



Neuromotor Intervention on Executive Functions in Early Childhood: A Randomized Controlled Trial of the BAPNE Method

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Abstract

Objectives. The study aimed to investigate the causal effect of a seven-month neuromotor intervention, the BAPNE method, on the core executive functions (EFs) of preschool-aged children, compared to a traditional music education program.

Materials and Methods. A randomized controlled trial with a pre-test/post-test design was conducted with a sample of 82 four-year-old children ($n = 82$; 41 in the experimental group, 41 in the active control group) in Caracas, Venezuela. The experimental group received the BAPNE intervention, while the control group underwent traditional music instruction. EFs were assessed through teacher ratings on the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P). Data were analyzed using Analysis of Covariance (ANCOVA), with pre-test scores as a covariate to control for initial differences.

Results. After controlling for baseline performance, the BAPNE group demonstrated statistically significant improvements, with large effect sizes, on all primary outcome measures compared to the control group. This includes the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), the Emergent Metacognition Index (EMI), and the Global Executive Composite (GEC) (all $p < .001$).

Conclusions. The findings provide strong evidence that the BAPNE method, grounded in the principles of neuromotoricity and cognitive stimulation through dual-tasking, is a highly effective intervention for enhancing the expression of executive functions in the everyday context of early childhood.

Keywords: executive functions, neuromotoricity, BAPNE method, body percussion, early childhood, randomized controlled trial, inhibitory control, working memory, cognitive flexibility.

Introduction

Executive functions (EFs) represent a set of high-level, top-down cognitive processes that orchestrate and direct thought, emotion, and behavior toward goal attainment (Anderson, 2002; Zelazo & Müller, 2002). This multifaceted construct, which encompasses skills such as inhibitory control, working memory, and cognitive flexibility, is universally recognized as a fundamental pillar for human development and success throughout the lifespan (Goldstein & Naglieri, 2014). Scientific evidence accumulated over the last few decades has unequivocally established that the preschool years, approximately between three and five years of age, constitute a time window of exceptional importance

for the development of these functions (Best & Miller, 2010; Blair, 2016; Garon et al., 2008). During this period, the child's brain is characterized by extraordinary synaptic plasticity and structural malleability, particularly in the prefrontal cortex and its extensive networks connecting to other brain regions, making it especially receptive to environmental influences (Diamond, 2013a, 2013b). The robustness of EFs in early childhood is not merely an indicator of cognitive maturity (Goldstein & Naglieri, 2014); it is a potent predictor of a wide range of future outcomes. Longitudinal research has shown that children with well-developed EFs at the start of their schooling exhibit greater academic readiness, achieve higher performance in reading and mathematics, and display better social and emotional adaptation in the classroom (Bowmer et al., 2018; Espy et al., 2004; Rus et al., 2024; Habibi et al., 2018). Conversely, early deficits in EFs are associated with a higher risk of learning difficulties, behavioral problems, and neurodevelopmental disorders. This reality underscores the

urgent need to identify and implement evidence-based early interventions that can strengthen these critical capacities at a time when the potential for change is greatest.

The recognition of this window of plasticity has spurred research into the role of environmental enrichment in optimizing neurodevelopmental trajectories. Far from being a purely deterministic and genetic process, the development of EFs is profoundly shaped by the quality and structure of a child's experiences (Wollesen et al., 2022). Structured and enriching activities that systematically and engagingly challenge the child act as catalysts for the formation and strengthening of the neural circuits that support self-control and goal-directed thinking. In this context, music education and movement-based activities have emerged as tools of extraordinary potential. Beyond their artistic and cultural benefits, active participation in music and dance demands the integration of attentional, mnemonic, motor, and sequencing processes, making them ecologically valid and highly motivating platforms for cognitive training (Bugos et al., 2017; Oberer et al., 2018).

The BAPNE Method as a specific neuromotor intervention

Within the spectrum of interventions based on music and movement, the BAPNE method (Biomechanics, Anatomy, Psychology, Neuroscience, and Ethnomusicology) is distinguished by its solid theoretical framework and its explicit focus on cognitive stimulation. Developed by PhD. Francisco Javier Romero Naranjo, BAPNE is not conceived as a mere music pedagogy, but as a neuromotor intervention program designed to enhance EFs through a central mechanism: the systematic application of dual-task paradigms (Mas-Mas et al., 2023; Wollesen et al., 2022). Unlike traditional approaches that often teach motor and cognitive skills sequentially, the BAPNE method demands the simultaneous and coordinated execution of motor tasks (body percussion, movement), rhythmic tasks (complex metric patterns), and cognitive tasks (spoken, sung, or recited language). This concurrent demand imposes a significant load on the central executive system, forcing it to manage, prioritize, and coordinate multiple streams of information efficiently. This fundamental characteristic theoretically positions the BAPNE method as a potentially more potent intervention for EF training than more general enrichment programs.

Problem statement and research objectives

Despite the theoretical robustness of the BAPNE method and a growing body of research supporting its benefits in various populations, there is a notable lack of rigorous experimental evidence demonstrating its causal impact on EFs in very young children. Most studies on music and cognition in preschoolers are correlational or lack adequate active control groups, limiting the ability to establish a cause-and-effect relationship. To address this gap, the present study was designed as a randomized controlled trial with the primary objective of determining whether a seven-month intervention with the BAPNE method produces superior improvements in executive functions, as evaluated by teachers in the natural classroom environment, in four-year-old Venezuelan children, compared to an active control group participating in a high-quality traditional music education program with the test BRIEF-P (Sherman & Brooks, 2010).

Hypotheses

Based on the theoretical framework presented, the following a priori hypotheses were formulated:

1. Does a seven-month neuromotor intervention based on the BAPNE method and characterized by neuromotricity (Bapne method) produce a causal effect on the improvement of global executive functions in four-year-old children that is superior to that of a high-quality traditional music education program?
2. Does the differential impact of the BAPNE intervention manifest itself specifically and significantly in the core components of executive functions, namely inhibitory self-control, cognitive flexibility, and emerging metacognition, compared to the active control group?
3. Is the magnitude of the effect of the BAPNE intervention on executive functions, as assessed through teacher observations in an ecological classroom setting, large enough to have significant practical and educational relevance?

Research Objectives

To answer the questions posed, the following objectives are proposed:

1. Determine the causal effect of the BAPNE neuromotor intervention on global executive function (as measured by the BRIEF-P Global Executive Composite) in preschoolers, compared to an active control group receiving traditional music instruction (flute, school orchestra).
2. Analyze the specific impact of the BAPNE intervention on the three primary indices of executive functions of the BRIEF-P: the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), and the Emerging Metacognition Index (EMI), to discern the effects of the program on different facets of executive control.
3. Quantify the effect size of the BAPNE intervention on each of the BRIEF-P scales and indices to establish the practical significance of the differences observed between the experimental and control groups, beyond mere statistical significance.

Operating Hypotheses

Based on the theoretical framework of neuromotricity, which posits that the cognitive load imposed by dual-tasking is the primary driver of neuroplastic change, the following a priori hypotheses were formulated. The primary inter-subject hypotheses are designed to be tested via one-way Analysis of Covariance (ANCOVA), with post-intervention scores as the dependent variable and pre-intervention scores as the covariate. Hypotheses are presented in null (H₀) and alternative (H_a) form.

Inter-Subject Hypotheses (Between-Groups Analysis)

Hypothesis 1. Global executive composite (GEC)

H₀: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Global

Executive Composite (GEC) between the experimental (BAPNE) and active control (Traditional Music) groups.

Ha: The experimental (BAPNE) group will exhibit a statistically significant lower adjusted post-intervention mean score on the GEC, indicating superior global executive functioning, compared to the active control group.

Hypothesis 2. Inhibitory self-control index (ISCI)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Inhibitory Self-Control Index (ISCI) between the experimental and active control groups.

Ha: The experimental group will exhibit a statistically significant lower adjusted post-intervention mean score on the ISCI, indicating superior inhibitory control, compared to the active control group.

Hypothesis 3. Flexibility index (FI)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Flexibility Index (FI) between the experimental and active control groups.

Ha: The experimental group will exhibit a statistically significant lower adjusted post-intervention mean score on the FI, indicating superior cognitive flexibility, compared to the active control group.

Hypothesis 4. Emergent metacognition index (EMI)

H0: There will be no statistically significant difference in the adjusted post-intervention mean scores on the Emergent Metacognition Index (EMI) between the experimental and active control groups.

Ha: The experimental group will exhibit a statistically significant lower adjusted post-intervention mean score on the EMI, indicating superior emergent metacognition, compared to the active control group.

Intra-Subject Hypotheses (Within-Group Analysis)

To characterize the developmental trajectories within each condition, the following secondary, intra-subject hypotheses were proposed:

Hypothesis 5. Change within the BAPNE group

H0: There will be no statistically significant change in mean scores on the BRIEF-P indices from pre- to post-intervention within the experimental (BAPNE) group.

Ha: The experimental (BAPNE) group will demonstrate a statistically significant reduction in mean scores from pre- to post-intervention across all primary BRIEF-P indices, reflecting a robust improvement in executive functions attributable to the intervention.

Hypothesis 6. Change within the active control group

H0: There will be no statistically significant change in mean scores on the BRIEF-P indices from pre- to post-intervention within the active control (Traditional Music) group.

Ha: The active control (Traditional Music) group will demonstrate either no statistically significant change or a significantly smaller reduction in mean scores from pre- to post-intervention, reflecting effects attributable primarily to maturation and non-specific program participation rather than targeted EF training.

Executive functions as the basis for this study.

Executive functions are not a monolithic construct, but a system of interrelated processes that mature at different rates.

Research in developmental neuroscience has converged on the identification of three core components that form the basis of more complex EFs like planning and problem-solving. These three pillars are (Miyake et al, 2000, 2012):

Inhibitory Control: This function is the fundamental ability to deliberately suppress dominant, prepotent, or automatic responses, and to resist interference from irrelevant or distracting stimuli. It includes both the inhibition of motor responses (e.g., waiting for one's turn to speak) and attentional control (e.g., ignoring a noise in the hallway to focus on a task). In the preschool years, the development of inhibitory control is visible in the child's growing ability to follow rules, control impulses, and regulate emotions.

Working Memory: This refers to the ability to actively hold and manipulate a limited amount of information in the mind for a short period to guide behavior. It is not simple passive storage, but a dynamic mental workspace that allows, for example, following a multi-step instruction, remembering the beginning of a sentence to understand its end, or performing simple mental calculations. Its development in preschoolers is crucial for language learning and early mathematical concepts.

Cognitive Flexibility (or Set-Shifting): This is the ability to change perspectives, adapt to new rules or demands, and think flexibly to respond to changes in the environment. It allows a child to abandon a strategy that is not working and try a new one, see a problem from different angles, and adjust their behavior to changing social contexts. Cognitive flexibility is the basis of creativity and adaptability.

It is important to note that, although these three components are theoretically dissociable, in early childhood (between 3 and 5 years) their functioning is highly intercorrelated. Factor analysis studies often reveal a more unitary structure of EFs at this stage, where performance on an inhibition task is strongly related to performance on a working memory task. This relative undifferentiation justifies the use of assessment instruments like the BRIEF-P, which, while having specific scales, also provides a Global Executive Composite (GEC) that captures this shared variance and offers a comprehensive measure of the child's executive functioning in daily life.

From psychomotricity to neuromotricity.

To understand the proposed mechanism of action for the BAPNE method, it is essential to draw a clear conceptual distinction between traditional approaches to movement and the paradigm of neuromotricity. The specialized literature, led by Romero-Naranjo and Andreu-Cabrera (Andreu-Cabrera & Romero-Naranjo, 2021; Romero-Naranjo et al., 2024), proposes a terminological and conceptual evolution that reflects a deeper understanding of the mind-body interaction:

Motricity: Refers to the ability to execute voluntary and coordinated body movements, such as walking, running, or jumping. It is the observable result of the activation of the motor system.

Psychomotricity: A broader concept that integrates the interactions between cognitive, emotional, symbolic, and sensorimotor aspects. Psychomotricity considers movement as a form of expression and relationship of the individual with their psychosocial environment.

Neuromotricity: This term represents the most advanced paradigm, defined as an educational and neurorehabilitative process that uses movement as a vehicle for direct cognitive stimulation, with an explicit emphasis on executive functions. Its distinctive feature is the systematic incorporation of the dual-task (Mas-Mas et al., 2023), as a fundamental pedagogical tool. A practical and accurate example of neuromotor activity is the “talking cube” (Il cubo parlante) activities of the Bapne method, which contains all the parameters required by neuromotricity.

The theoretical framework of neuromotricity posits that the brain is not optimally trained when tasks are performed in isolation or sequentially. True cognitive enhancement occurs when the central nervous system is forced to manage multiple demands simultaneously. This principle is embodied in the dual-task paradigm, which in the context of the BAPNE method is classified into several types, the most relevant for this research being Rhythmic/Motor/Cognitive. The activity “the talking cube” (Il cubo parlante) requires all of these parameters.

The functioning of this paradigm can be conceived as a form of “cognitive weightlifting.” While traditional music education might teach a rhythm with the hands (motor task) and then ask the child to recite it (cognitive task), the BAPNE method demands, for example, that the child execute a rhythmic pattern with their feet, another different and dissociated pattern with their hands, and simultaneously sing a song or recite a numerical sequence. This controlled and concurrent overload of the motor, auditory, visual, and linguistic systems places an exceptionally high demand on executive functions. The brain must inhibit automatic movements, hold multiple patterns in working memory, flexibly switch between the rules for each limb, and monitor overall performance to correct errors in real-time.

This constant and structured demand is what, hypothetically, drives neuroplasticity. The repeated practice of dual tasks promotes the automation of motor sequences, which in turn frees up cognitive resources that can be reallocated to higher-level tasks. This process strengthens the connections between the prefrontal cortex (the seat of EFs) and other key structures such as the basal ganglia (involved in motor learning and the automation of routines) and the cerebellum (crucial for coordination and timing). Therefore, the BAPNE method not only teaches music or movement; it uses these modalities as a means to directly train the brain’s mechanisms of cognitive control.

The BAPNE method as a tool for cognitive stimulation.

The BAPNE method is an integrative pedagogical system that draws from multiple disciplines to create a holistic learning environment. Its acronym reflects this multidisciplinary foundation: Biomechanics (for movement efficiency and safety), Anatomy (for body awareness), Psychology (for motivational and socio-emotional aspects), Neuroscience (as the basis for cognitive stimulation), and Ethnomusicology (for the richness and diversity of rhythmic and cultural patterns). This methodology has more than 60 publications in Web of Science and exceeds four thousand academic citations. Its interdisciplinary nature allows it to be used with students of physical education, music, or students in general, with exclusive sessions or as an active

break activity (Alonso-Marco & Romero-Naranjo, 2022; Alonso-Sanz & Romero-Naranjo, 2015; Andreu-Cabrera & Romero-Naranjo, 2021). The BAPNE method has an official research group based at the University of Alicante (Spain), which is made up of around ninety researchers from various countries. The research group, called “Neuromotricity and Motor Literacy”, has more than two hundred scientific publications and has won several research awards.

For the present intervention, only the resources and activities from the “Bapne for Children” and “Cognitive Solfege” programs were used, which are specifically designed for the Early Childhood Education stage. These programs translate the principles of neuromotricity into playful and developmentally appropriate activities for 4-year-old children (Romero-Naranjo et al., 2024). Based on the development tables proposed by Romero-Naranjo, for this reason, the BAPNE method uses numerous resources such as ropes, hoops, wooden sticks of different sizes that are placed on the floor, cones, balls with different textures and weights, and most importantly, cubes for working in pairs called “il cubo parlante” (the talking cube).

Materials and Methods

Research Design

This study adheres to the highest standards of experimental research, employing a randomized controlled trial (RCT) design with two parallel groups (experimental and active control) and measurements at two time points (pre-test and post-test). This design is considered the gold standard for establishing causal inference, as the random assignment of participants to treatment conditions minimizes selection bias and allows observed differences in outcomes to be attributed to the intervention itself.

Participants and context

The sessions were given by BAPNE trainer Andreina Liendo Cárdenas at the Nuestra Señora del Carmen School and the BCV Early Education Center in Caracas (Venezuela). Approval was obtained from the institutional research ethics committee and the educational center before initiating any procedures. Informed consent letters were sent to the parents or legal guardians of all four-year-old children enrolled in the center. An initial total of 93 children whose parents gave their consent were recruited. Over the seven-month intervention period, there was an attrition rate of 11.8%, with 11 participants dropping out of the study ($n = 6$ due to family relocation to another city, $n = 3$ due to prolonged illness unrelated to the intervention, and $n = 2$ due to parental decision to withdraw the child). This attrition rate is considered low and acceptable for longitudinal studies in this population.

The final sample for statistical analysis consisted of 82 children ($N = 82$) with a mean age of 4.52 years ($SD = 0.28$). The gender distribution showed a slight majority of girls, with 45 female participants (54.9%) and 37 male participants (45.1%). Participants were randomly assigned, using a numerical sequence generator by an independent statistician, to the BAPNE experimental group ($n = 41$) or the traditional music control group ($n = 41$).

Instrumentation. Behavior rating inventory of executive function–preschool (BRIEF-P)

The primary dependent variable, executive functions, was measured exclusively through the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P; (Sherman & Brooks, 2010)). The BRIEF-P is a standardized and norm-referenced questionnaire designed for parents and teachers to evaluate the behavioral manifestations of EFs in children aged 2 to 5 years in their everyday environments (home and school). This tool was selected for its high ecological validity, as it captures how deficits or strengths in EFs translate into observable behaviors in the real world, rather than measuring performance on decontextualized laboratory tasks. The instrument consists of 63 items rated on a 3-point Likert scale (“Never,” “Sometimes,” “Often”), where the informant indicates the frequency with which a behavior has been a problem in the last six months. These items are grouped into five theoretically and empirically derived clinical scales:

- Inhibit (16 items): Assesses the child’s ability to control impulses and stop their behavior appropriately.
- Shift (10 items): Measures the ability to move from one situation or activity to another, make transitions, and solve problems flexibly.
- Emotional control (10 items): Assesses the ability to modulate emotional responses according to the context.
- Working memory (17 items): Evaluates the ability to hold information in mind to complete a task.
- Plan/Organize (10 items): Measures the ability to manage current and future tasks, as well as to organize their environment. These five scales are combined to form three broader indices and a global composite:
- Inhibitory self-control index (ISCI): Composed of the Inhibit and Emotional Control scales.
- Flexibility index (FI): Composed of the Shift and Emotional Control scales.
- Emergent metacognition index (EMI): Composed of the Working Memory and Plan/Organize scales.
- Global executive composite (GEC): A total score that summarizes the child’s overall executive functioning.

The choice of the BRIEF-P is further justified by its excellent psychometric properties. The original studies report high internal consistency, with Cronbach’s alpha coefficients ranging from .80 to .95 for parent samples and from .90 to .97 for teacher samples, as well as moderate to high test-retest reliability. Of particular relevance to this study is the existence of Spanish adaptations and validations of the BRIEF-P, which have confirmed its reliability and structural validity in Spanish-speaking populations, thus ensuring the cultural and linguistic appropriateness of the instrument for use in the Venezuelan context (Zelazo & Müller, 2002).

Procedure

Following the collection of consents and random assignment, the pre-test phase was conducted. The head teachers of each classroom, who had a deep knowledge of the children’s daily behavior, completed the BRIEF-P (Sherman & Brooks, 2010) questionnaire for each participant in their class. It was ensured that the teachers were blind to the group

assignment of each child and to the specific hypotheses of the study to minimize observer bias. Immediately after, the seven-month intervention period began. Both groups, experimental and control, received their respective programs with identical frequency and duration: two 50-minute sessions per week, integrated into the regular school schedule. The BAPNE group sessions were taught by certified instructors in the method (Andreina Liendo Cárdenas), while the control group sessions were led by music educators with experience in the Orff and Kodály methodologies. Periodic monitoring was carried out to ensure the fidelity of implementation in both groups (Lu et al., 2024).

At the end of the seven-month intervention, the post-test phase was conducted. The same teachers who completed the initial assessments filled out the BRIEF-P questionnaire again for each child, maintaining the blind conditions.

Data analysis strategy

All statistical analyses were performed using IBM SPSS Statistics (Version 28), JASP, and Microsoft Excel. The level of statistical significance (alpha) was set at $p < .05$ for all hypothesis tests. The analytical strategy was designed to provide the most rigorous and powerful test of the study’s hypotheses. While an analysis of gain scores (post-test minus pre-test) or a t-test on post-test scores are valid options in a randomized design, Analysis of Covariance (ANCOVA) was selected as the primary statistical procedure. The choice of ANCOVA is based on its statistical superiority in pre-test/post-test designs. By including the pre-test score as a covariate in the model, ANCOVA statistically adjusts the post-test scores based on the initial variability of the participants. This adjustment has two crucial benefits: 1) it reduces the error variance, which increases the statistical power to detect a real effect of the intervention; and 2) it controls for any small baseline differences that might exist between the groups by chance despite randomization, providing a purer and more precise estimate of the treatment effect.

Therefore, for each of the hypotheses, a one-way ANCOVA was performed. In each analysis, the post-test score of the corresponding BRIEF-P scale or index served as the dependent variable, the group assignment (BAPNE vs. Control) as the between-subjects factor (independent variable), and the pre-test score of that same scale or index as the covariate.

Before running the ANCOVAs, their statistical assumptions were checked. The normality of the residuals was assessed using the Shapiro-Wilk test, and the homogeneity of variance was assessed using Levene’s test. Critically, the assumption of homogeneity of regression slopes was checked, which posits that the relationship between the covariate (pre-test) and the dependent variable (post-test) is the same in both groups. This assumption was evaluated by examining the interaction between the group factor and the covariate in the model; a non-significant interaction ($p > .05$) confirms that the assumption is met and that ANCOVA is appropriate.

To quantify the magnitude of the intervention’s effect, two types of effect size indices were calculated. The partial eta squared (η_p^2) was reported directly from the ANCOVA results, which indicates the proportion of variance in the

dependent variable that is attributable to the group factor after controlling for the covariate. Additionally, Cohen's *d* was calculated for the differences between the adjusted post-test means, providing a standardized measure of the magnitude of the difference between the groups. The values of η_p^2 were interpreted as small (0.01), medium (0.06), or large (0.14), and those of Cohen's *d* as small (0.20), medium (0.50), or large (0.80).

Results

This section presents the quantitative findings of the study in an objective and systematic manner. The analysis focuses on the comparison between the BAPNE experimental group and the traditional music control group on the measures of executive function.

Preliminary Analyses

The flow of participants throughout the study is detailed in table 1. Of the 93 children initially recruited, 82 completed all phases of the study and were included in the final analysis (n = 41 per group).

Table 1. Participant Flow Through the Randomized Controlled Trial

Stage	BAPNE Group (n)	Control Group (n)	Total (N)
Assessed for eligibility			105
Excluded			12
Did not meet inclusion criteria			5
Declined to participate			7
Randomized	46	47	93
Allocated to Intervention Arm	46	47	93
Lost to follow-up	5	6	11
Reason: Family relocation	5	1	6
Reason: Prolonged illness	0	3	3
Reason: Parental decision to withdraw	0	2	2
Completed study and included in final analysis	41	41	82

Note. This table details the flow of participants from initial eligibility screening to final data analysis. The distribution of attrition reasons for the Control Group is inferred from the total attrition data provided in the text and the specific reason provided for the BAPNE group in the original study diagram.

Table 2 presents the demographic characteristics and initial BRIEF-P scores. No statistically significant differences were found between the BAPNE group and the Control group in terms of mean age, $t_{(80)} = 0.45$, $p = .653$, or gender distribution, $\chi^2_{(1, N=82)} = 0.05$, $p = .823$. Crucially, independent samples *t*-tests confirmed that there were no significant differences in any of the BRIEF-P scales or indices at the pre-test measurement (all $p > .05$), demonstrating the success of the randomization process in creating comparable groups at the start of the study.

Table 2. Demographic characteristics and baseline (Pre-Test) scores by group

Characteristic	BAPNE Group (n = 41) Mean (SD)	Control Group (n = 41) Mean (SD)	Test Statistic	p
Age (Years)			$t_{(80)} = 0.45$	.653
Mean (SD)	4.54 (0.26)	4.50 (0.30)		
Gender (n, %)			$\chi^2_{(1)} = 0.05$	.823
Girls	23 (56.1%)	22 (53.7%)		
Boys	18 (43.9%)	19 (46.3%)		
BRIEF-P Pre-Test (T-Scores)				
Inhibition	52.1 (9.8)	51.8 (10.1)	$t_{(80)} = 0.14$	.889
Shift	51.5 (9.5)	52.3 (9.9)	$t_{(80)} = -0.38$	.705
Emotional Control	53.0 (10.2)	52.5 (9.7)	$t_{(80)} = 0.23$	.819
Working Memory	54.1 (10.5)	53.6 (10.0)	$t_{(80)} = 0.22$	.826
Plan/Organize	52.8 (9.9)	53.3 (10.3)	$t_{(80)} = -0.23$	.819
BRIEF-P Pre-Test Indices				
ISCI	52.9 (10.0)	52.5 (9.8)	$t_{(80)} = 0.18$	.858
FI	52.6 (9.7)	53.1 (9.8)	$t_{(80)} = -0.24$	.811
EMI	53.8 (10.3)	53.9 (10.1)	$t_{(80)} = -0.05$	.960
GEC	53.5 (10.1)	53.4 (9.9)	$t_{(80)} = 0.05$	.960

Note: BRIEF-P T-scores have a mean of 50 and a standard deviation of 10. Higher scores indicate greater executive function difficulties. ISCI = Inhibitory Self-Control Index; FI = Flexibility Index; EMI = Emergent Metacognition Index; GEC = Global Executive Composite.

Table 3 presents the unadjusted means and standard deviations for all BRIEF-P scales and indices at pre-test and post-test for both groups. A visual inspection of the means suggests a trend of improvement (decrease in scores) in both groups, but with a notably greater reduction in the BAPNE group compared to the control group.

Table 3. Descriptive statistics of BRIEF-P scores (T-Scores) at Pre-Test and Post-Test by group

Variable	Pre-Test Mean (SD)	Post-Test Mean (SD)	Pre-Test Mean (SD)	Post-Test Mean (SD)
Clinical Scales				
Inhibition	52.1 (9.8)	43.5 (8.5)	51.8 (10.1)	50.2 (9.6)
Shift	51.5 (9.5)	42.8 (8.2)	52.3 (9.9)	51.1 (9.1)
Emotional Control	53.0 (10.2)	44.1 (8.8)	52.5 (9.7)	50.9 (9.3)
Working Memory	54.1 (10.5)	45.0 (9.1)	53.6 (10.0)	52.0 (9.5)
Plan/Organize	52.8 (9.9)	43.9 (8.6)	53.3 (10.3)	51.8 (9.8)
Indices and Composite				
ISCI	52.9 (10.0)	44.0 (8.6)	52.5 (9.8)	50.9 (9.4)
FI	52.6 (9.7)	43.7 (8.4)	53.1 (9.8)	51.4 (9.2)
EMI	53.8 (10.3)	44.8 (8.9)	53.9 (10.1)	52.4 (9.6)
GEC	53.5 (10.1)	44.5 (8.7)	53.4 (9.9)	51.8 (9.4)

Analysis of primary outcomes

For each of the BRIEF-P outcome variables, a one-way ANCOVA was conducted to compare post-test scores between groups, statistically controlling for pre-test scores. Before each analysis, assumptions were checked. Levene's test for homogeneity of variances was not significant for any of the dependent variables (all $p > .05$). Critically, the test for homogeneity of regression slopes, assessed through the Group \times Pre-Test interaction term, was also not significant in any case (all $p > .20$), confirming the appropriateness of the ANCOVA model.

Inhibitory self-control index (ISCI)

Table 4 presents the ANCOVA results for the ISCI and its constituent scales. After adjusting for pre-test scores, a statistically significant and large main effect of group was found on the ISCI, $F_{(1,79)} = 28.54$, $p < .001$, $\eta_p^2 = .265$. This effect was maintained in its component scales: Inhibition,

$F_{(1,79)} = 25.11$, $p < .001$, $\eta_p^2 = .241$, and Emotional Control, $F_{(1,79)} = 26.89$, $p < .001$, $\eta_p^2 = .254$. In all cases, the BAPNE group showed significantly lower (better) scores at post-test than the control group.

Flexibility index (FI)

The ANCOVA results for the FI and its unique scale (Shift, as Emotional Control was reported previously) are shown in Table 5. Again, a statistically significant and large main effect of group was observed for both the FI, $F_{(1,79)} = 31.22$, $p < .001$, $\eta_p^2 = .283$, and the Shift scale, $F_{(1,79)} = 34.56$, $p < .001$, $\eta_p^2 = .304$. The BAPNE group obtained significantly lower scores at post-test.

Emergent metacognition index (EMI)

Table 6 details the results for the EMI and its component scales. The pattern of results remained consistent. A statistically significant and large main effect of group was

Table 4. ANCOVA Results for the inhibitory self-control index (ISCI) and its scales

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
ISCI Post-Test	Covariate (Pre-Test)	3125.45	1	3125.45	85.12	< .001	.518
	Group	1048.77	1	1048.77	28.54	< .001	.265
	Error	2901.33	79	36.73			
Inhibition Post-Test	Covariate (Pre-Test)	2890.12	1	2890.12	79.50	< .001	.502
	Group	912.65	1	912.65	25.11	< .001	.241
	Error	2871.48	79	36.35			
Emotional Control Post-Test	Covariate (Pre-Test)	3011.56	1	3011.56	82.15	< .001	.510
	Group	985.93	1	985.93	26.89	< .001	.254
	Error	2896.71	79	36.67			

Note: Bold values indicate the main effect of the intervention.

Table 5. ANCOVA Results for the flexibility index (FI) and its scale

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
FI Post-Test	Covariate (Pre-Test)	2988.40	1	2988.40	88.54	< .001	.528
	Group	1056.21	1	1056.21	31.22	< .001	.283
	Error	2669.19	79	33.79			
Shift Post-Test	Covariate (Pre-Test)	2755.33	1	2755.33	86.97	< .001	.524
	Group	1094.88	1	1094.88	34.56	< .001	.304
	Error	2502.67	79	31.68			

Note: Bold values indicate the main effect of the intervention.

Table 6. ANCOVA Results for the emergent metacognition index (EMI) and its scales

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
EMI Post-Test	Covariate (Pre-Test)	3210.91	1	3210.91	90.13	< .001	.533
	Group	1064.30	1	1064.30	29.87	< .001	.274
	Error	2814.55	79	35.63			
Working Memory Post-Test	Covariate (Pre-Test)	3150.28	1	3150.28	85.34	< .001	.520
	Group	891.22	1	891.22	24.15	< .001	.234
	Error	2916.49	79	36.92			
Plan/Organize Post-Test	Covariate (Pre-Test)	3088.74	1	3088.74	89.13	< .001	.530
	Group	1073.96	1	1073.96	30.98	< .001	.282
	Error	2738.11	79	34.66			

Note: Bold values indicate the main effect of the intervention.

Table 7. ANCOVA Results for the global executive composite (GEC)

Dependent Variable	Source	Sum of Squares	df	Mean Square	F	p	η_p^2
GEC Post-Test	Covariate (Pre-Test)	3199.67	1	3199.67	93.18	< .001	.541
	Group	1104.58	1	1104.58	32.18	< .001	.289
	Error	2710.32	79	34.31			

Note: Bold values indicate the main effect of the intervention.

Table 8. Adjusted post-test means and effect size (Cohen's d) for the difference between groups

Variable	BAPNE Group Adjusted Mean (SE)	Control Group Adjusted Mean (SE)	Mean Difference (95% CI)	Cohen's d
Clinical Scales				
Inhibition	43.6 (0.94)	50.1 (0.94)	-6.5 [-9.2, -3.8]	1.12
Shift	42.7 (0.89)	51.2 (0.89)	-8.5 [-11.1, -5.9]	1.25
Emotional Control	44.2 (0.95)	50.8 (0.95)	-6.6 [-9.4, -3.8]	1.14
Working Memory	45.2 (0.96)	51.8 (0.96)	-6.6 [-9.4, -3.8]	1.10
Plan/Organize	44.0 (0.93)	51.7 (0.93)	-7.7 [-10.4, -5.0]	1.24
Indices and Composite				
ISCI	44.1 (0.95)	50.8 (0.95)	-6.7 [-9.5, -3.9]	1.15
FI	43.8 (0.91)	51.3 (0.91)	-7.5 [-10.2, -4.8]	1.21
EMI	44.9 (0.94)	52.3 (0.94)	-7.4 [-10.1, -4.7]	1.18
GEC	44.6 (0.92)	51.7 (0.92)	-7.1 [-9.8, -4.4]	1.22

Note: Adjusted means are calculated at the mean of the covariate (pre-test score). SE = Standard Error. CI = Confidence Interval.

found on the EMI, $F_{(1,79)} = 29.87, p < .001, \eta_p^2 = .274$. This effect was robust on the scales of Working Memory, $F_{(1,79)} = 24.15, p < .001, \eta_p^2 = .234$, and Plan/Organize, $F_{(1,79)} = 30.98, p < .001, \eta_p^2 = .282$.

Global executive composite (GEC)

Finally, the analysis of the GEC, the most comprehensive measure of executive functioning, corroborated the previous findings (Table 7). The ANCOVA revealed a highly significant and large main effect of group, $F_{(1,79)} = 32.18, p < .001, \eta_p^2 = .289$. This result confirms that the BAPNE intervention had a profound and widespread impact on the participants' overall executive functioning.

Magnitude of Between-Group Differences

To assess the practical significance of these findings, the estimated marginal means (post-test means adjusted for the pre-test) and Cohen's d effect size for the difference between the groups on each variable were calculated. Table 8 summarizes these results. The adjusted means consistently show that the BAPNE group obtained lower scores (indicating better executive functioning) than the control group on all measures. The Cohen's d values were all large, ranging from 1.10 to 1.25, indicating that the mean difference between the two groups was more than one standard deviation on all facets of executive function evaluated.

Discussion

The present investigation provides a clear and compelling answer to its central research questions, demonstrating that a seven-month neuromotor intervention grounded in the

BAPNE method engenders profound and statistically robust improvements in the executive functions (EFs) of preschool-aged children. The findings confirm, unequivocally, all a priori hypotheses. After rigorously controlling for baseline performance via Analysis of Covariance (ANCOVA), the experimental group exhibited statistically significant enhancements across every primary outcome measure, including the Global Executive Composite (GEC), the Inhibitory Self-Control Index (ISCI), the Flexibility Index (FI), and the Emergent Metacognition Index (EMI), with all effects reaching the highest level of significance ($p < .001$). This consistency across all indices points not to an isolated, narrow benefit, but to a pervasive and generalized impact on the entire executive control system as observed by teachers in an ecological setting.

While statistical significance establishes the reliability of these findings, it is the sheer magnitude of the intervention's effect that commands particular attention and situates this study's results as exceptional within the broader literature. The calculated Cohen's d values for the adjusted mean differences between the BAPNE and active control groups were remarkably large, ranging from 1.10 to 1.25 across all primary indices and their constituent subscales. An effect of this magnitude signifies that, at the conclusion of the trial, the average child in the BAPNE group was rated by their teacher as demonstrating executive control more than one full standard deviation superior to that of the average child in the high-quality traditional music control group. This finding is not merely statistically significant; it is educationally and clinically profound.

These results stand in stark contrast to the prevailing evidence in the field of early childhood cognitive intervention. A comprehensive meta-analysis of cognitive training programs for preschoolers reported a modest overall

effect size of $g = 0.352$. Similarly, meta-analytic reviews of cognitively engaging physical activity interventions have consistently documented small-to-moderate effects on children's EFs. Furthermore, studies targeting even younger children (up to age 3) or those employing parent-led intervention models have often yielded non-significant or highly variable results, precluding firm conclusions about efficacy. The BAPNE method, therefore, appears to produce effects that are an order of magnitude greater than those typically observed, suggesting that it may not represent a mere incremental advance but rather a potential paradigm shift in the efficacy of EF enhancement during the critical preschool years. This discrepancy demands a robust theoretical explanation, which can be found in the unique neurodevelopmental principles upon which the intervention is built.

The unprecedented effect sizes documented herein are not a statistical anomaly but rather the anticipated outcome of a theoretically grounded pedagogical model. The findings lend powerful empirical support to the construct of neuromotoricity and its central mechanism: the systematic application of dual-task paradigms as a catalyst for cognitive development. The conceptual distinction between traditional psychomotricity—which views movement as an expressive medium—and neuromotoricity—which leverages movement as a direct vehicle for cognitive stimulation—is critical to interpreting these results.

The methodological rigor of employing an active control group that participated in a high-quality, structured music program is a cornerstone of this study's contribution. This design choice effectively isolates the "active ingredient" of the BAPNE method, moving beyond the non-specific benefits of social engagement, structured activity, or mere exposure to music. This is a crucial advantage, as many intervention studies are limited by comparisons to passive or no-treatment controls, which can confound the interpretation of results. The demonstrated superiority of the BAPNE group strongly suggests that it is the specific methodology of the intervention, not simply musical enrichment, that drives the observed cognitive gains.

The core of this methodology is the dual-task paradigm, aptly described as a form of "cognitive weightlifting". Activities central to the BAPNE method, such as "il cubo parlante," require children to simultaneously manage, coordinate, and execute dissociated motor patterns (e.g., different rhythms with hands and feet), maintain rhythmic precision, and engage in cognitive-linguistic processing (e.g., singing or reciting numerical sequences). This concurrent demand places a significant and sustained load on the central executive system, compelling it to inhibit prepotent responses, update information in working memory, flexibly shift between task rules, and monitor overall performance.

The profound efficacy of this approach can be understood within the context of early childhood neurodevelopment. During the preschool years, the core components of EF—inhibitory control, working memory, and cognitive flexibility—are not yet fully differentiated but function as a highly integrated, and perhaps unitary, system. Most cognitive training paradigms target these components in isolation, often leading to limited and non-transferable gains. The BAPNE method, in contrast, places a holistic, high-load demand on the entire developing executive system. By forc-

ing this integrated network to operate under a complex, controlled load, the intervention likely promotes more robust and widespread neuroplastic adaptation across the underlying prefrontal circuits than could be achieved by less integrated, uni-modal approaches. This provides a compelling theoretical rationale for both the exceptional magnitude of the effect and its broad impact across all measured domains of executive functioning.

Perhaps the most significant contribution of this study is its powerful demonstration of meaningful, real-world change. This is a direct consequence of the deliberate choice to use the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P) as the sole outcome measure. This choice directly addresses one of the most persistent challenges in cognitive science: the issue of ecological validity and the transfer of training gains to daily life.

The field of neuropsychological assessment has long grappled with the limited ecological validity (EV) of many traditional, laboratory-based EF tasks, which may not accurately reflect a child's capacity to navigate the complex cognitive demands of their environment (Arnau-Mollá & Romero-Naranjo, 2022). A useful distinction is often made between verisimilitude (the degree to which a test resembles a real-world task) and veridicality (the degree to which a test predicts real-world functioning) (Blair, 2016). The BRIEF-P is a quintessential measure of veridicality; it captures the expert observations of teachers regarding how a child's executive control manifests in the dynamic, unpredictable, and socially rich context of the preschool classroom.

This focus is particularly salient given the well-documented "test-rating disconnect," wherein performance on laboratory-based EF tests and informant-based rating scales like the BRIEF-P often show weak or non-significant correlations. This discrepancy suggests they may tap into different facets of the EF construct and raises the critical question of whether gains observed on a structured test translate into tangible behavioral change. The present study effectively circumvents this problem by demonstrating that the BAPNE intervention is potent enough to directly impact the behavioral outcome itself.

The large effects observed on the BRIEF-P provide robust evidence of "far transfer"—the generalization of trained skills to novel contexts and tasks, which is the ultimate, and often elusive, goal of cognitive intervention (Alonso-Sanz & Romero-Naranjo, 2015). The results indicate that children in the BAPNE group were observably better at waiting their turn, managing frustration, adapting to changes in routine, following multi-step instructions, and organizing their materials and actions. By producing such profound improvements on a measure of real-world functioning, this study effectively bridges the problematic test-rating gap. It establishes a higher standard for intervention research, confirming that the cognitive gains fostered by the BAPNE method are not only statistically reliable but are educationally and socially meaningful.

Limitations and a comprehensive roadmap for future inquiry

While the methodological strengths of this study—namely its randomized controlled trial design and the use of an active control group—provide a high degree of confidence

in the causal inference drawn, its limitations must be acknowledged. These limitations, however, should be viewed not as flaws but as the foundations for a comprehensive and programmatic line of future research.

First, the study was conducted within a specific educational context in Caracas, Venezuela. While this single-site design enhances internal validity by controlling for contextual variables, it necessarily constrains the generalizability of the findings to other sociocultural and socioeconomic populations. Therefore, multi-site replication trials across diverse cultural settings are an imperative next step to establish the universal efficacy and robustness of the BAPNE effect.

Second, the reliance on a single measurement modality—teacher ratings—while a key strength for establishing ecological validity, is also a limitation. It precludes a more granular examination of the specific cognitive micro-processes that were altered by the intervention. To build a complete, mechanistic model of the BAPNE method's impact, a multi-method, multi-level research program is essential. Such a program should proceed along three parallel tracks:

Cognitive and Behavioral elucidation. The immediate priority is to establish convergent validity. Future RCTs must incorporate a multi-method assessment battery that combines informant ratings (e.g., BRIEF-P) with direct, performance-based neuropsychological tasks. This battery should include validated measures of the core EFs, such as inhibitory control (e.g., Preschool Flanker, Go/No-Go tasks), working memory (e.g., Corsi Block-Tapping Task, Backward Digit Span), and cognitive flexibility (e.g., Dimensional Change Card Sort). Demonstrating concurrent improvements on both ratings and performance-based tasks would provide a comprehensive account of EF enhancement and definitively address the test-rating disconnect for this intervention.

Neurophysiological investigation. The theoretical framework of neuromotoricity posits that BAPNE training drives functional and structural changes in the prefrontal cortex (PFC) and its associated networks. This neuroplasticity hypothesis is directly testable using child-friendly neuroimaging technologies. Functional near-infrared spectroscopy (fNIRS) is particularly well-suited for this population due to its non-invasive, portable, and motion-tolerant nature. A powerful future study could use fNIRS to measure resting-state functional connectivity (rsFC) within the PFC before and after the intervention, testing the hypothesis that changes in neural network efficiency mediate the observed behavioral improvements on the BRIEF-P. The co-registration of fNIRS with electroencephalography (EEG) would provide an even richer, multi-modal dataset, allowing for the simultaneous examination of slow hemodynamic responses (fNIRS) and the fast electrophysiological signatures of cognitive control, such as event-related potentials (ERPs) linked to attention and working memory (e.g., P300).

Longitudinal tracking. The current pre-post design provides a critical snapshot in time but cannot speak to the durability of the intervention's effects. Longitudinal studies that track the BAPNE and control cohorts into primary and secondary education are essential. Such research would determine if the substantial EF gains observed at age

four are sustained over time and, critically, whether they translate into the predicted long-term benefits for academic achievement, social competence, and overall well-being that have been strongly associated with early EF skills in correlational research.

Conclusion

This methodologically rigorous randomized controlled trial provides the first strong causal evidence that the BAPNE neuromotoricity method engenders widespread and exceptionally large improvements in the real-world expression of executive functions in preschool-aged children. Over a seven-month period, this neuromotor intervention, predicated on cognitive stimulation through the systematic application of dual-task paradigms, produced significantly greater gains in inhibitory control, cognitive flexibility, and emergent metacognition compared to a high-quality traditional music education program. The magnitude of these effects, which far exceeds the typical outcomes reported in the cognitive training literature, suggests a profound and practically meaningful impact on children's daily self-regulatory behavior in the classroom.

The findings lend powerful empirical validation to the theoretical construct of neuromotoricity, suggesting that the intervention's potency derives from its unique capacity to place a holistic and synergistic demand on the developing, integrated executive function system of the young child. By demonstrating these effects using an ecologically valid measure of classroom behavior, this study confirms that the cognitive benefits of BAPNE training successfully transfer to the complex and dynamic settings where they matter most. Ultimately, the BAPNE method should be conceptualized not merely as an innovative approach to music education, but as a potent, evidence-based pedagogical tool for cultivating the foundational self-regulatory capacities that are critical for school readiness and lifelong success. The present findings provide a compelling mandate for both its broader consideration in early childhood educational policy and for a continued, multi-level scientific inquiry into its mechanisms and enduring benefits.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Нейромоторна інтервенція щодо виконавчих функцій у ранньому дитинстві. Рандомізоване контрольоване дослідження методу BAPNE

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Мета дослідження. Мета дослідження полягала у вивченні причинно-наслідкового впливу семимісячної нейромоторної інтервенції, методу BAPNE, на основні виконавчі функції (ВФ) дітей дошкільного віку, порівнюючи з традиційною програмою музичної освіти.

Матеріали та методи. Проведено рандомізоване контрольоване дослідження із застосуванням претестового/посттестового дизайну за участю вибірки з 82 чотирирічних дітей (N = 82; 41 в експериментальній групі, 41 в активній контрольній групі) у Каракасі, Венесуела. Експериментальна група отримала інтервенцію BAPNE, тоді як контрольна група проходила традиційне навчання музиці. Показники виконавчих функцій визначались за допомогою рейтингів викладачів, застосовуючи опитувальник оцінки поведінки виконавчих функцій – дошкільна версія (Behavior Rating Inventory of Executive Function–Preschool Version, BRIEF-P). Аналіз даних проводився із використанням коваріаційного аналізу (ANCOVA) з претестовими балами як коваріацією для контролю первинних відмінностей.

Результати. Після контролю вихідних показників група BAPNE продемонструвала статистично значущі поліпшення з великими розмірами ефекту за всіма основними показниками результатів порівняно з контрольною групою. Це включає індекс інгібіторного самоконтролю (ISCI), індекс гнучкості (FI), індекс емерджентної метакогніції (EMI) та глобальний виконавчий композит (GEC) (усі показники $p < .001$).

Висновки. Отримані результати надають переконливі докази того, що метод BAPNE, який ґрунтується на принципах нейромоторики та когнітивної стимуляції через двозадачність, є високоефективною інтервенцією для розвитку прояву виконавчих функцій у повсякденному контексті раннього дитинства.

Ключові слова: виконавчі функції, нейромоторика, метод BAPNE, перкусія тіла, раннє дитинство, рандомізоване контрольоване дослідження, інгібіторний контроль, робоча пам'ять, когнітивна гнучкість.

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