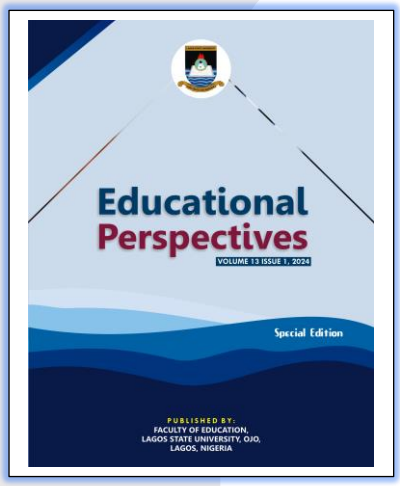

Effects of Neuro-Cognitive Training on Learning Outcomes; A Systematic Review

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ABSTRACT

In this systematic review neurocognitive training, involving exercises targeting cognitive functions like memory and attention, was explored for its potential to enhance cognitive functions for both learning and health outcomes. Empirical evidence was synthesized from several studies for patterns, trends and gaps. Results showed aimed neurocognitive interventions like Dynamic Neuro-Cognitive Imagery (DNI) and mindfulness meditation, cause significant improvement in learning outcomes and cognitive functions across different populations. Limitations observed include: sample sizes were small, durations of the studies were short, and a number of interventions were resource-intensive. For interventions like Mindfulness meditation, personalized approaches are vital because of individual differences. Intervention approaches like biofeedback for rehabilitation and cognitive training intervention in bipolar disorder, there is a potential but their accessibility and scalability may be a challenge in real life. Targeted and early interventions especially those that are aimed at addressing developmental problems such as social anxiety and the learning of mathematical skills underscore the use of infusing neuro-cognitive approaches into educational frameworks. In the future, researches should be focused on larger studies that are long term to confirm findings and explore implementations that may be scalable. By integrating neurocognitive training, educators can enhance student's learning outcomes.

HOW TO CITE

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Introduction

The introduction of neurocognitive training has emerged as a promising method to improve students' learning experiences and ultimately academic performance. Neuro-cognitive training are interventions and activities designed to enhance cognitive functioning by leveraging the flexible nature of the brain. This involves practices or procedures targeted at enhancing memory, attention, problem-solving, and other cognitive skills. According to a study published in the *Journal of Cognitive Enhancement*, "neuro-cognitive training leverages the brain's capacity for change by employing systematic, repetitive cognitive tasks to strengthen neural connections and improve overall cognitive performance" (Smith et al., 2020).

To have a good understanding of the topic, it is important to explain some terms.

Neurocognitive Training: Neurocognitive training involves structured activities aimed at enhancing cognitive functions such as memory, attention, and problem-solving through techniques that leverage neuroplasticity (Belleville et al., 2011; Diamond & Ling, 2016).

Neurocognitive training involves structured activities that stimulate specific neural pathways and cognitive functions, aiming to optimize brain health and cognitive performance. These interventions, including computer-based programs, cognitive-behavioral therapy, mindfulness practices, and physical exercises, are tailored to individual strengths and weaknesses. In educational settings, they enhance academic achievement, learning strategies, and self-regulation.

Beyond education, neurocognitive training plays a pivotal role in mental health by managing disorders like bipolar disorder and anxiety, and in professional settings by improving decision-making and stress management. In sports, it enhances motor skills and focus, while in healthcare, it aids rehabilitation from conditions like Parkinson's disease and stroke, improving quality of life and independence.

Overall, neurocognitive training spans diverse fields, enhancing cognitive functions and supporting overall well-being beyond traditional educational contexts.

Cognitive Functions: Cognitive functions encompass mental processes like memory, attention, and reasoning (Baddeley, 2012; Miyake & Friedman, 2012).

Neuroplasticity: Neuroplasticity is the brain's ability to reorganize itself by forming new neural connections in response to learning, experience, or injury (Pascual-Leone et al., 2011; Zatorre et al., 2012).

Working Memory: Working memory refers to the cognitive system that temporarily holds and manipulates information necessary for tasks such as problem-solving and comprehension (Baddeley, 2012; Cowan, 2017).

Executive Function: Executive function involves cognitive processes like planning, organizing, and self-regulation necessary for goal-directed behavior (Diamond, 2013; Miyake & Friedman, 2012).

Fraction Learning: Fraction learning is the process of understanding and manipulating fractions, which are numerical representations of parts of a whole (Booth & Newton, 2012; Rittle-Johnson et al., 2017).

Statement of the problem

Over the last few years, there has been increasing interest in exploring the potential advantages of neurocognitive training within educational settings.

This keen attention stems from the recognition of the many challenges faced by educators in ensuring that learners are effectively engaged in the classroom, especially in today's world where there are a lot of digital distractions and information overload. By leveraging and exploring the principles of neuroscience, educators seek to create intensely engaging learning experiences that not only captures students' interest but also promotes deeper understanding and lesson retention. Gaining an understanding of the impact of neurocognitive training on learning outcomes is of great priority in the field of educational psychology. It offers valuable insights into the dynamics of effective learning, the factors influencing student motivation and engagement, and the creation of ingenious teaching methods. In addition, this research work has the ability to guide the creation of evidence-based interventions and educational technologies targeted at optimizing learning outcomes for a wide range of learners. Neurocognitive training therefore hinges on the concept of the brain's flexibility by providing individuals with opportunities to engage in activities that stimulate specific neural pathways and cognitive functions.

Neurocognitive training interventions can be in different forms, including computer-based programs, interactive tasks, cognitive-behavioral therapy techniques, mindfulness practices, and physical movements. These interventions are typically designed to be systematic, progressive, and customized to suit the individual's cognitive strengths and weaknesses. In educational settings, neurocognitive training programs may seek to improve students' academic achievements, enhance learning strategies, promote self-regulation and metacognition, or target specific learning disabilities or disorders. Overall, neurocognitive training refers to a multidimensional approach to cognitive enhancement, leveraging on principles from neuroscience, psychology, education, and rehabilitation.

The importance of neurocognitive training in the classroom lies in its potential to boost students' cognitive abilities, academic performance, and overall learning experiences.

Objectives

The systematic review sets out to examine in details the existing literature on the impact of neurocognitive training on learning outcomes. Its main aim is to integrate empirical evidence from various studies to gain a better understanding of how these interventions impact learning outcomes. The objectives of this research in a summary are to;

Systematically review existing literature on the effects of neurocognitive training on learning outcomes.

Examine the effectiveness of various neurocognitive training methods in enhancing learning.

Identify gaps in the current research and provide recommendations for future studies aimed at optimizing the integration of neurocognitive training in educational settings.

Based on the above objectives, the following are the research questions adopted for the systematic review:

Research Questions:

1. What are the impacts of neurocognitive training on the learning outcomes of students?
2. How effective are different neurocognitive training engagements in improving cognitive functions and academic outcomes?
3. What are the common patterns, trends, and deficiencies in existing studies on neurocognitive training in education?
4. How do various neurocognitive training intervention programs impact students of different academic capabilities, age groups, and subject areas?

5. What are the recommendations that can be made towards future integration of neurocognitive training into the educational space based on the present state of research?

Methodology

This systematic review was carried out to synthesize existing literature that address how neurocognitive training affect learning outcomes. The methodology that was employed was rigorous and adhered to guidelines that have been established for systematic reviews. This ensured that the findings of the research are credible, comprehensive and applicable to the field of Educational Psychology.

The following methodology was implemented for the purpose of this systematic review:

Only eligible studies were considered using some basic eligibility criteria after which Search Strategy was employed. Databases and grey literature were searched using keywords and Boolean operators to arrive at appropriate study selection and data extraction for the review.

The following are further details on the methodology:

Eligibility Criteria (Inclusion/Exclusion) was achieved with PICOs (Population, Intervention, Comparison, Outcome) framework: Eligibility criteria for the research was applied using the PICO framework as follows: **Population**: the research was made to capture research reports on neuro-cognitive training in education and other sectors. **Intervention:** the intervention adopted was Neuro-cognitive training. **Comparison:** Learning and general performance outcomes including health and well-being. **Outcomes:** Relationship between neuro-cognitive training and learning outcomes. Inclusion Criteria: this systematic review was only based on Peer-reviewed studies that have been published in English, focusing on all categories of people, neuro-cognitive training, and improved learning outcomes within the last 10 years. Exclusion Criteria: Studies without neuro-cognitive training were not included, non-English publications, and those not specifically addressing education, health and related areas. Studies that were done more than ten years ago were also excluded.

Search Strategy:

The process involved the retrieval of relevant studies from PubMed, a database, by employing keywords such as "neuro-cognitive training," "academic performance," and "learning", “well-being”. To improve search precision, Boolean operators (e.g., AND) was used to combine these terms. Filters refined the search, restricting results to peer-reviewed articles published within the last decade and in English. This systematic approach seeks to comprehensively gather pertinent literature for thorough analysis and synthesis in the research endeavor.

Databases and grey literature:

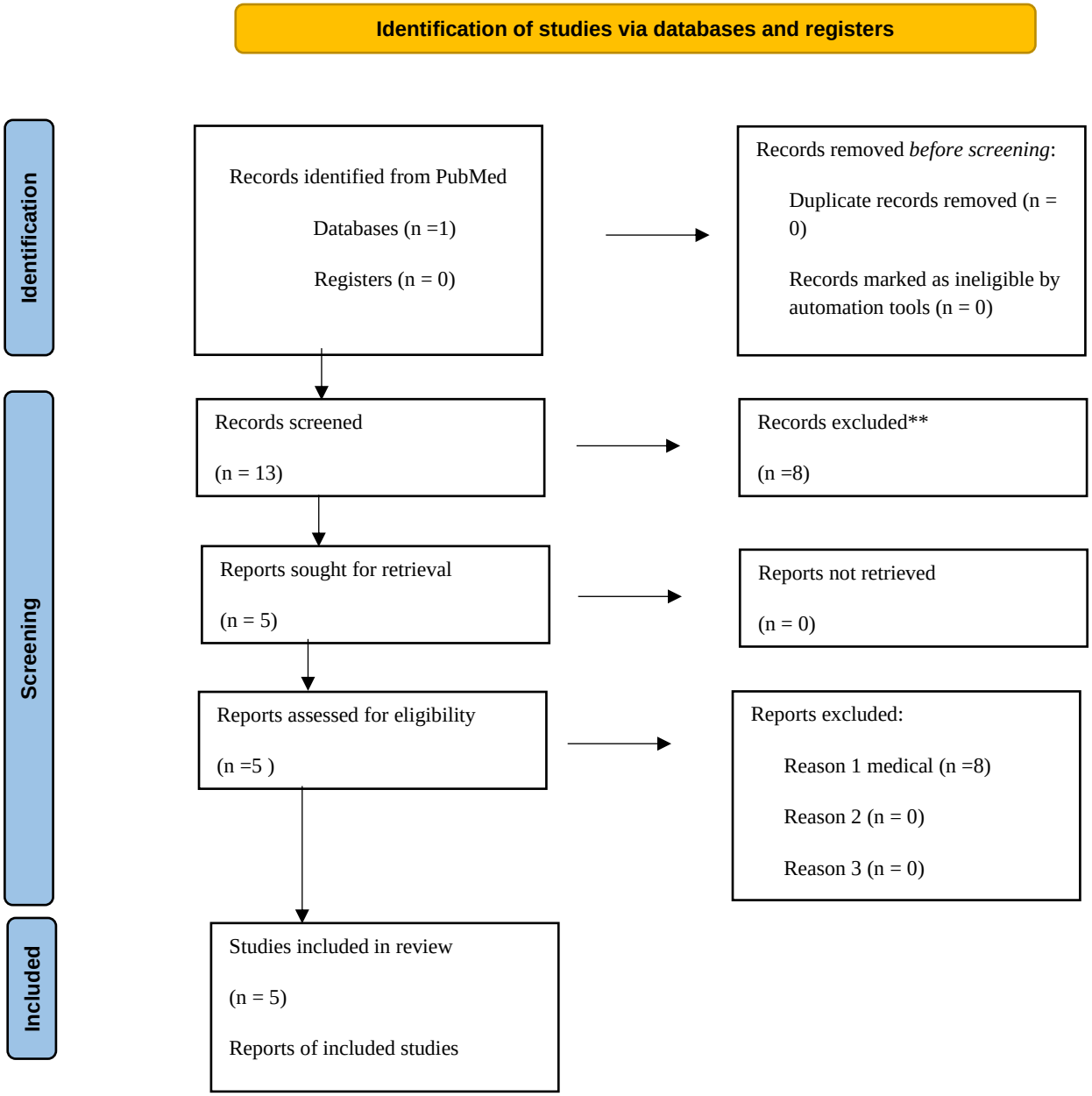
For gathering relevant research, PubMed served as the primary source for peer-reviewed articles. In addition, grey literature, including conference proceedings and dissertations, was extensively searched to ensure a thorough examination of pertinent studies, thus enhancing the comprehensiveness of the literature review.

Keywords and Boolean operators:

The research inquiry employed keywords such as neuro-cognitive training, learning, and health to guide the search process. Boolean operators "AND" were utilized to combine these terms, ensuring a targeted exploration of the relationship between various types of neuro-cognitive training and learning outcomes. This systematic approach facilitated a more focused investigation into the dynamics shaping student learning as it relates to neuro-cognitive training.

Study Selection and Data Extraction: In the process of study selection and data extraction, adherence to eligibility criteria is paramount. The focus lied on exploring the correlation between neuro-cognitive training and learning outcomes. Leveraging EPPI-Reviewer facilitated seamless management and analysis of the extracted data, ensuring efficiency throughout the research endeavor. By employing this tool, I was able to streamline the screening process, extract relevant information, and delve deeper into understanding the intricate relationship between neuro-cognitive training and learning outcomes, optimizing the overall research workflow.

Results



We searched databases like PubMed and found 13 records. After removing irrelevant studies, we retrieved and evaluated five reports, all of which met our criteria. These five studies were included in our final review to provide a detailed understanding of how neuro-cognitive training impacts learning outcomes.

Neurofunctional Plasticity in Fraction Learning

Wortha et al. (2021) investigated the neural correlates of fraction learning through a number line estimation (NLE) training. The study involved behavioral performance and neural activity measurements before and after a five-day training period of 48 participants. Results indicated that NLE training significantly improved fraction magnitude processing, as evidenced by increased activation in a fronto-parietal network associated with the numerical distance effect. The study observed that the distance effect on intraparietal activation for symbolic fractions was only present after training, suggesting that NLE training facilitates more automatic and efficient processing of fraction magnitudes. This enhanced neural processing corresponds to improved mathematical competence, demonstrating the potential of targeted training interventions to improve specific cognitive skills (Wortha et al., 2021).

Meditation and Cognitive Function

Research by Berkovich-Ohana et al. (2021) demonstrated that long-term mindfulness meditation promotes visual cortex responsiveness and reduces Default Mode Network (DMN) activity. During a visual recognition memory task, meditation practitioners exhibited faster cognitive processing speeds and improved visual recognition memory compared to controls. These findings suggest that meditation can serve as an effective tool for enhancing cognitive functions and learning capabilities through neuroplastic changes (Berkovich-Ohana et al., 2021).

Adolescent Social Anxiety

Haller et al. (2022) highlighted the potential of developmental cognitive neuroscience approaches in understanding social anxiety in adolescents. Targeted interventions leveraging developmental neuroplasticity did improve social and cognitive learning outcomes. This highlights the importance of early, tailored brain-training interventions in educational settings to address social and cognitive challenges in adolescents (Haller et al., 2022).

Cognitive Training in Aging

Smith et al. (2022) explored cognitive and structural predictors of novel task learning in older adults through a gamified working memory updating task known as the Bird-Watch Game. This study identified verbal episodic memory and the volume of the left inferior frontal gyrus as significant predictors of learning rates. The results also showed that these neuro-cognitive measures were more predictive of learning outcomes when considered together rather than separately, indicating a complementary effect. Furthermore, contextual factors such as mood, stress, busyness, and hours of sleep were found to meaningfully predict daily task performance in 50% of cases. This highlights the variability of individual influences on task performance and underscores the importance of considering both neuro-cognitive and contextual factors in designing effective cognitive interventions for older adults (Smith et al., 2022).

Neuro-Cognitive Training in Parkinson's disease

Dynamic Neuro-Cognitive Imagery (DNI) has shown promising results in improving mental imagery abilities, reducing disease severity, and boosting motor and cognitive functions in individuals with Parkinson's disease (PD). In a study by Abraham et al. (2020), twenty participants with idiopathic PD were randomly assigned to either a DNI training group or a control group that participated in an in-home learning and exercise program. Both groups completed at least 16 hours of training over two weeks. The study found that the DNI group exhibited significant improvements ($p < .05$) in mental imagery abilities, disease severity, motor, and spatial cognitive functions compared to the control group. Additionally, participants in the DNI group reported

improvements in balance, walking, mood, and coordination, and they were more physically active. Both groups expressed high levels of enjoyment and increased mental activity from their respective programs, highlighting DNI as a viable complementary therapeutic approach for PD rehabilitation (Abraham et al., 2020).

In a related study by Abraham et al. (2021), the focus was on the effect of DNI on pelvic schema and graphic-metric representation in PD patients. This randomized controlled trial involved twenty participants who were asked to complete a "Draw Your Pelvis" test before and after a two-week intervention. The results indicated significant improvements in the DNI group in terms of pelvic schema scores and drawing dimensions, specifically in pelvic width and width-height difference ($p < .05$). These findings suggest that DNI can effectively improve body schema, which may help mitigate motor and cognitive deficits in PD patients (Abraham et al., 2021).

Parkinson's Disease: Dynamic Neuro-Cognitive Imagery (DNI) training shows promise in improving mental imagery abilities, disease severity, and motor and cognitive functions in individuals with Parkinson's Disease. This highlights the potential of imagery training as a rehabilitative approach to enhance both motor and cognitive learning in neurodegenerative conditions.

In a nutshell, these studies highlight the efficacy of targeted neuro-cognitive interventions, imagery training, and personalized educational strategies in improving learning outcomes across various populations with neurological and cognitive challenges. These findings advocate for the integration of neuro-cognitive training and personalized approaches in educational and rehabilitative practices to enhance learning and cognitive functions.

CRITICAL ANALYSIS OF THE RESULTS.

The systematic review highlights the promising impact of neuro-cognitive training on educational and learning outcomes, but several critical aspects warrant further consideration.

Wortha et al. (2021) shows that targeted educational interventions, such as number line estimation (NLE) training, significantly enhance mathematical understanding through specific neural activation patterns. While the short-term training effects are notable, the sustainability of these improvements over time remains uncertain. Longitudinal studies are needed to determine if these gains persist, which is crucial for developing lasting educational strategies in mathematics.

Berkovich-Ohana et al. (2021) reveal that long-term mindfulness meditation can lead to neuroplastic changes that enhance cognitive functions, particularly in visual recognition memory and processing speed. Although these findings suggest meditation could be a valuable educational tool, potential confounding variables, such as participants' lifestyle or baseline cognitive abilities, were not fully addressed. Further research is needed to isolate the effects of meditation on learning outcomes.

Haller et al. (2022) emphasize the benefits of early, targeted interventions for adolescents with social anxiety. By leveraging developmental neuroplasticity, these interventions can significantly improve social and cognitive learning outcomes. However, the mechanisms behind these improvements are not fully understood. Future studies should explore the neurobiological underpinnings to refine these educational interventions further.

Smith et al. (2022) highlight the importance of personalized cognitive training for older adults. Their findings suggest that tailored interventions considering individual neuro-cognitive profiles and

contextual factors like mood and stress can optimize learning outcomes. Nevertheless, the reliance on self-reported data introduces subjectivity. Incorporating objective measures and extending follow-up periods would enhance the reliability of these educational interventions, ensuring they can be effectively integrated into cognitive training curricula for aging populations.

The studies on Dynamic Neuro-Cognitive Imagery (DNI) for Parkinson's disease (PD) demonstrate significant improvements in motor and cognitive functions. However, the small sample sizes (n=20) limit the generalizability of these findings (Abraham et al., 2020; Abraham et al., 2021). To solidify the educational implications, larger and more diverse cohorts are essential to confirm that DNI can be widely adopted in PD rehabilitation programs.

While the reviewed studies demonstrate the efficacy of neuro-cognitive training in enhancing learning outcomes, addressing limitations such as sample size, subjectivity, and long-term sustainability is essential for developing robust, evidence-based educational programs.

Discussion

The results from the systematic review highlight the potential of neuro-cognitive training across various contexts, from educational interventions to aging and even neurodegenerative diseases.

Haller et al. (2022) showed that neurocognitive training enhanced cognitive learning significantly as highlighted in its importance in early, tailored interventions for adolescents with social anxiety. By leveraging developmental neuroplasticity, these interventions can significantly improve social and cognitive learning outcomes, emphasizing the need for early and targeted brain-training programs in educational settings.

Furthermore, Berkovich-Ohana et al. (2021) revealed that long-term mindfulness meditation can lead to neuroplastic changes that enhance cognitive functions. The reduction in Default Mode Network (DMN) activity and increased visual cortex responsiveness observed in meditators suggest that meditation can be a potent tool for improving cognitive processing speed and visual recognition memory.

The study by Wortha et al. (2021) on fraction learning further underscores the efficacy of targeted educational interventions. By employing number line estimation (NLE) training, the researchers demonstrated significant improvements in fraction magnitude processing, linked to enhanced activation in a fronto-parietal network. This indicates that specific neural activation patterns can be harnessed to improve mathematical learning and understanding, providing a neurofunctional basis for educational strategies.

In the context of cognitive aging, Smith et al. (2022) identified critical predictors of learning outcomes in older adults. Their findings emphasize the importance of verbal episodic memory and the structural integrity of the left inferior frontal gyrus in task learning. Additionally, the study highlights the role of contextual factors such as mood and stress, suggesting that personalized cognitive training programs that account for these individual differences can optimize learning outcomes. This insight is crucial for developing targeted interventions that cater to the unique neuro-cognitive profiles of older adults.

Finally, Dynamic Neuro-Cognitive Imagery (DNI) has shown significant promise in Parkinson's disease (PD) rehabilitation. The studies by Abraham et al. (2020, 2021) demonstrate that DNI training can enhance both cognitive and motor functions, with improvements in mental imagery abilities, disease severity, balance, and

coordination. These findings suggest that DNI could serve as a valuable complementary therapeutic approach, addressing both the cognitive and physical challenges faced by individuals with PD.

In summary, the reviewed studies collectively underscore the effectiveness of neuro-cognitive training in enhancing learning outcomes across various populations. Future research should continue to explore these interventions' underlying mechanisms and develop optimized, personalized training protocols to maximize their efficacy.

Conclusion

Neurocognitive training offers great hope for enhancing learning outcomes across different groups, from students to older adults and those with health issues like neurodegenerative conditions. Studies show that methods like number line estimation training and mindfulness meditation can reshape how our brains work, promoting skills like math understanding, memory, and how quickly we can think.

Beyond classrooms, these techniques also offer benefits in mental health, job performance, sports, recovery and rehabilitation. Customized training based on individual's strengths and weaknesses, and factors like mood and stress is also important for lasting improvements.

However, while these discoveries are quite encouraging, more studies is needed to further understand long-term effects and details of exactly how the brain is affected and to what extent. Future research should focus on refining these techniques and discovering why they work so well.

Overall, neurocognitive training offers exciting possibilities for boosting cognitive abilities and improving learning across different stages of life. It's a bridge between neuroscience and education, paving the way for smarter and more effective learning strategies made to fit everyone's needs.

Recommendations

Based on the findings of the study, the following recommendations are made;

Implementation of teachers' workshops and trainings.

Teachers are at the fore front of students learning, proper orientation for teachers on neurocognitive training and how to infuse them in the classrooms and their teaching will result in a great turnout of positive reviews.

Inclusion of neurocognitive trainings in curriculum:

This study has shown that neurocognitive trainings significantly influence students learning so neurocognitive trainings and activities should be properly structured around various subjects to improve their overall cognitive functioning.

Parents workshop and orientation programs:

Awareness and orientation workshop for parents to inform them of the benefits of neurocognitive trainings and how it is a positive addition to their children's education.

Government intervention:

Rules and laws should be put in place that propagate the integration and inclusion of neurocognitive trainings across all educational systems. Financial support should equally be given to implement these techniques and further research.

Longitudinal research and continuous monitoring:

More studies like this one should be carried out to ascertain the relevance of neurocognitive trainings and the institutions where neurocognitive trainings are implemented should be closely monitored.

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