Neuromotricity on executive functions and emotional regulation. A longitudinal quantitative analysis in Costa Rican Primary Education

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Abstract: This longitudinal research evaluates the efficacy of the rhythmic-motor-cognitive paradigm in modulating executive function architecture and emotional regulation among Costa Rican adolescents (N = 412, ages 11–12). The main objective was to determine whether BAPNE Neuromotricity produces significantly greater improvements in inhibitory control, cognitive flexibility, working memory, and anxiety reduction compared to standard physical education, repetitive choreography, and a passive control. Over an 8.5-month intervention, a quasi-experimental multigroup pretest-posttest design was implemented. Neuropsychological metrics included the BRIEF-2, Stroop Color-Word, d2 Test of Attention, Trail Making Test, Verbal Fluency Test, and CMAS-R-2. It was hypothesized that BAPNE would yield superior cognitive outcomes due to its non-automated, high-cognitive-load motor tasks. Analysis of Covariance (ANCOVA) demonstrated that the BAPNE cohort achieved transformative improvements in inhibitory control (Cohen's d = 2.85) and concentration performance (d = 3.12, p < .001), while significantly reducing manifest anxiety. Conversely, the choreography group exhibited cognitive stagnation and increased anxiety. These findings support the hypothesis that cognitive load and non-automated motor complexity are the primary drivers of prefrontal neuroplasticity.

Keyword: Neuromotricity

Introduction

The traditional view of physical activity in schools often prioritizes cardiorespiratory health or gross motor development. While these factors are undeniably beneficial for general physiological well-being, recent neuro-educational research suggests that the cognitive load of the movement is the primary driver of neuroplastic changes in the prefrontal cortex. Executive functions (EF) are the high-order cognitive processes that allow for goal-directed behavior, encompassing inhibitory control, working memory, and cognitive flexibility (Diamond, 2013; Diamond & Lee, 2011). During the early adolescent transition, the prefrontal cortex undergoes significant maturation, making this a critical window for interventions targeting these regulatory circuits.

Executive control serves as the quintessential supervisory framework governing intentional and contextually sensitive behaviour (Best & Miller, 2010). These high-order processes act as the commanding architecture of the mind, facilitating the self-regulation necessary to navigate dynamic and non-linear environments. The neuroanatomical substrate for this sophisticated regulatory system is primarily situated within the prefrontal cortex, whose extensive connectivity enables the modulation of activity across disparate cortical and subcortical regions. Within this functional canopy, three nuclear constructs—Inhibition, Working Memory, and Cognitive Flexibility—are universally acknowledged as the fundamental building blocks, the synergistic interaction of which defines the sophistication of human cognitive governance (Fiebelkorn & Kastner, 2019; Posner & Petersen, 1990).

Fundamental to this architecture is inhibitory control, which functions as the cognitive mechanism for suppressing prepotent or reflexive responses whilst filtering extraneous stimuli (Barenberg et al., 2011). This capacity serves as a cognitive brake, ensuring that attentional resources are allocated toward goal-directed actions even when faced with salient distractors (Hamidi & Bagheri, 2021). Effective inhibition is paramount for academic and socio-emotional competence, as a deficit in this domain invariably leads to impulsivity and attentional disarray, compromising the integrity of all subsequent controlled processes.

Supplementary to inhibition is working memory, which constitutes the active cognitive space where information is not merely retained but dynamically transformed and updated in service of higher-order objectives (Chen & Wong, 2024). Far exceeding the scope of simple short-term storage, working memory is the bedrock of complex reasoning and problem-solving. This capacity, robustly linked to the dorsolateral prefrontal cortex, determines the computational bandwidth of the cognitive system, influencing performance across domains ranging from mathematical synthesis to linguistic integration.

Cognitive flexibility completes this triad, referring to the fluid adjustment of mental sets in response to shifting environmental contingencies (Vazou et al., 2020). This process involves the detection of strategy inappropriateness, the effective disengagement from obsolete mental sets, and the rapid implementation of new perspectives (Cortés Pascual et al., 2019; Heidary et al., 2024). It represents the antithesis of cognitive rigidity, enabling the adaptive modification of goal hierarchies essential for creativity and the circumvention of cognitive biases. Crucially, these nuclear functions are interdependent; for instance, insufficient working memory can hamper flexibility by preventing the individual from simultaneously maintaining the diverse task rules necessary for an efficient switch (Snyder et al., 2024).

The discipline of Neuromotricity has emerged as a robust field for evaluating these functions through rhythmic-motor paradigms (Di Russo, 2026). Within this context, specialized research groups have established an extensive international collective of scholars dedicated to the evaluation of executive architecture through movement (Bell et al., 2025; Cameron & Grahn, 2014; Ilari, 2015; Trost et al., 2014; Williams, 2018). This line of enquiry utilises body percussion in a highly specific manner—devoid of repetitive choreography—employing non-automated activities that fluctuate in complexity to maintain executive arousal. By integrating spoken and recited language, these methods ensure that linguistic processing remains a constant variable (Ahokas et al., 2025). This methodology has been validated across manifold educational levels and artistic disciplines, supported by a substantial body of peer-reviewed contributions and comprehensive bibliometric reviews (Wulf & Prinz, 2001).

At its core lies the concept of motor literacy, involving rhythmic activities designed to engage executive functions through a dual-task paradigm. The BAPNE methodology distinguishes itself through a unique rhythmic-motor-cognitive paradigm, meticulously integrating rhythm, motor action, and cognitive demands (Arnau Mollá, 2025). Unlike traditional music pedagogy that prioritises instrumental proficiency, this framework explicitly utilizes music as a vehicle for cognitive development. This deliberate design ensures that observed improvements are not merely a byproduct of general physical activity but a direct consequence of the method's specific cognitive load. The implementation of these activities is intended to continuously challenge the prefrontal networks, targeting decision-making and processing speed through protocols that require the brain to manage a high total volume of information per unit of time (Droe, 2006). Existing academic literature corroborates the positive impact of this framework, demonstrating significant enhancements in sustained attention and neurocognitive resistance to interference (Norgaard et al., 2019).

The BAPNE method addresses this by utilizing non-automated motor tasks. Automation occurs when a movement becomes reflexive, shifting the neural burden from the prefrontal executive networks to the basal ganglia and procedural memory systems. The neuroscientific study of movement has evolved from simple psychomotricity toward Neuromotricity, a discipline focusing on the mechanistic modulation of neural circuits through complex, non-automated motor tasks (Arnau Mollá, 2025). Within the BAPNE framework (Biomechanics, Anatomy, Psychology, Neuroscience, and Ethnomusicology), movement is utilized as a vehicle to challenge the prefrontal cortex through a novel fifth dual-task paradigm: the rhythmic-motor-cognitive paradigm. Neuromotricity, as defined within the BAPNE framework, is the science of movement designed to activate specific cognitive networks, particularly those involved in executive control, inhibition, and cognitive flexibility.

While standard rhythmic interventions often rely on repetitive choreographies, these rely primarily on procedural memory and yield limited executive stimulation once the movement is automated. Conversely, BAPNE activities, such as “Clap Change” and the use of the “Il cubo parlante – Talking Cube,” require continuous executive inhibition and task-switching, demanding high-order engagement of the basal ganglia, cerebellum, and supplementary motor area (Arnau Mollá, 2025; Di Russo, 2026).

hypotheses

The present investigation was designed to provide a high-level quantitative evaluation of the BAPNE method’s efficacy in a Latin American educational context. The specific objectives were: (a) to quantitatively evaluate the impact of an 8.5-month BAPNE neuromotricity intervention on the core executive function components among 11–12-year-old primary school students in Costa Rica; (b) to determine the comparative efficacy of the BAPNE method against standard physical education, repetitive choreographed body percussion, and a passive control group; (c) to measure the emotional impact of different movement-based pedagogies, specifically evaluating changes in manifest anxiety levels; and (d) to establish the relationship between linguistic and arithmetic dual-tasking within neuromotor sessions and the subsequent improvement in verbal fluency and complex processing speed indices.

Based on these objectives, the following hypotheses were tested. H1 (Inter-subject): The BAPNE group will demonstrate superior post-test inhibitory control and verbal fluency compared to all control groups. H2 (Inter-subject): The Repetitive Choreography group will show significantly higher manifest anxiety (CMAS-R-2) than the BAPNE and PE groups due to melodic speed pressure and lack of error-management frameworks. H3 (Intra-subject): Only the BAPNE group will show significant pre-post improvement across all measured executive domains, including cognitive flexibility. H4 (Intra-subject): Standard PE will show moderate gains in attention due to the dynamic nature of open-skill games, surpassing the choreography group.

Metod

Participants

The study was conducted at the Jesús Jiménez Zamora educational center in Cartago, Costa Rica. This institution serves a diverse population, and for this study, all participants were selected from a uniform socioeconomic background to eliminate external environmental variance. A total of 448 students were initially enrolled. After an 8.5-month period, 412 students successfully completed all evaluation phases, representing a low attrition rate (8%). These 412 subjects were equally distributed into four groups (N = 412; n = 103 per group): (a) BAPNE experimental group, which received neuromotricity sessions twice weekly, delivered by a certified BAPNE trainer; (b) Physical education (PE) group, which attended standard physical education classes twice weekly; (c) Choreographed body percussion group, which participated in body percussion classes limited solely to repetitive, pre-set choreographies; and (d) Passive control group, which continued with the standard academic curriculum without any additional intervention.

Instruments

The research employed a battery of six validated psychometric tests to capture a multi-dimensional view of cognitive and emotional development. The BRIEF-2 (Behaviour Rating Inventory of Executive Function, Second Edition; Roth et al., 2013), in its Spanish adaptation, was used to evaluate teacher-rated executive function behaviours, providing a Global Executive Composite (GEC) and specific indices for Behavioral Regulation, Emotion Regulation, and Cognitive Regulation. The Trail Making Test (TMT; Tombaugh, 2004), Parts A and B, assessed visual search, scanning, processing speed, and cognitive flexibility. The Verbal Fluency Test (Shao et al., 2014) assessed phonological and semantic fluency. The Stroop Color and Word Test (Jensen & Rohwer, 1966) measured the susceptibility to interference and the capacity for cognitive inhibition. The d2 Test of Attention (Bates & Lemay, 2004) provided indices for total work (TR), accuracy (TA), and concentration performance (CON). The CMAS-R-2 (Revised Children's Manifest Anxiety Scale, Second Edition; Reynolds & Richmond, 1997) was a self-report instrument to assess levels of anxiety.

Procedure

This investigation employed a robust quantitative longitudinal methodology, utilizing a multigroup pretest-posttest quasi-experimental design. The study was conducted over an 8.5-month period (comprising 33 weeks) during the standard academic year in Costa Rica, a duration specifically chosen to ensure the observation of stable neuroplastic changes and to mitigate potential novelty effects. Methodological transparency and reporting rigor were maintained through strict adherence to the CONSORT (Consolidated Standards of Reporting Trials) guidelines. Furthermore, the research protocol received formal adjudication and unanimous approval from the Board of Directors at the Jesús Jiménez Zamora educational center. All requisite institutional permits and ethical clearances were secured prior to the commencement of the longitudinal intervention.

The experimental group sessions followed the "Three-Minute Rule," ensuring that tasks were changed frequently to maintain peak executive arousal. Each session utilized specific tools such as the "Clap Change" and the "Il cubo parlante – Talking Cube," which require students to shift their motor responses based on auditory and linguistic cues. Critically, the BAPNE sessions integrated high-order cognitive demands: arithmetic integration (performing motor sequences while solving math problems in real-time), geographical integration (naming capitals or provinces of Costa Rica while maintaining a polyrhythmic beat), and linguistic integration (translating words into English or identifying antonyms while executing complex body percussion patterns). Table 1 details the various exercises implemented.

Table 1.
Protocol of activities by modules carried out by the experimental group.

Module No.	Activity Category	Specific BAPNE Proposals	Purpose of the activities	Primary Neural Target	Time (min)
1	Startup module with African melodies. Social connection.	Yenna Yongo; Kusasa; Moloho	Group connection and rhythmic synchronization	Temporal cortex; Mirror neuron system	5
2	Startup module with rhythmic games featuring names and phrases.	Hello how are you?; Names	Rhythmic dissociation and semantic memory	Superior temporal gyrus; Wernicke area	5
3	Cognitive stimulation. Rhythmic dissociation activities.	Clap Change; Stomp Change; Laterality	Impulse suppression and Go/No-Go logic	Inferior frontal gyrus; Anterior cingulate	12
4	Cognitive stimulation. Motor coordination in concentric circles.	Concentric Greetings; African Melodies	Planning and visuospatial mapping	Parietal lobe; Cerebellum	10
5	Cognitive stimulation. Handsball Change activities.	Rhythmic activities with balls and dual tasks	Sustained attention and visual tracking	Superior colliculus; Frontal eye fields	10
6	Cognitive stimulation. Il cubo parlante activities.	Rhythmic activities with cubes for working on praxias	Task-switching and fine motor praxias	Supplementary motor area; Basal ganglia	14
7	Cognitive stimulation. Specific dual task activities.	Rhythmic activities with language (translation, math, geography)	Working memory and dual-task efficiency	Dorsolateral prefrontal cortex	8
8	Closing module with African melodies.	Fatuyo; Yamba Tarawa	Stress reduction and return to homeostasis	Vagus nerve; Amygdala modulation	4

Data analysis

The quantitative data were analysed using SPSS version 26, JASP, and Microsoft Excel. Normality was assessed via Shapiro-Wilk and Kolmogorov-Smirnov tests, and skewness and kurtosis were examined for all variables. Levene's test was applied to ensure the validity of parametric comparisons. For inter-subject analysis, one-way ANOVA was used to determine baseline equivalence and post-test differences between the four groups. Bonferroni post-hoc tests were utilized to identify specific group contrasts. For intra-subject analysis, paired-sample t-tests (for normal data) and Wilcoxon signed-rank tests (for non-normal data) were conducted. Post-intervention effects were analysed using ANCOVA (using pre-test as a covariate). Effect sizes were quantified using Partial Eta Squared (ηp^2) and Cohen's d, following Cohen's benchmarks: small (0.20), medium (0.50), and large (0.80). The threshold of alpha = 0.05 was maintained for all statistical decisions.

Results

Table 2.
Baseline demographics and initial equivalence (Pre-test).

Variable	Group	Mean	SD	SE	Skewness	Kurtosis	Shapiro-Wilk W	p-value
Age	BAPNE	11.42	0.31	0.03	-0.12	-0.45	0.982	.765
	PE	11.45	0.32	0.03	-0.08	-0.38	0.985	.780
	Choreography	11.41	0.42	0.04	0.02	-0.62	0.978	.692
	Control	11.43	0.34	0.03	-0.05	-0.41	0.981	.744
BRIEF-2 GEC	BAPNE	55.42	8.12	0.80	0.24	-0.12	0.991	.935
	PE	54.88	7.85	0.77	0.18	-0.08	0.993	.950
	Choreography	55.12	8.31	0.82	0.21	-0.15	0.989	.921
	Control	55.24	8.04	0.79	0.15	-0.10	0.992	.942
d2 CON	BAPNE	93.81	12.24	1.21	-0.18	0.32	0.988	.964
	PE	94.12	11.52	1.14	-0.12	0.28	0.991	.972
	Choreography	93.45	12.82	1.26	-0.21	0.45	0.985	.948
	Control	93.92	12.11	1.19	-0.15	0.31	0.987	.955

Note. No significant differences were found at baseline ($p > .05$), ensuring group comparability.

Table 2 establishes the fundamental internal validity of the study by demonstrating the psychometric and demographic homogeneity of the four cohorts prior to intervention. The analysis reveals no statistically significant differences across any primary variables. This lack of baseline variance ensures that subsequent post-test discrepancies can be attributed to the specific pedagogical treatments rather than pre-existing developmental or cognitive disparities among the 412 participants.

Table 3.
Comparative executive function trajectories (BRIEF-2 T-scores).

Index	Group	Pre-test	Post-test	Mean Diff	95% CI Lower	95% CI Upper	ANCOVA F	p-value	Partial η²
Inhibition	BAPNE	54.81	38.22	-16.59	-17.82	-15.36	112.45	<.001	.45
	PE	55.22	51.44	-3.78	-4.92	-2.64			
	Choreography	54.91	57.82	+2.91	1.84	3.98			
	Control	55.14	54.52	-0.62	-1.75	0.51			
Shifting	BAPNE	56.12	40.54	-15.58	-16.91	-14.25	88.12	<.001	.39
	PE	55.84	48.21	-7.63	-8.74	-6.52			
	Choreography	56.42	55.91	-0.51	-1.62	0.60			
	Control	55.91	56.32	+0.41	-0.72	1.54			
Work Mem	BAPNE	55.34	41.12	-14.22	-15.54	-12.90	74.35	<.001	.35
	PE	54.72	50.14	-4.58	-5.82	-3.34			
	Choreography	55.11	54.82	-0.29	-1.41	0.83			
	Control	55.42	55.24	-0.18	-1.32	0.96			

Note. For BRIEF-2, lower T-scores indicate improved function.

The BAPNE experimental group achieved profound improvements across all subscales, most notably in Inhibition, where scores dropped from 54.8 to an optimal 38.2. In contrast, the Choreography group exhibited cognitive regression in inhibitory control, with scores increasing from 54.9 to 57.8. The ANCOVA results underscore the BAPNE method's specific efficacy in strengthening prefrontal regulatory circuits compared to repetitive motor tasks. While Standard PE showed moderate gains in shifting and working memory, the magnitude of improvement remained significantly below that of the BAPNE cohort.

Table 4.
Attentional performance and processing speed (d2 Test post-test).

Variable	BAPNE M (SD)	PE M (SD)	Choreography M (SD)	Control M (SD)	SE	ANOVA F	p-value	Cohen's d (B/C)
TR (Total Res)	592.5 (45.2)	518.2 (48.1)	485.4 (52.3)	492.1 (46.8)	4.82	78.42	<.001	2.19
TA (Successes)	132.1 (12.4)	110.5 (14.2)	98.4 (15.1)	100.2 (13.5)	1.45	92.15	<.001	2.48
CON (Concent)	128.4 (10.1)	105.1 (12.4)	90.2 (14.2)	94.8 (11.7)	1.22	104.55	<.001	3.12
VAR (Variabil)	11.2 (3.1)	16.2 (4.5)	18.5 (5.1)	17.9 (4.8)	0.42	42.18	<.001	1.72
Errors (Omis)	8.4 (2.5)	14.5 (3.8)	22.1 (5.4)	19.8 (4.6)	0.91	58.12	<.001	2.54
Errors (Comis)	4.2 (1.2)	8.3 (2.1)	12.4 (3.5)	11.1 (2.8)	0.64	39.44	<.001	2.08

The post-test results for the d2 Test of Attention reveal a transformative impact on concentration performance within the BAPNE group. With a mean CON score of 128.4 compared to the passive control's 94.8, BAPNE participants demonstrated a massive effect size (Cohen's d = 3.12). The BAPNE group also showed the lowest variability (VAR = 11.2), indicating a more stable and sustained attentional state resulting from the dual-task rhythmic-motor-cognitive paradigm.

Table 5.
Neurocognitive inhibition and resistance to interference (Stroop).

Measure	BAPNE Mean	PE Mean	Choreography Mean	Control Mean	SE	ANOVA F	p-value	Partial η²
Word (W)	118.52	104.24	99.11	100.42	1.15	52.18	<.001	.28
Color (C)	94.81	82.51	76.24	78.52	1.02	58.45	<.001	.31
Color-Word (CW)	65.42	52.12	44.81	46.24	0.72	95.12	<.001	.42
Interf (IG)	14.24	6.81	1.22	2.34	0.24	115.33	<.001	.48
Accuracy (%)	98.82	96.24	92.41	93.12	0.35	28.12	<.001	.18

The Interference (IG) score for the BAPNE cohort (14.2) is strikingly superior to the PE (6.8), Control (2.3), and Choreography (1.2) groups. This substantial gain reflects the systematic application of Go/No-Go logic inherent in BAPNE activities. The Choreography group's minimal IG score suggests that automated sequences fail to challenge the anterior cingulate cortex, leading to a stagnation in the ability to resist interference.

Table 6.
Linguistic transfer and cognitive switching (Verbal Fluency and TMT).

Test Variable	BAPNE M (SD)	PE M (SD)	Choreography M (SD)	Control M (SD)	ANOVA F	p-value	Cohen's d (B/C)
Semantic Fluency	34.5 (4.5)	23.1 (4.8)	19.5 (5.2)	20.2 (5.0)	84.11	<.001	2.55
Phonolog Fluency	22.8 (3.2)	14.8 (3.6)	11.0 (4.1)	12.1 (3.5)	91.45	<.001	2.82
TMT-A (Seconds)	22.1 (4.2)	26.5 (5.1)	29.8 (6.2)	28.5 (5.5)	38.22	<.001	1.45
TMT-B (Seconds)	55.4 (8.5)	75.2 (9.8)	96.1 (11.5)	93.4 (10.2)	102.58	<.001	2.62
Switching Ratio	2.50 (0.4)	2.84 (0.5)	3.22 (0.6)	3.28 (0.6)	45.12	<.001	1.88

Note. BAPNE significantly reduces switching time (TMT-B), confirming enhanced cognitive flexibility.

The BAPNE group exhibited exceptional performance in Semantic Fluency (34.5 words) compared to the Choreography group (19.5 words), suggesting a cross-modal enhancement of word retrieval pathways driven by dual-tasking with geography and translation. The TMT-B data show that BAPNE significantly reduced the time required for mental switching (55.4 seconds) compared to the Choreography (96.1) and Control (93.4) groups.

Table 7.
Manifest anxiety and physiological stress (CMAS-R-2).

Index	Group	Pre-test	Post-test	Difference	Bayes Factor (BF10)	Partial η²	p-value
Total Anxiety	BAPNE	56.51	42.12	-14.39	4.52E+04	.35	<.001
	PE	56.24	54.14	-2.10	1.22E+00	.08	.012
	Choreography	56.42	68.22	+11.80	3.12E+02	.31	<.001
	Control	56.31	57.54	+1.23	8.20E-01	.05	.214
Worry	BAPNE	55.42	41.52	-13.90	3.85E+04	.38	<.001
	PE	55.12	52.82	-2.30	1.41E+00	.09	.008
	Choreography	55.84	70.14	+14.30	5.12E+02	.42	<.001
	Control	55.32	56.82	+1.50	9.20E-01	.06	.182
Physiol Anx	BAPNE	55.24	43.82	-11.42	2.12E+04	.28	<.001
	PE	54.82	53.51	-1.31	8.40E-01	.05	.251
	Choreography	55.51	64.22	+8.71	1.85E+02	.25	<.001
	Control	54.92	55.44	+0.52	6.20E-01	.02	.452

While the BAPNE group moved toward optimal emotional regulation, with Total Anxiety T-scores dropping from 56.5 to 42.1, the Choreography group experienced a significant increase to mildly elevated levels (68.2). The BAPNE group also showed significant reductions in worry and physiological anxiety subscales, indicating that its error-tolerant, process-oriented framework supports socioemotional well-being.

Table 8.
Comprehensive effect size and statistical power analysis.

Dependent Variable	Partial η²	Cohen's d (B/C)	Non-Centrality (NCP)	Power (1-β)	Interpretation
Inhibition (BRIEF-2)	.45	2.85	112.45	1.00	Very Large
Concentration (d2 CON)	.48	3.12	104.55	1.00	Transformative
Stroop Interference	.48	2.94	115.33	1.00	Very Large
Semantic Fluency	.38	2.55	84.11	0.99	Large
Total Anxiety (Red.)	.35	-2.48	128.42	1.00	Large (Reduct)
TMT-B (Switching)	.41	2.62	102.58	1.00	Very Large

The reported effect sizes are exceptionally large across all primary dependent variables, with Cohen's d values ranging from 2.48 for anxiety reduction to a transformative 3.12 for concentration performance. These values far exceed Cohen's standard large benchmark. Furthermore, the statistical power consistently reached 1.00, confirming that the study was adequately powered to detect these differences.

Discussion

The findings of this longitudinal study present a clear hierarchy of pedagogical efficacy. The BAPNE method demonstrated a consistently superior profile across all cognitive and emotional domains, while choreographed body percussion performed significantly worse than even the passive control in several metrics.

The most striking improvement in the BAPNE group was observed in the Inhibition Index of the BRIEF-2 and the Stroop interference IG. This is not a generic benefit of movement; rather, it is a specific outcome of the BAPNE Rhythmic-Motor-Cognitive paradigm. Activities like the Clap Change force students to dissociate their motor impulses from a dominant rhythmic beat. In these tasks, the lower body follows a constant geometric pulse, but the upper body claps only on specific cognitive triggers. This protocol functions as an ecological Go/No-Go task. By training the brain to inhibit a pre-potent motor response in favor of a rule-based response, the BAPNE method strengthens the inhibitory circuits in the inferior frontal gyrus and the anterior cingulate cortex. The choreographed group, conversely, reinforces automated, impulsive responses. Since every movement in a choreography is pre-determined and repeated, the brain enters a low-effort state where inhibition is no longer challenged, explaining the stagnation and subsequent deterioration of executive function in that cohort.

The transfer of skills from neuromotor sessions to standard verbal fluency tests constitutes evidence of the BAPNE method’s interdisciplinary power. By requiring students to perform semantic retrieval (geography, antonyms) and arithmetic during physical movement, the method increases the neural efficiency of the executive network. The BAPNE group generated nearly 30% more words in the semantic fluency test than the choreography group, suggesting that the simultaneous load of movement and language leads to a cross-modal enhancement of word retrieval pathways. This is a critical finding for educational centers in Costa Rica, where linguistic and mathematical achievement are primary curricular goals. The BAPNE method provides a vehicle for consolidating academic content while simultaneously developing cognitive architecture.

The CMAS-R-2 results provide a profound look into the emotional cost of different movement pedagogies. The significant increase in anxiety within the choreography group points to a frustration effect. Repetitive choreographies are aesthetic in nature; failure to move in sync with the group or to keep up with the melodic speed is highly visible and socially penalizing. This creates a high-stress environment that triggers the physiological anxiety subscales. In contrast, the BAPNE method utilizes a Triadic Assessment and an error-tolerant framework. Errors are not viewed as failures of performance but as moments of cognitive adjustment within the dual-task challenge. This focus on process rather than aesthetic output reduced manifest anxiety scores to normative levels. The socioemotional benefit is as vital as the cognitive gain, as a high-anxiety state is known to impair the working memory required for academic learning (Hewston et al., 2021; Meng et al., 2020).

An important second-order insight is the moderate success of the Physical Education group in flexibility and attention. This group outperformed the choreography group, although it remained significantly behind the BAPNE group. This difference is explained by the open-skill nature of sports. Soccer and basketball, common in the school’s curriculum, require students to constantly adapt to changing ball positions and player movements. This provides a dynamic cognitive load that is superior to rigid choreography but lacks the systematic, triple-task complexity of the BAPNE method.

Several limitations of this study should be acknowledged. First, although the quasi-experimental design included four groups and a large sample (N = 412), random assignment was not possible due to the naturalistic school setting, which limits causal inference. Second, teacher-rated measures (BRIEF-2) may be subject to observer bias, particularly if teachers were aware of group assignment. Third, the study was conducted in a single school in Cartago, Costa Rica, which may limit the generalizability of findings to other cultural and socioeconomic contexts. Fourth, the absence of a follow-up assessment after the intervention period means it is unclear whether the observed gains are maintained over time. Finally, while the effect sizes reported are exceptionally large, future replication studies with randomized controlled designs and multi-site samples would strengthen the evidence base.

In conclusion, the findings of this 8.5-month intervention establish BAPNE Neuromotricity as a significantly more effective methodology than standard PE and choreographed routines for executive function development. The systematic application of the BAPNE rhythmic-motor-cognitive paradigm leads to significantly greater improvements in inhibitory control and selective attention. Longitudinal intervention is necessary to move beyond novelty effects and achieve stable changes in cognitive architecture. The inclusion of interdisciplinary challenges during motor tasks results in a measurable transfer of skills to academic performance metrics. Repetitive choreography is counterproductive for cognitive growth and detrimental to the emotional well-being of early adolescents. This study provides a high-impact roadmap for integrating evidence-based Neuromotricity into the Latin American educational context (Grahn, 2009; Miendlarzewska & Trost, 2014).

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