

Effect of Ayò Ọlọpọ̀n on Children's Executive Functions and Processing Speed

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Abstract

This study examined whether structured engagement of Ayò Ọlọpọ̀nỌlọpọ̀Ọlọpọ̀, a traditional board game, could enhance children's executive functions and processing speed. Eighty-two elementary school children were randomly assigned to a control group (n = 41) or an intervention group (n = 41) from the same peri-urban school. Executive functions (inhibitory control, working memory, and cognitive flexibility) and processing speed were assessed using the NIH Toolbox Cognition Battery before and after a six-week intervention. Children in the intervention group played Ayò Ọlọpọ̀nỌlọpọ̀Ọlọpọ̀ three times a week for 20 minutes, whereas the control group engaged in normal unstructured activities. Results from the non-parametric analyses showed pre-post gains in both groups. However, children in the intervention group showed significantly greater gains than children in the control group across inhibitory control, working memory, cognitive flexibility, and processing speed. These findings showed that structured engagement with Ayò Ọlọpọ̀nỌlọpọ̀Ọlọpọ̀ can improve core cognitive skills in elementary school children and highlight the potential of culturally grounded traditional games as low-cost, scalable cognitive interventions in low-resource contexts.

Introduction

Early childhood is crucial for children's cognitive development, laying the foundation for skills like executive function and processing speed [1]. Executive functions refer to the ability to manage cognitive processes that support goal-directed behaviors [2]. This includes inhibitory control, which helps inhibit prepotent responses; working memory, which allows for the temporary storage and manipulation of information; and cognitive flexibility, which enables shifting attention between tasks or mental frameworks in response to changing demands [3, 4]. Processing speed, on the other hand, refers to the pace at which simple or complex tasks are performed [5]. Together, executive functions and processing speed are associated with learning outcomes, including numeracy, literacy, and school readiness [6].

Several interventions have shown that different activities, including computerized games, physical activities, music, chess, and mindfulness, are significantly associated with improvements in children's executive functions and information-processing speed [7,8,9,10,11,12,13]. However, intervention findings are mixed in underrepresented low-income contexts due to cultural and environmental variability [14].

For example, while activities such as yoga and aerobic dance have been shown to improve executive functions [15,16], expressive writing and dancing [17,18] have not. Specific game intervention, including red-light purple light, did not improve children's executive functions [19]. Interventions specifically targeting processing speed are limited in our study context, despite their importance to children's learning outcomes.

Importantly, while many of these interventions, including computerized games, demonstrate potential in improving cognitive outcomes, they often lack transfer and cultural adaptability in diverse real-world contexts [20,21]. Contrastingly, traditional games, rooted in everyday indigenous practices, may provide

cost-effective and developmentally appropriate interventions to improve children's executive functions and processing speed, due to the malleability of their cognitive systems.

Ayò Ọlópọ̀n, a traditional Yoruba board game similar to the Mancala game, is a strategic decision-making game that originated in the South-Western part of Nigeria. While its precise historical origin is undocumented, it has been passed down intergenerationally and remains prevalent globally [22]. The game is played on a board of two rows of six pits with 48 identical seeds distributed evenly, four per pit, at the start. Each player owns one of the rows and play proceeds in turns, with the starter selecting one of their non-empty pits and emptying the seeds across other pits counterclockwise, skipping the starting pit even when there is an overlap (e.g., when there are more seeds). Seeds are captured when the move falls directly into the opponent's pit side containing one or more seeds, which are then removed from the board. The game ends when one of the players can no longer move or when the pits are all empty (e.g., seeds are captured by the opponents). The player with the greater number of seeds is considered the winner.

Ayò Ọlópọ̀n engages executive functioning, as players mentally track the number of seeds in multiple pits and hold information about their opponent's current and future moves (working memory). Players also resist impulsive, obvious moves in favor of future strategic gains (inhibitory control), and they must adapt to their opponent's changing position and tactics, and shift perspectives and strategies in real-time (cognitive flexibility). The game also requires processing speed demands, as players rapidly compute possible moves and outcomes under their opponent's pressure and time constraints. Therefore, Ayò Ọlópọ̀n is considered a suitable traditional game that could improve children's executive functions and processing speed.

This study aimed to investigate whether structured continuous engagement with Ayò Ọlópọ̀n can effectively improve children's executive functions and processing speed. We adopted the NIH Toolbox to assess children's cognitive skills because it has been previously validated in this context [23]. We hypothesized that playing Ayò Ọlópọ̀n would lead to significant improvement in the intervention group compared to the control group. Our study is significant because it explores the cognitive benefits of a low-cost, culturally embedded traditional game for supporting early cognitive development, particularly in low-resource settings where access to digital cognitive training may be limited.

Results

The Shapiro-Wilk test showed significant deviations from normality for some outcome variables, particularly post-intervention scores for inhibitory control ($W = 0.56, p < .001$) and across both groups and measurement periods for working memory ($W = 0.88-0.92, p < .001 - .03$) and processing speed scores ($W = 0.88 - 0.94, p < .001 - .30$). Non-parametric statistical methods were therefore applied to subsequent inferential statistics. Results from the Mann-Whitney U test in Table 2 comparing baseline differences between the intervention and control groups showed no significant differences across all outcome domains.

Results from the within-group analysis in Table 3 showed significant pre-post gains in outcome domains in both groups. In the control group, small but significant gains were observed in inhibitory control ($W = 10$, $p_{adj} < .001$), working memory ($W = 122$, $p_{adj} < .01$), cognitive flexibility ($W = 5$, $p_{adj} < .001$), and processing speed ($W = 23.5$, $p_{adj} < .001$). In the intervention group, robust gains were observed across all outcome domains, including inhibitory control, working memory, cognitive flexibility, and processing speed, with Wilcoxon signed-rank statistics of zero ($W = 0$, $p_{adj} < .001$), indicating that all participants scored higher post-intervention than pre-intervention.

Results of the between-group intervention-related gains assessed using the Mann-Whitney U test in Table 4 indicated that children in the intervention group showed higher gains than those in the control group across all four cognitive domains. All results remained significant after Bonferroni correction for multiple comparisons; inhibitory control ($U = 43$, $p_{adj} = 5.76 \times 10^{-13}$), working memory ($U = 259$, $p_{adj} = 2.34 \times 10^{-7}$), cognitive flexibility ($U = 0$, $p_{adj} = 2.64 \times 10^{-14}$), and processing speed ($U = 0$, $p_{adj} = 2.40 \times 10^{-14}$). Zero Mann-Whitney U statistics for cognitive flexibility and processing speed indicate complete statistical separation between groups, specifically uniformly higher gains among children in the intervention group.

Discussion

This study examined whether structured engagement with Ayò Ọlọpọ̀n improves executive functions and processing speed in elementary school children. The results showed that although children in the control group showed small improvements over time, they exhibited significantly lower executive function and processing speed than children who played Ayò Ọlọpọ̀n three times a week for 20 minutes over six weeks. These small gains in the control group may reflect practice effects arising from repeated exposure to the assessment tasks [24], whereas the substantially larger gains observed in the intervention group indicate an additional effect associated with the structured Ayò Ọlọpọ̀n gameplay [25,3,26].

These findings align with previous evidence demonstrating that cognitively demanding games can improve cognitive processes, including executive functions and processing speed [27,8,28,26,29]. Importantly, our intervention draws on low-cost, indigenous, and familiar activities, which may enhance contextual relevance in low-resource contexts. Board games such as Ayò Ọlọpọ̀n may engage cognitive processes associated with executive functioning, thereby providing repeated opportunities to strengthen core executive functions and processing speed in an engaging and developmentally appropriate manner [3,8]. This may explain why the intervention group that played Ayò Ọlọpọ̀n significantly outperformed the control group.

Beyond showing the efficacy of Ayò Ọlọpọ̀n, our findings highlight the potential of culturally grounded traditional games as a scalable tool for supporting early cognitive processes in diverse and resource-constrained contexts. Integrating Ayò Ọlọpọ̀n into schools may underscore the importance of leveraging

indigenous knowledge systems while complementing technology-based cognitive training programs, which are often difficult to sustain in low-resource settings due to high subscription costs.

Our study draws on a low-cost, culturally embedded, and scalable traditional game, which increases the ecological validity and practical relevance of our findings. However, our sample size was relatively small and drawn from a single school, which may limit the generalizability of our findings. Similarly, the familiarity effect and the absence of long-term follow-up limit conclusions about the durability of observed gains. Future studies should include large multi-site samples, alternate test forms, and longer follow-up periods to evaluate the robustness of the intervention effects.

Methods

Participants

The intervention group comprised 41 randomly assigned children (22 girls and 19 boys; $M = 6.5$ years, $SD = 0.3$), and the control group included 41 children (19 boys, 22 girls; $M = 6.6$ years, $SD = 0.4$). Children in both groups were enrolled in grades 1 and 2 in an elementary school in Ondo State, Nigeria, and were randomly selected for the study. Demographic characteristics are shown in Table 1. Sample size calculations using G*power version 3.1 indicated that 41 children in each group (intervention and control) would provide 0.80 ($1 - \beta$) of power based on an α level of 0.05, two measurements, and a correlation among repeated measures of 0.5 [30].

Measures

Children's executive functions and processing speed were assessed using the NIH Toolbox Cognition Battery, a tablet-based, validated cognitive assessment designed to assess cognitive domains for participants aged 3 years and above [31,32,33]. We selected four tasks, including the *Flanker Inhibitory Control and Attention Test (FICAT)*, to measure children's inhibitory control. FICAT requires children to identify the direction of a central stimulus while ignoring the congruent and incongruent flankers. Children's performance reflects the ability to suppress interference from distracting stimuli. The *List Sorting Working Memory Test* was used to measure working memory. The test requires children to recall and sequence pictures of items (e.g., foods or animals) in size order, capturing children's ability to manipulate information over a short period [34]. Cognitive flexibility was assessed using the *Dimensional Change Card Sort (DCCS)*, which requires children to sort bivalent visual stimuli by one dimension (e.g., color) and then by another dimension (e.g., shape). Performance on DCCS reflects the ability to shift between task demands [33]. Processing speed was assessed using the *Pattern Comparison Processing Speed Test*. The test required children to identify whether two visual patterns are the same or different. Children respond by agreeing (e.g., pressing yes) or disagreeing (e.g., pressing no). Patterns were either identical or varied. Scores reflect simple processing efficiency under time constraints [35].

Procedures

Children in both the intervention and control groups completed baseline assessments of executive functions and processing speed prior to the intervention in October 2025. For the *intervention group*, children were randomly assigned and engaged in continuous structured Ayò Ọlópón game sessions over six weeks between October and November 2025. Sessions were conducted three times per week for 20 minutes during a scheduled 40-minute school break. Children were relocated to a small, designated hall within the school during each session to minimize distractions. This short, high-frequency dosage aligns with recommendations from previous research [2,36]. Children were divided into four groups, with five children on each side of the board. The two instructors play first and show the children the rules, then play with at least one of them before leaving them to play with randomly assigned opponents. To facilitate sustained interests and an interactive environment, children were allowed to talk while observing but were instructed not to disrupt active players, including touching the game seeds. Post-intervention measures were administered in November 2025 by two trained research assistants and supervised by the first author.

Children in the *control group* spent their 20-minute break on unstructured activities, including napping, chatting, or free play with classmates. These activities were either indoors or outdoors, depending on the child's preference and the teachers' approval. The control group completed post-intervention assessments in November 2025, simultaneously with the intervention group.

Ethical Considerations

The study was conducted in compliance with the Declaration of Helsinki. The study was approved by the Ondo State Ministry of Education through the Ondo State Universal Basic Education Board. The study purpose and procedures were sent in writing through the children to their primary caregivers, and a signed informed consent was obtained. We also obtained assent (e.g., children said yes or nodded) from participating children and were informed they could withdraw from the study at any time without consequences. Ethics approval was obtained from the Institutional Review Board of Harvard University and the Social Sciences and Humanities Research Ethics Committee of the University of Ibadan. All data were anonymized before analysis.

Data Analysis

Data for the 82 participants in the intervention and control groups were included for analysis, as there was no missing data. The Shapiro-Wilk test indicated significant deviations from normality across several outcome variables. Hence, non-parametric statistical methods were applied to the data for all inferential analyses. The Mann-Whitney U test was conducted to compare baseline differences between intervention and control groups and between-group effects. The Wilcoxon signed-rank test was used to assess the within-group intervention effects. Bonferroni correction was applied to account for multiple comparisons across outcomes. All analyses were performed using R version 4.5 [37].

Declarations

Author Contribution: C.E. designed the study. C.E. & A.O. supervised intervention and data collection. A.O.O., C.E., and A.O. performed statistical analysis. C.E., A.O.O., A.O., and I.I.M contributed to the manuscript draft and approved the final manuscript.

Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author on request.

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Competing Interest: The authors declare no competing interest.

References

1. Hendry, A., Jones, E. J. H. & Charman, T. Executive function in the first three years of life: precursors, predictors and patterns. *Dev. Rev.* **42**, 1–33; 10.1016/j.dr.2016.06.005 (2016).
2. Diamond, A. Executive functions. *Annu. Rev. Psychol.* **64**, 135–168; 10.1146/annurev-psych-113011-143750 (2013).
3. Diamond, A. Insights from a career at the border of developmental psychology and cognitive neuroscience. *Annu. Rev. Dev. Psychol.* **7**, 1–40; 10.1146/annurev-devpsych-010923-114435 (2025).
4. Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A. & Wager, T. D. The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: a latent variable analysis. *Cogn. Psychol.* **41**, 49–100 (2000).
5. Vanhala, A., Lee, K., Korhonen, J. & Aunio, P. Dimensionality of executive functions and processing speed in preschoolers. *Learn. Individ. Differ.* **107**, 102361; 10.1016/j.lindif.2023.102361 (2023).
6. Hardy, J. L. et al. Enhancing cognitive abilities with comprehensive training: a large, online, randomized, active-controlled trial. *PLoS One* **10**, e0134467; 10.1371/journal.pone.0134467 (2015).
7. Chaddock, L., Pontifex, M. B., Hillman, C. H. & Kramer, A. F. A review of the relation of aerobic fitness and physical activity to brain structure and function in children. *J. Int. Neuropsychol. Soc.* **17**, 1–11; 10.1017/S135561771100001X (2011).
8. Diamond, A. & Lee, K. Interventions shown to aid executive function development in children 4 to 12 years old. *Science* **333**, 959–964; 10.1126/science.1204529 (2011).
9. Holmes, J., Gathercole, S. E., & Dunning, D. L. Adaptive training leads to sustained enhancement of poor working memory in children. *Dev. Sci.* **12**, 1–7; 10.1080/16506070902980729 (2009).
10. Koch, C. & Hasbrouck, L. Exploring the link between physical activity, fitness and cognitive function. *Illinois Enhance PE Task Force* **1**, 1–11 (2013).
11. Kolovelonis, A., Pesce, C. & Goudas, M. The effects of a cognitively challenging physical activity intervention on school children’s executive functions and motivational regulations. *Int. J. Environ. Res. Public Health* **19**, 12742; 10.3390/ijerph191912742 (2022).

12. Masoudi, M., Seghatoleslami, A. & Saghebjo, M. The effect of 8 weeks of aerobic training on cognitive performance in children with learning disorders. *J. Fundam. Ment. Health* **18**, 161–168 (2016).
13. Spencer-Smith, M. & Klingberg, T. Benefits of a working memory training program for inattention in daily life: a systematic review and meta-analysis. *PLoS One* **10**, 1-18; 10.1371/journal.pone.0119522 (2015).
14. Rakesh, D., Lee, P., Gaikwad, A. & McLaughlin, K. Annual research review: associations of socioeconomic status with cognitive function, language ability, and academic achievement in youth: a systematic review of mechanisms and protective factors. *J. Child Psychol. Psychiatry* **66**, 417–439; 10.1111/jcpp.14082 (2024).
15. Jarraya, S., Wagner, M., Jarraya, M. & Engel, F. A. Twelve weeks of kindergarten-based yoga practice increases visual attention, visual-motor precision and decreases behavior of inattention and hyperactivity in 5-year-old children. *Front. Psychol.* **10**, 796; 10.3389/fpsyg.2019.00796 (2019).
16. Zinelabidine, K., Elghoul, Y., Jouira, G. & Sahli, S. The effect of an 8-week aerobic dance program on executive function in children. *Percept. Mot. Skills* **129**, 1–14; 10.1177/00315125211058001 (2021).
17. Ben Waer, F. et al. The relationship between postural control and cognitive functioning following Zumba dancing in middle-aged women: a randomized clinical trial. *J. Women Aging* **36**, 273–285; 10.1080/08952841.2024.2325195 (2024).
18. Swart, J. & Janeke, C. Investigating the influence of expressive writing exercises on the working memory of middle adolescents and young adults in South Africa. *S. Afr. J. Psychol.* **52**, 2, 117–131; 10.1177/0081246321104345 (2021).
19. Willoughby, M. & Hudson, K. Current issues in the conceptualization and measurement of executive function skills. In *Executive Functions and Writing* (Oxford Univ. Press, Oxford, UK, 2021).
20. Owen, A. M. et al. Putting brain training to the test. *Nature* **465**, 775–778; 10.1038/nature09042 (2010).
21. Sala, G. et al. Near and far transfer in cognitive training: a second-order meta-analysis. *Collabra Psychol.* **5**, 18; 10.1525/collabra.203 (2019).
22. Okewande, O. Numerical symbols as paradigm of intracultural trace element of relationship in between Ifá and Ayò-Olópón among the Yoruba of south-west Nigeria: a comparative symbolic analysis. *J. Multidiscip. Stud.* **11**, 102–131; 10.62249/jmds.2013.2424 (2022).
23. McHenry, M. S. et al. The current landscape and future of tablet-based cognitive assessments for children in low-resourced settings. *PLoS Digit. Health* **2**, e0000196; 10.1371/journal.pdig.0000196 (2023).
24. Müller, U., Kerns, K. & Konkin, K. Test–retest reliability and practice effects of executive function tasks in preschool children. *Clin. Neuropsychol.* **26**, 271–287; <https://doi.org/10.1080/13854046.2011.645558> (2012).

25. Birtwistle, E., Chernikova, O., Wunsch, M. & Niklas, F. Training of executive functions in children: a meta-analysis of cognitive training interventions. *SAGE Open* **15**, 1–18; 10.1177/21582440241311060 (2025).
26. Johann, V. & Karbach, J. Effects of game-based and standard executive control training on cognitive and academic abilities in elementary school children. *Dev. Sci.* e12866; 10.1111/desc.12866 (2020).
27. De Cerqueira, B. *et al.* Stimulation of inhibitory control in school children: measuring the effect of a pilot intervention using a digital game in elementary school. *Educ. Inf. Technol.* **30**, 7515–7547; 10.1007/s10639-024-13101-3 (2024).
28. Gashaj, V., Dapp, L., Trninic, D. & Roebers, C. The effect of video games, exergames and board games on executive functions in kindergarten and 2nd grade: an explorative longitudinal study. *Trends Neurosci. Educ.* **25**, 100162 (2021).
29. Moya-Higueras, J. *et al.* Just play cognitive modern board and card games, it's going to be good for your executive functions: a randomized controlled trial with children at risk of social exclusion. *Children* **10**, 1492; 10.3390/children10091492 (2023).
30. Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. G* power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* **39**, 175–191 (2007).
31. McHenry, M. S. *et al.* A psychometric evaluation of the NIH Toolbox fluid cognition tests adapted for Swahili and Dholuo languages in Kenyan children and adolescents. *J. Int. Neuropsychol. Soc.* **29**, 933–942 (2023).
32. Weintraub, S. *et al.* Cognition assessment using the NIH Toolbox. *Neurology* **80**, S54–S64; 10.1212/WNL.0b013e3182872ded (2013).
33. Zelazo, P. D. *et al.* NIH Toolbox Cognition Battery: validation of executive function measures in adults. *J. Int. Neuropsychol. Soc.* **20**, 620–629 (2014).
34. Tulsky, D. S. *et al.* NIH Toolbox Cognition Battery (NIHTB-CB): List Sorting Test to measure working memory. *J. Int. Neuropsychol. Soc.* **20**, 599–610; doi:10.1017/S135561771400040X (2014).
35. Carlozzi, N. E. *et al.* NIH Toolbox Cognitive Battery (NIHTB-CB): The NIHTB Pattern Comparison Processing Speed Test. *J. Int. Neuropsychol. Soc.* **20**, 630–641 (2014).
36. Wang, H. *et al.* Meta-analysis on the effects of moderate-intensity exercise intervention on executive functioning in children. *PLoS One* **18**, e0279846 (2023).
37. R Core Team. *R: A language and environment for statistical computing*: R Foundation for Statistical Computing, Vienna, Austria; <https://www.R-project.org/> (2025).

Tables

Table 1. Participants characteristics

	All (n = 82)	Intervention group (n=41)	Control Group (n=41)
	M (SD)	M (SD)	M (SD)
Age (years)	6.6 (0.3)	6.5 (0.3)	6.6 (0.4)
Sex	44 females and 38 males	19 males and 22 females	19 males and 22 females

Note: M = Mean; SD = Standard Deviation; n = number of participants in the group

Table 2. Baseline group differences (Mann–Whitney U tests)

Measure	U	p	p_adj
Inhibitory Control_Pre	824	0.88	1
Working Memory_Pre	886	0.68	1
Cognitive Flexibility_Pre	941	0.35	1
Processing Speed_Pre	926	0.43	1

Table 3. Within-group pre–post effects (Wilcoxon signed-rank tests)

Group	Measure	W	p_adj
Control	Inhibitory Control	10	< .001
Control	Working Memory	122	.012
Control	Cognitive Flexibility	5	< .001
Control	Processing Speed	23.5	< .001
Intervention	Inhibitory Control	0	< .001
Intervention	Working Memory	0	< .001
Intervention	Cognitive Flexibility	0	< .001
Intervention	Processing Speed	0	< .001

Table 4. Between-group differences in change scores (Mann–Whitney U tests)

Measure	U	p_adj	r
Inhibitory Control_change	43	< .001	.82
Working Memory_change	259	< .001	.60
Cognitive Flexibility_change	0	< .001	.86
Processing Speed_change	0	< .001	.86