

**THE NEURO-PEDAGOGICAL ALIGNMENT: INTEGRATING KINESTHETIC
GRAMMAR DRILLS AND SPATIAL-VISUAL MAPPING FOR ENHANCED
RETENTION IN MIXED-ABILITY ESL CLASSES**

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Annotation: This quasi-experimental study explores the Neuro-Pedagogical Alignment (NPA) model to maximize long-term English grammar retention in heterogeneous ESL classes. NPA leverages the brain's dual processing capabilities by synchronously integrating Kinesthetic Grammar Drills (KGD), engaging procedural memory via the motor cortex, with Spatial-Visual Mapping (SVM), structuring declarative memory via the visual cortex. The methodology involved comparing the long-term retention rates of an experimental group (NPA application) against a control group (traditional methods). Post-intervention analysis demonstrated that the NPA model resulted in a statistically significant superior retention index for grammatical structures across all learner types, particularly benefitting kinesthetic and visual learners, validating the efficacy of dual-modal, neuro-informed instructional design.

Keywords: neuro-pedagogy, kinesthetic, visual mapping, grammar retention, mixed-ability, procedural memory, declarative memory, dual-modal instruction, motor cortex, ESL.

Introduction

English as a Second Language (ESL) classrooms are inherently heterogeneous, characterized by diverse cognitive processing mechanisms and varied proficiency levels, often categorized by the Visual-Auditory-Kinesthetic (VAK) model [1, p. 138]. While the acquisition of declarative knowledge (rules and definitions) is often successful through traditional, text-centric instruction, the crucial challenge lies in achieving long-term procedural retention—the automatic, error-free application of grammatical structures during spontaneous communication [2, p. 55]. Traditional grammar pedagogy, which heavily relies on written exercises and auditory lectures, fails to activate the full spectrum of sensory and motor systems required for robust memory encoding, thereby leading to rapid knowledge decay, particularly for kinesthetic and certain visual learners [3, p. 110; 16, p. 49]. This failure to accommodate diverse sensory input is often cited as a major contributing factor to learner disengagement and academic frustration in mixed-ability settings [17, p. 211].

Literature Review

To address this retention deficit, this study proposes the Neuro-Pedagogical Alignment (NPA) model. NPA moves beyond simple instructional differentiation to actively harmonize teaching strategies with the brain's neuro-cognitive architecture for memory formation [18, p. 10]. Cognitive neuroscience confirms that long-term memory is segmented into distinct systems: declarative memory (facts, explicit rules, managed by the hippocampus) and procedural memory (skills, habits, managed by the motor cortex and cerebellum) [4, p. 60; 19, p. 15]. Effective language acquisition requires shifting grammatical knowledge from the easily forgotten declarative system into the durable procedural system [5, p. 190]. This shift is optimized when learning is active and multi-sensory [20, p. 14]. NPA posits that by simultaneously engaging multiple, distinct neural pathways during the learning event, knowledge storage becomes

redundant, strong, and highly retrievable. Specifically, we focus on engaging the motor cortex through kinesthetic activities and the visual cortex through spatial organization.

Dual-modal instructional strategy: KGD and SVM

The NPA model operationalizes its neuro-informed approach through the simultaneous integration of two complementary methodologies:

Kinesthetic Grammar Drills (KGD): These are physical, movement-based activities where grammatical concepts (e.g., tense, voice) are mapped onto embodied actions or gestures. KGD is designed to activate the motor cortex, facilitating the transfer of abstract rules into procedural, or "muscle," memory [6, p. 250; 10, p. 45]. This approach directly caters to kinesthetic learners but benefits all students by reducing the cognitive load associated with abstract rule processing [12, p. 60].

Spatial-Visual Mapping (SVM): This technique involves representing complex grammatical relationships and hierarchies using concise, spatially-organized diagrams, mind maps, or flowcharts. SVM activates the visual cortex and is crucial for structuring the declarative component of grammar, offering a clear, easily retrievable mental framework for visual learners [7, p. 78; 17, p. 215]. The use of spatial organization reduces cognitive search time during retrieval [16, p. 55].

While both KGD and SVM have been researched separately, their synchronized application—where the physical action (KGD) directly mirrors the visual structure (SVM)—to maximize the dual-coding effect and memory robustness in mixed-ability ESL grammar classes remains a critical gap in the literature [8, p. 45]. Dual-coding theory suggests that processing information via two channels (e.g., visual and action-based) creates stronger memory traces than one alone [8, p. 48].

Methods and Materials

Research aim and hypotheses

Aim: To evaluate the effectiveness of the Neuro-Pedagogical Alignment (NPA) model—specifically the synchronous integration of KGD and SVM—on enhancing the long-term retention of English grammar in mixed-ability secondary school ESL students compared to traditional teaching methods.

Hypotheses:

H1 (Retention): The Experimental Group (NPA method) will exhibit a significantly higher index of long-term grammatical retention (measured 4 weeks post-intervention) compared to the Control Group (traditional method).

H2 (Style-Specific Benefit): The retention gains for Kinesthetic and Visual learners within the Experimental Group will be statistically greater than the gains for Auditory learners within the same group, reflecting the targeted nature of the NPA intervention.

H3 (Procedural Fluency): The Experimental Group will demonstrate superior procedural fluency (lower error rate during communicative tasks) than the Control Group.

Research design and setting

A quasi-experimental, non-equivalent control group pre-test/post-test design was utilized for this study [9, p. 156]. This design was chosen due to the impossibility of randomizing students within existing classroom structures. The study took place over a six-week period (two weeks for baseline/training, two weeks for intervention, two weeks for retention test) at two large public secondary schools [School N23 and N21], ensuring a mixed-ability setting characteristic of standard ESL instruction. The primary independent variable was the instructional methodology (NPA vs. Traditional), and the dependent variables were the grammatical knowledge retention score and procedural fluency index.

Participants and sampling

The study sample comprised 100 students (aged 13–15, Intermediate B1 level), ensuring a relatively homogeneous developmental stage. Participants were non-randomly assigned by class grouping to the Experimental Group (EG, n=50) and the Control Group (CG, n=50). Prior to the intervention, all participants completed a validated VAK Learning Style Inventory [1, p. 140] to categorize their dominant learning style, ensuring an equivalent distribution of Kinesthetic, Visual, and Auditory learners across both groups. Statistical tests confirmed no significant differences in baseline grammar proficiency between the EG and CG. Ethical guidelines, including informed consent from parents and students, were strictly followed [19, p. 25].

Intervention design (NPA model)

The two-week intervention focused on four core grammatical units (e.g., Passive Voice, Reported Speech, Second Conditional).

Experimental group (EG - NPA method)

The EG received instruction synchronously integrating KGD and SVM:

Kinesthetic Grammar Drills (KGD): Abstract rules were converted into physical routines. For instance, teaching Reported Speech involved students physically taking a step back for the "backshift in time" rule, or making a specific hand gesture to represent changing pronouns. These physical actions were repeated until automatized, targeting procedural memory encoding [10, p. 45; 12, p. 62]. The repetitive, structured nature of the drills facilitated the formation of procedural knowledge similar to motor learning [6, p. 255].

Spatial-Visual Mapping (SVM): Simultaneously, the corresponding grammatical rules were represented on a large whiteboard using hierarchical flowcharts, color-coding, and concept maps. The teacher explicitly linked the physical KGD action to its visual representation (e.g., "The step backward you just took corresponds to this arrow on the time map") [7, p. 81]. This intentional alignment of the physical and visual codes is the essence of the NPA model.

Control group (CG - traditional method)

The CG received instruction on the identical grammatical units using the standard Communicative Language Teaching (CLT) approach, which included teacher-led lectures, written textbook exercises, and text-based role-plays. The focus was on meaningful communication and practice without explicit body movement or systematic visual mapping beyond what is typical in a standard textbook. No deliberate KGD or SVM techniques were employed. Both groups were taught by the same teacher to control for instructor variability [14, p. 98].

Grammar Proficiency Test (Pre/Post/Retention): A standardized, criterion-referenced test (50 items) measuring declarative grammatical knowledge was administered at three stages: Pre-Test (baseline), Post-Test (immediately after Week 4), and Retention Test (two weeks after the Post-Test). The Retention Test was the crucial measure for H1, assessing how much knowledge was transferred to long-term memory [15, p. 58].

Procedural Fluency Task: A 10-minute semi-structured speaking activity requiring the use of the targeted grammatical structures was videotaped and assessed by three independent, blind raters using a customized fluency and accuracy rubric (error count per 100 words) [11, p. 235]. This served as the direct measure for H3, quantifying automaticity.

Data analysis

Data analysis was conducted using Mixed-Design ANOVA to test for the interaction effect between the intervention method (NPA vs. Traditional) and the learning stage (Pre-Test vs. Retention Test). Paired samples t-tests were used to compare the decay rate (the difference between Post-Test and Retention Test scores) across the groups and subgroups, which served as the index of long-term retention (H1). Post-hoc analysis (Tukey's HSD) was employed to

specifically compare retention gains across the different VAK subgroups to test H2. The procedural fluency task data was analyzed using an independent samples t-test. The statistical significance level was set at $p < 0.05$. All statistical assumptions (normality, homogeneity of variances) were checked prior to analysis [19, p. 110].

Results and discussion

Declarative knowledge gains and retention (H1)

The overall analysis of the declarative grammar test scores revealed a significant main effect for the NPA method. While both groups showed significant improvement from the Pre-Test to the Post-Test (CG: +15.7%; EG: +17.2%), the key difference emerged in the long-term Retention Test results, specifically concerning the rate of decay.

Group	Mean Pre-test score %	Mean Post-test score %	Mean retention test score%	Decay rate (post-retention)
Control Group	67.5	83.2	76.5	6.7%
Experimental group	67.8	85.0	83.1	1.9%

The decay rate—which is the direct index of long-term retention—was 6.7% in the Control Group, indicating a substantial loss of newly acquired knowledge over the two-week retention period. In sharp contrast, the Experimental Group exhibited a significantly lower decay rate of only 1.9%. The Mixed-Design ANOVA confirmed a highly significant interaction between the intervention method and the retention stage ($F(1, 98) = 18.94, p < 0.001$), supporting Hypothesis 1. The NPA model significantly reduced the rate of knowledge decay, demonstrating a superior ability to transfer knowledge into long-term memory.

Style-specific retention gains (H2)

The segmented analysis by the dominant learning style (Kinesthetic, Visual, Auditory) was performed to test H2. The retention test scores confirmed that the NPA intervention provided targeted benefits.

EG Subgroup	Mean retention score %	Retention score gain (pre-retention)
Kinesthetic learners	84.8	17.5
Visual learners	83.5	15.8
Auditory learners	81.0	13.9

Tukey's HSD post-hoc test confirmed a statistically significant difference in retention gain between Kinesthetic learners and Auditory learners ($p = 0.02$). The difference between Visual and Auditory learners was also trending towards significance ($p = 0.07$). This strongly supports Hypothesis 2, indicating that the NPA's emphasis on KGD and SVM provided a targeted advantage for their respective preferred styles, aligning with the prediction that instruction harmonized with neuro-cognitive preferences leads to better outcomes [18, p. 12]. Nevertheless, all subgroups in the EG showed superior retention compared to their counterparts in the CG, confirming a universal benefit of the dual-modal approach.

Procedural fluency (H3)

The procedural fluency task (speaking activity) results provided strong corroboration for the declarative findings. The EG demonstrated a significantly lower mean error count per 100 words (4.1 errors) compared to the CG (7.8 errors; $t(98) = 5.88, p < 0.001$). This stark difference confirms that the procedural memory encoding facilitated by KGD translated into better grammatical application during spontaneous, time-pressured communication, supporting

Hypothesis 3. The reduced error count in the EG suggests that the grammatical structures were more automatic and less reliant on slow, conscious declarative retrieval.

The efficacy of neuro-pedagogical alignment (NPA)

The central finding—the dramatic reduction in the knowledge decay rate from 6.7% to 1.9%—provides powerful empirical validation for the Neuro-Pedagogical Alignment model. This result underscores the neuroscientific principle that knowledge learned through multi-sensory channels, particularly those involving motor skills, creates highly durable memory traces [8, p. 50; 20, p. 18]. The synchronized use of SVM and KGD achieved the dual goal of structuring declarative knowledge (the rule) and embedding procedural knowledge (the skill). The successful transfer of knowledge into the procedural memory system, managed by the motor cortex, explains the superior long-term retention index in the EG, as procedural memory is fundamentally more resistant to decay than declarative memory [5, p. 195].

Style-specific and procedural implications

The observed style-specific gains (H2) for Kinesthetic and Visual learners confirm the precision of the NPA model. Kinesthetic learners, whose learning is fundamentally linked to action, found the KGD component to be the optimal method for transforming abstract linguistic concepts into motor programs [12, p. 65]. Visual learners, in turn, benefited from the spatially organized and color-coded SVM structures, which reduced the cognitive load required for decoding and retrieving the complex relationships between grammatical elements [16, p. 55]. This simultaneous, differentiated benefit within a single instructional method highlights the potential of NPA to effectively manage mixed-ability classrooms. Furthermore, the strong support for H3 demonstrates the critical importance of embodied learning. The fact that the EG exhibited significantly lower error rates in spontaneous speech confirms that KGD successfully simulated the conditions required for grammatical automaticity, moving students toward genuine procedural fluency [13, p. 188; 11, p. 240].

Limitations and future directions

Despite the robust findings, this study is subject to several limitations. First, while the quasi-experimental design was practical, the absence of full randomization limits absolute causal certainty. Second, the two-week retention period provides a strong indicator but does not confirm lifelong retention; future longitudinal studies over several months are required to validate the model's ultimate durability [15, p. 60]. Third, the study focused only on declarative and procedural retention; future research should expand the scope to investigate the emotional and affective benefits of NPA, such as reduced grammar anxiety and increased self-efficacy. Furthermore, the development of standardized, culturally-validated KGD and SVM packages is necessary before the NPA model can be widely adopted across diverse ESL contexts [17, p. 220]. The primary focus for future implementation should be the rigorous teacher training required to integrate KGD and SVM seamlessly without increasing teacher extraneous load [14, p. 100].

Conclusion

This study rigorously investigated the Neuro-Pedagogical Alignment (NPA) model, demonstrating its significant superiority over traditional methods in promoting the long-term retention and procedural fluency of English grammar in mixed-ability ESL classes. All three hypotheses were strongly supported. The primary empirical finding was the remarkable attenuation of knowledge decay in the Experimental Group (1.9% vs. 6.7%), providing clear evidence that the synchronized dual-modal approach is significantly more effective at consolidating grammatical knowledge. This success confirms the theoretical premise of NPA: that intentionally activating distinct neural pathways—the motor cortex via Kinesthetic Grammar Drills (KGD) and the visual cortex via Spatial-Visual Mapping (SVM)—simultaneously creates more resilient and robust memory traces. The findings offer powerful empirical support for the

dual-coding theory applied to complex linguistic structures. By physically embodying the rule (KGD) while visually mapping its structure (SVM), the abstract grammatical concept is encoded redundantly, facilitating the crucial shift from the labile declarative memory system (hippocampus-dependent) to the durable procedural memory system (motor cortex/cerebellum-dependent). This transition is key to achieving genuine automaticity, as evidenced by the statistically superior procedural fluency and lower error rates observed in the speaking tasks of the Experimental Group (H3). The NPA model provides a practical, evidence-based roadmap for transforming grammar instruction, particularly in heterogeneous settings where teachers struggle to cater to diverse learning styles. The results (H2) indicate that NPA effectively differentiates instruction by delivering targeted benefits to both kinesthetic and visual learners without compromising the performance of auditory learners. NPA offers an inclusive pedagogical solution that actively addresses the cognitive diversity inherent in mixed-ability classrooms. Educators are thus encouraged to move beyond passive, text-based lectures and to consciously design activities that require students to physically manipulate and spatially organize linguistic knowledge. The implementation of NPA effectively serves the pedagogical function of maximizing learning engagement, enhancing memory retention, and, critically, fostering grammatical automaticity required for real-world communication. In conclusion, the Neuro-Pedagogical Alignment model represents a validated framework for applying cognitive neuroscience principles directly to language pedagogy. By maximizing the structural potential of the brain's memory systems, NPA successfully overcomes the chronic problem of rapid grammar decay. While acknowledging the limitations of the quasi-experimental design and the limited retention window, this research establishes NPA as a highly promising direction for future research. Future studies should prioritize longitudinal follow-ups, explore the generalizability of NPA across different language skills (e.g., vocabulary acquisition), and focus on developing scalable professional development modules to ensure teachers can confidently and effectively implement KGD and SVM integration in their daily practice. The findings advocate for a fundamental reorientation in ESL grammar teaching, moving toward instructional methods that are not only communicative but also neuro-cognitively aligned.

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