2025). Brain-compatible pedagogy promotes deeper processing by integrating cognitive engagement with emotional safety and meaningful repetition (Jean Paul, 2019; Koşar, 2018). Similarly, investigations involving medical and academic EFL learners show enhanced speaking performance following brain-based teaching interventions (Iranmanesh et al., 2022, 2023). The present study extends these findings by demonstrating that not only instruction but also feedback delivery grounded in neuroscience principles can significantly influence oral accuracy development.

The simultaneous improvement of fluency and accuracy observed in this study contributes an important theoretical implication to SLA research. Traditional perspectives often conceptualize fluency and accuracy as competing dimensions due to limited attentional capacity. However, the present results suggest that appropriately designed feedback may enable concurrent development by optimizing cognitive and emotional learning conditions. Neuroscience-informed pedagogy emphasizes alignment with brain functioning rather than prioritizing one performance dimension over another (Cearon & de Moraes Feltes, 2020; Leisman, 2022).

E-ISSN: 2645-3460

By minimizing cognitive overload while strengthening memory consolidation processes, brain-based feedback appears capable of supporting integrated oral proficiency development.

Taken together, the findings reinforce the argument that feedback effectiveness is not solely determined by corrective technique but by how feedback interacts with learners' neurocognitive systems. Brain-based feedback integrates principles of attention management, emotional regulation, and spaced learning, thereby creating learning environments conducive to sustainable language acquisition. These results provide empirical support for the growing movement advocating integration of neuroscience insights into language pedagogy and extend previous research linking brain-based learning with improved learner engagement and performance (Gashmardi, 2025; Winantaka et al., 2024).

The study also contributes methodologically by employing a comparative quasi-experimental design that directly tested developmental change across time. While earlier research often examined brain-based learning descriptively, the present findings offer quantitative evidence confirming its effectiveness specifically at the level of feedback practices. As speaking remains one of the most challenging skills for EFL learners, identifying feedback strategies that simultaneously enhance fluency and accuracy represents a meaningful advancement for communicative language teaching and applied linguistics research.

The findings should nevertheless be interpreted in light of several limitations. The use of intact classes prevented full random assignment, which may limit internal validity despite efforts to ensure group equivalence. The duration of the intervention was relatively short, restricting observation of long-term retention effects. The sample consisted solely of intermediate learners within a single institutional context, which may constrain generalizability to learners of different proficiency levels or educational settings. Additionally, speaking performance was measured through structured tasks rather than spontaneous real-world communication, and different task types might produce varying outcomes.

Future research could extend the present findings by conducting longitudinal studies including delayed post-tests to examine the durability of brain-based feedback effects. Investigations involving beginner and advanced proficiency levels would clarify whether cognitive load differences influence responsiveness to neuroscience-informed feedback. Mixed-methods designs incorporating qualitative data such as learner reflections or classroom observations may provide deeper insight into cognitive and emotional mechanisms underlying improvement. Further studies could also compare different forms of brain-based feedback timing or modality and explore technology-mediated environments where digital tools support adaptive feedback delivery.

From a practical perspective, the findings suggest several pedagogical implications. Language teachers may benefit from delaying correction until learners complete their utterances in order to preserve communicative flow and reduce cognitive overload. Feedback should prioritize recurring patterns rather than isolated errors and employ supportive emotional tone to maintain learner confidence. Teacher education programs could incorporate brain-based principles into professional development to help instructors understand how timing, emotional climate, and repetition influence learning effectiveness. Curriculum designers may also integrate neuroscience-informed feedback strategies into speaking assessment frameworks, ensuring that feedback becomes an intentional component of communicative instruction rather than a spontaneous corrective act. Overall, adopting brain-based feedback practices may help create learner-centered classrooms that promote both accuracy and fluency while aligning language teaching with contemporary scientific understanding of how the brain learns.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We hereby thank all participants for agreeing to record the interview and participate in the research.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethical Considerations

All procedures performed in studies involving human participants were under the ethical standards of the institutional and, or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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E-ISSN: 2645-3460