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Effects of integrated yogic practices on cognitive performance in children aged 8-12: An experimental study

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Abstract

This study investigates the effects of an integrated yogic intervention on cognitive performance – specifically, attention, memory, and reaction time – in children aged 8-12 years. A total of 31 school students were allocated to an experimental group ($n = 18$) receiving a 56-day integrated yogic programme comprising Bhramari Pranayama with Adi Mudra, Navasana, and Yoga Nidra, or a control group ($n = 13$) engaged in structured non-yogic activities. One control participant was lost to follow-up, yielding a final analysed sample of 30. Cognitive performance was assessed using custom-built digital tools measuring sustained attention (Continuous Performance Test), spatial memory (Corsi-style block-tapping task), and simple reaction time before and after the intervention. Paired-samples t-tests and Cohen's d effect sizes revealed that the experimental group showed statistically significant improvements in reaction time (Pre: $M = 809.94$, $SD = 418.09$; Post: $M = 477.61$, $SD = 202.99$; $p <.001$, $d = -1.04$), CPT correct responses ($p <.001$, $d = 1.16$), and memory level ($p <.001$, $d = 1.18$). The control group showed negligible changes. These findings suggest that structured, integrated yogic interventions can serve as effective, low-cost school-based programmes for enhancing cognitive functioning in children.

Keywords: Integrated yoga, attention, memory, reaction time, cognitive performance, school children, Bhramari Pranayama, Yoga Nidra, quasi-experimental design, digital cognitive assessment

Introduction

Cognitive abilities such as attention, memory, and processing speed are fundamental to learning and academic success during childhood (Diamond, 2013) [8]. These abilities underpin a child's capacity to absorb new information, follow instructions, complete academic tasks, and engage meaningfully in classroom interactions. However, recent trends indicate a noticeable decline in sustained attention and increased distractibility among school-aged children, often attributed to rapid shifts in environmental stimuli and increased engagement with digital media (Rosen *et al*, 2013; Twenge *et al*, 2019) [23, 31]. The World Health Organization has highlighted the growing concern surrounding childhood mental health and cognitive well-being, emphasising the need for evidence-based interventions in educational settings (WHO, 2021).

Attention, in particular, serves as a foundational cognitive process that supports information encoding, memory formation, and task execution (Posner & Rothbart, 2007) [21]. Children who struggle with sustaining attention often face cascading difficulties: reduced comprehension during lessons, incomplete homework, lower test performance, and diminished confidence in their academic abilities (Mahone & Schneider, 2012) [17]. These challenges are not isolated but interact with other cognitive domains in complex ways. For instance, attentional deficits directly impair working memory function, as information that is not adequately attended to cannot be effectively encoded or manipulated (Baddeley, 2003) [2].

Memory processes including working memory and short-term retention are essential for learning new material and integrating knowledge across different subject areas. Working memory, which involves the temporary storage and manipulation of information, has been identified as one of the strongest predictors of academic achievement in childhood (Baddeley, 2003; Diamond, 2013) [2, 8]. Children with limited working memory capacity frequently struggle with tasks that require following multi-step instructions, solving mathematical problems, and reading comprehension. Reaction time, reflecting the speed of cognitive processing and motor response, is another important indicator of neural efficiency and attentional control (Jensen, 2006 [13]; Donders, 1868).

Given the importance of these cognitive functions, there is a growing interest in interventions that can enhance cognitive performance in children without the side effects associated with pharmacological approaches. Mind-body practices, particularly those derived from yogic traditions, have gained attention for their potential to influence cognitive processes through mechanisms such as improved attentional control, autonomic regulation, and neurophysiological balance (Khalsa *et al*, 2012; Tang *et al*, 2015) [14, 28]. Techniques such as controlled breathing (pranayama) may enhance cerebral oxygenation and regulate neural activity, while practices like Yoga Nidra may facilitate deep relaxation and improve cognitive recovery and consolidation processes (Saraswati, 1976; Brown & Gerbarg, 2005) [3, 26].

Despite these theoretical mechanisms, empirical research examining the effects of integrated yogic practices on objective cognitive measures in children remains limited. Many existing studies rely on subjective assessments such as teacher ratings or self-report questionnaires, or focus on isolated components of yoga rather than a structured, multi-component intervention (Butzer *et al*, 2015; Hedman-Lagerlof *et al*, 2024) [4, 12]. Additionally, there is a need for studies employing measurable, performance-based tools – particularly digital instruments – to assess changes in attention, memory, and reaction time with precision and reliability (Roebuck *et al*, 2016) [22].

The present study addresses this gap by evaluating the impact of an integrated yogic intervention – including Bhramari Pranayama, Navasana, Adi Mudra, and Yoga Nidra – on cognitive performance in children aged 8-12 years. Using custom-built digital, game-based assessments to measure attention, memory, and reaction time, this study aims to provide objective evidence on the effectiveness of yogic practices in enhancing core cognitive functions within a school-based setting. This research forms part of a larger investigation examining the effects of integrated yogic practices on multiple developmental outcomes in children, with a companion paper addressing emotional and behavioural outcomes (Dama & Seidlitz, in press).

Literature Review

Cognitive Functions in Childhood Development

Cognitive functions such as attention, memory, and processing speed are fundamental to learning and academic success in childhood. Attention serves as the basis for information processing, enabling children to selectively focus on relevant stimuli while ignoring distractions (Posner & Rothbart, 2007) [21]. The development of attentional control follows a protracted trajectory during childhood, with significant maturation occurring between ages 8 and 12 – the precise developmental window targeted in the present study. However, increasing exposure to digital technologies and multitasking environments has been associated with reduced attentional capacity and increased distractibility among children (Rosen *et al*, 2013; Dai & Ouyang, 2025) [7, 23].

Memory, particularly working memory, plays a central role in learning by allowing temporary storage and manipulation of information (Baddeley, 2003) [2]. Research has consistently demonstrated that deficits in working memory are strongly linked to academic difficulties, especially in tasks requiring reading comprehension, mathematical reasoning, and problem-solving. Spatial memory, assessed through tasks such as the Corsi block-tapping paradigm, provides a measure of visuospatial working memory that is particularly relevant to mathematical and scientific reasoning (Corsi, 1972; Mammarella & Cornoldi, 2005) [6, 18]. Reaction time, an indicator of processing speed and neural efficiency, reflects the ability to perceive and respond quickly to stimuli and is closely associated with attentional control (Jensen, 2006) [13].

Recent theoretical and empirical work has emphasized the importance of executive functions in cognitive development. Executive functions – including attentional control, inhibitory regulation, and cognitive flexibility – are critical for academic performance and adaptive behaviour (Diamond & Ling, 2020; Diamond, 2013) [8, 9]. These higher-order cognitive processes are subserved by prefrontal cortical networks that undergo substantial development during middle childhood, making this period particularly sensitive to both positive and negative environmental influences. Interventions that enhance these functions may therefore have significant and lasting educational benefits.

Yoga-Based Interventions and Cognitive Enhancement

Mind-body practices such as yoga and mindfulness have gained significant attention as potential tools for enhancing cognitive performance in both adults and children. Neurocognitive research suggests that such practices can improve attentional control, executive functioning, and emotional regulation through changes in brain networks and neural efficiency (Tang *et al*, 2015; Tang *et al*, 2020) [28, 29]. A comprehensive meta-analysis by Zhang *et al.* (2021) [36] provided strong evidence that mindfulness-based interventions improve cognitive function in children, with particularly robust effects on sustained attention and executive control. Similarly, Zenner *et al.* (2014) [35] found significant positive effects of mindfulness programmes in school settings across multiple cognitive and psychological domains.

Breathing-based practices (pranayama) may influence cognitive processes through several physiological mechanisms, including modulation of the autonomic nervous system and improved oxygenation (Brown & Gerbarg, 2005; Saoji *et al*, 2021) [3, 25]. Bhramari Pranayama, specifically, involves slow controlled exhalation with humming, which activates the vagus nerve and promotes parasympathetic dominance. The resonant humming component is associated with increased nitric oxide production in the nasal sinuses, which may contribute to improved respiratory function and neural regulation (Weitzberg & Lundberg, 2002; Kuppusamy *et al*, 2018) [15, 33]. Relaxation practices such as Yoga Nidra may facilitate cognitive recovery, enhance mental clarity, and support memory consolidation by reducing cognitive fatigue (Saraswati, 1976; Vijay & Pal, 2023). Pandya (2024) [20, 26, 32] conducted a comprehensive review emphasising the specific utility of Yoga Nidra for addressing paediatric cognitive and behavioural concerns.

Empirical studies in school settings provide preliminary support for these effects. Telles *et al.* (2013) [30] reported improvements in attention and cognitive performance following yoga interventions in children. Chaya *et al.* (2012) [5] found that regular yoga practice enhanced memory and concentration in school-aged children from socioeconomically disadvantaged backgrounds in a randomised controlled study. More recently, Anusuya *et al.* (2021) [1] demonstrated that the Mind Sound Resonance Technique significantly improved cognitive function in school children through a randomised controlled trial. Meena *et al.* (2025) [19] reported significant improvements in academic stress, emotional stability, and learning outcomes following integrated yoga interventions in village children aged 6-12 years, providing evidence for the feasibility and effectiveness of yogic practices in diverse educational settings.

Gaps in the Literature

Several limitations persist in the existing literature that the present study seeks to address. First, many studies rely on subjective assessments rather than objective performance-based measures (Felver *et al*, 2016) [11]. Second, there is a lack of research examining multiple cognitive domains – attention, memory, and reaction time – within a single integrated intervention framework. Third, few studies utilise digital or game-based tools that can provide precise and reliable measurements of cognitive performance (Ludyga *et al*, 2020) [16]. Fourth, much of the existing research focuses on isolated yoga components rather than multi-component programmes that combine breathing, postures, mudras, and deep relaxation. The present study addresses all of these gaps simultaneously.

Objectives and Hypotheses

Objectives

The primary objective of this study is to evaluate the effectiveness of an integrated yogic intervention in enhancing cognitive performance in children aged 8-12 years. Specifically, the study examines whether the intervention produces measurable improvements in: (a) sustained attention as measured by the Continuous Performance Test (CPT). The CPT is a well-established measure of sustained attention and vigilance (Rosvold *et al*, 1956; Roebuck *et al*, 2016; Mahone & Schneider, 2012) [17, 22, 24]; (b) spatial memory level and recall speed as measured by the Corsi-style block-tapping task. This task is widely used in developmental cognitive research (Corsi, 1972; Mammarella & Cornoldi, 2005) [6, 18]; and (c) simple reaction time speed and consistency as measured by, first conceptualised by Donders (1868), provides a reliable measure of basic processing speed and neural efficiency.

Research Question

Does participation in an integrated yogic programme lead to significant improvements in attention, memory, and reaction time among school children compared to a control group engaged in structured non-yogic activities?

Hypotheses

H1: Children in the intervention group will demonstrate significantly faster reaction times post-intervention compared to pre-intervention.

H2: The intervention group will show significantly greater improvement in sustained attention (CPT scores) compared to the control group.

H3: Spatial memory performance (level achieved and recall time) will improve significantly in the intervention group relative to the control group.

H4: The control group will show no statistically significant changes across cognitive measures.

Methodology

Research Design

This study employed a quasi-experimental pre-test and post-test design with experimental and control groups. The quasi-experimental approach was selected as the most practical design given the school-based setting, where true randomisation of individual students was not feasible due to administrative and ethical constraints. The intervention was conducted over 56 days, with daily 40-minute sessions during school hours at a school in Auroville, Tamil Nadu, India. Figure 1 presents the complete participant flow through the study.

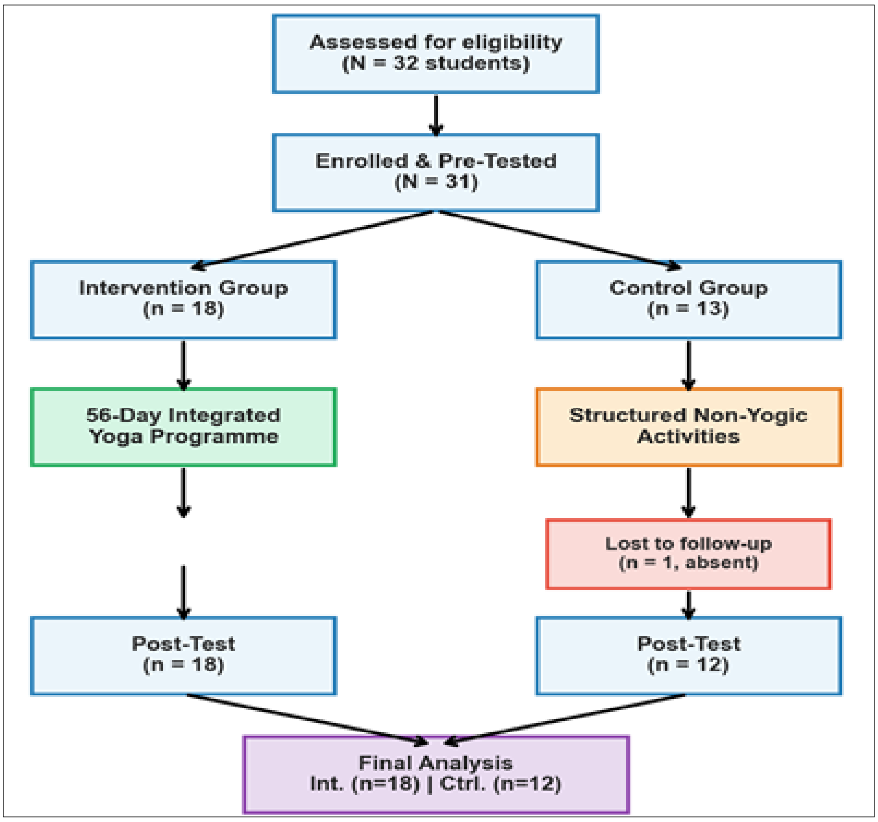

Fig 1: CONSORT-style participant flow diagram showing enrolment, allocation, follow-up, and analysis

As illustrated in the flow diagram above, the study followed a rigorous enrolment and assessment protocol. A total of 32 students were initially assessed for eligibility, of whom 31 met the inclusion criteria and were enrolled. Students were allocated to either the intervention or control group based on logistical considerations, specifically their transportation feasibility as determined by the school administration and teachers to either the intervention or control group, with one control participant lost to follow-up due to absence during the post-test assessment.

Participants

A total of 31 students aged 8-12 years participated in the study. The experimental group comprised 18 students (M age = 8.78, SD = 0.65) who received the integrated yogic intervention. The control group comprised 13 students (M age = 8.67, SD = 0.65) who participated in structured non-yogic activities to ensure comparable engagement and Hawthorne effect control. One control group participant was absent for the post-test assessment and was excluded from the final analysis, resulting in an analysed sample of n = 18 (intervention) and n = 12 (control). Figure 3 displays the demographic characteristics of the participant sample.

Intervention

The integrated yogic intervention consisted of four core components delivered in a structured, age-appropriate format. Figure 2 presents the conceptual framework of the intervention components and their synergistic relationship.

Bhramari Pranayama (humming bee breath) was performed for several rounds, followed by Adi Mudra with gentle smile, and this sequence was repeated to promote parasympathetic activation and vagal nerve stimulation (Saoji *et al*, 2021; Kuppusamy *et al*, 2018) [15, 25]. Navasana (Boat Pose) enhanced core body awareness, proprioceptive feedback, and sustained attention through physical engagement (Khalsa *et al*, 2012) [14]. Adi Mudra promoted internal focus and nervous system calming. Guided Yoga Nidra facilitated deep relaxation through systematic body scanning and conscious rest (Saraswati, 1976; Vijay & Pal, 2023) [26, 32]. Sessions were conducted daily for 40 minutes on school days across the 56-day intervention period, with 20 minutes of daily discussions. The control group participated in structured non-yogic activities such as art, craft, and group games to ensure comparable time engagement and social interaction.

Instruments and Data Collection

To ensure the highest accuracy and reliability in measurements, the research team developed a custom, user-friendly interface featuring a specialised keyboard and digital screen, which displayed results instantly. This innovation eliminated bias from variations in participants' familiarity with standard computer keyboards, ensuring all participants were on equal footing. Technical experts designed and imported components to build this setup, and the game-based assessments were programmed precisely for accurate, reproducible results. All assessments were conducted before and after the 56-day intervention.

Three cognitive assessment tools were employed:

Continuous Performance Test (CPT): This 90-second digital task measured sustained attention, where participants pressed a button whenever a target stimulus (green light) appeared, testing focus and response control. Both correct responses (hits) and commission errors (false alarms) were recorded. The CPT is a well-established measure of sustained attention and vigilance (Rosvold *et al*, 1956; Roebuck *et al*, 2016; Mahone & Schneider, 2012) [17, 22, 24].

Simple Reaction Time Test: This measured the speed of cognitive processing, where participants waited for a green key to light up and pressed it as quickly as possible. Reaction time was recorded in milliseconds. This paradigm, first conceptualised by Donders (1868), provides a reliable measure of basic processing speed and neural efficiency.

Corsi-style Block-Tapping Task: This assessed spatial short-term memory, where participants remembered and repeated progressively complex patterns of illuminated keys. Both the maximum level achieved (memory level) and the time taken (memory time) were recorded. This task is widely used in developmental cognitive research (Corsi, 1972; Mammarella & Cornoldi, 2005) [6, 18].

Data Analysis

Data were analysed using descriptive statistics (means, standard deviations), paired-samples t-tests for within-group pre-post comparisons, independent-samples t-tests for between-group comparisons of change scores, and Cohen's d for effect size estimation. Statistical significance was set at alpha =.05. All analyses were conducted using Python 3.10 with SciPy. Effect size benchmarks followed Cohen's conventions: small (d = 0.2), medium (d = 0.5), and large (d = 0.8).

Results

Baseline Equivalence

Independent-samples t-tests confirmed no statistically significant differences between the experimental and control groups at baseline across all cognitive measures (all p >.05), establishing group comparability prior to the intervention. This finding is critical for interpreting post-intervention differences as attributable to the intervention rather than pre-existing group differences.

Reaction Time

The experimental group demonstrated a substantial and statistically significant reduction in reaction time following the intervention (Pre: M = 809.94, SD = 418.09; Post: M = 477.61, SD = 202.99; t (17) = -4.42, p <.001, d = -1.04). This represents a mean reduction of 332.33 milliseconds, indicating substantially faster cognitive processing speed following the yogic intervention.

In contrast, the control group showed no significant improvement and in fact exhibited increased reaction times (Pre: M = 1297.42, SD = 575.25; Post: M = 1995.83, SD = 809.93; t (11) = 3.46, *p* = 0.005, d = 1.00). The between-group comparison of change scores confirmed a statistically significant difference (t = -5.48, p <.001), providing strong evidence for the specific effect of the yogic intervention on processing speed.

Figure 4 presents the grouped bar chart comparing mean reaction times between groups across test phases. The pattern clearly shows a marked decrease in the intervention group alongside a slight increase in the control group, forming a divergent trajectory that underscores the intervention effect.

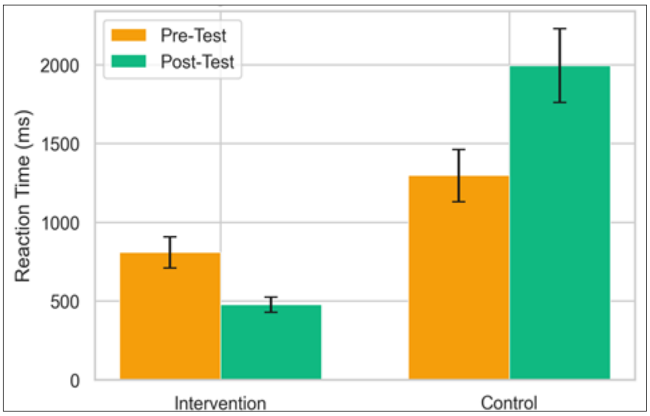

Fig 2: Grouped bar chart comparing mean reaction time (ms) before and after the intervention. Error bars represent SEM

To better understand the distributional characteristics of the reaction time data, Figure 6 presents a split violin plot. This visualisation reveals not only the shift in central tendency but also the narrowing of the distribution in the intervention group post-test, suggesting more consistent performance across participants following the yogic practice.

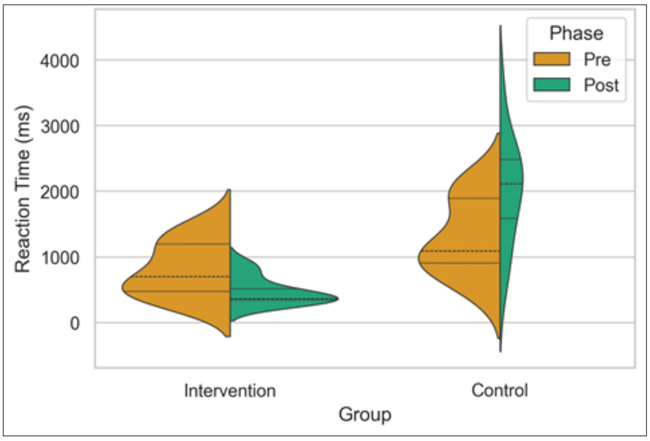

Fig 3: Split violin plot showing the density distribution of reaction time for both groups across test phases

Figure 8 maps the individual pre-to-post trajectories for each participant in the intervention group. Green lines indicate participants whose reaction time improved (decreased), while red lines indicate those who did not improve. The overwhelming majority of participants (88.9%) showed improvement, with several participants demonstrating dramatic reductions exceeding 500 milliseconds.

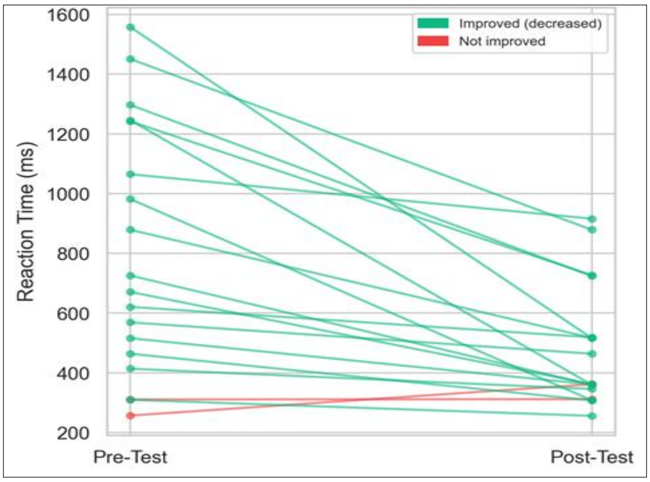

Fig 4: Slope graph mapping individual pre-to-post reaction time changes in the intervention group. Green = improvement

Sustained Attention (CPT Performance)

The experimental group showed significant improvement in sustained attention. CPT correct responses increased from M = 72.17 (SD = 7.31) to M = 85.61 (SD = 13.29); t (17) = 4.91, p <.001, d = 1.16. This increase in correct responses indicates enhanced ability to detect and respond to target stimuli during the sustained attention task.

Complementing this improvement, commission errors (wrong presses) showed a reduction from M = 4.44 to M = 2.56 (t (17) = -2.55, *p* = 0.021, d = -0.60), indicating improved response inhibition and reduced impulsive responding. The CPT total score, a composite measure reflecting overall attentional performance, improved significantly (Pre: M = 27.72; Post: M = 60.06; p <.001, d = 1.02). The control group showed negligible changes across all CPT measures, with significant between-group differences for correct responses, (t = 2.37, *p* = 0.025).

Figure 5 displays the grouped bar chart for CPT correct responses, illustrating the clear divergence between groups from pre-test to post-test.

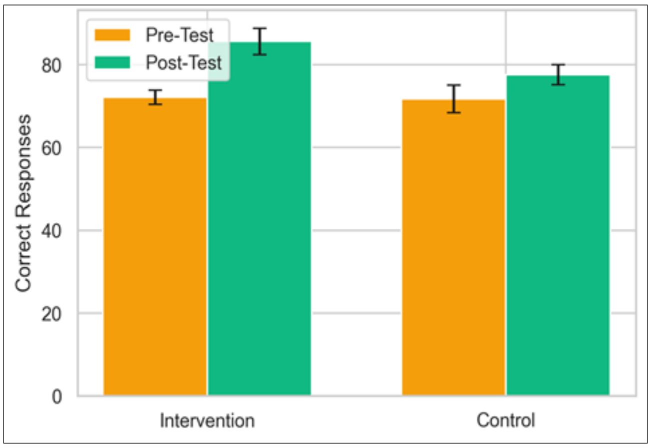

Fig 5: Grouped bar chart of CPT correct responses for both groups. Higher scores indicate better sustained attention

Figure 14 provides a more detailed view through stacked bar charts showing the composition of CPT responses (correct versus erroneous) for each group. This visualisation highlights how the intervention group not only increased correct responses but also reduced the proportion of errors, a pattern not observed in the control group.

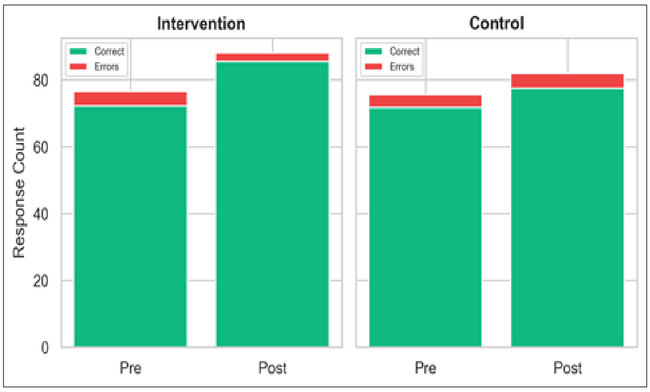

Fig 6: Stacked bar charts showing the proportion of correct and erroneous CPT responses before and after intervention

Memory Performance

Memory level scores showed improvement in the experimental group (Pre: M = 2.56, SD = 0.86; Post: M = 3.39, SD = 0.92; t (17) = 5.00, p <.001, d = 1.18). This indicates that participants were able to successfully complete more complex pattern sequences following the intervention, reflecting enhanced spatial working memory capacity.

Memory time-the time taken to complete the spatial recall task-decreased from M = 63.22 to M = 47.17 seconds (t(17) = -0.58, p = 0.567, d = -0.14), indicating faster recall speed. This combination of higher accuracy (memory level) and faster processing (memory time) suggests a genuine enhancement in memory efficiency rather than a speed-accuracy trade-off.

The control group demonstrated no significant changes in either memory measure (Memory level: p = 0.394; Memory time: p = 0.616).

Figure 7 presents box-and-swarm plots for memory level scores, with individual data points overlaid on quartile distributions. This visualisation reveals both the group-level trends and the individual variability within each group.

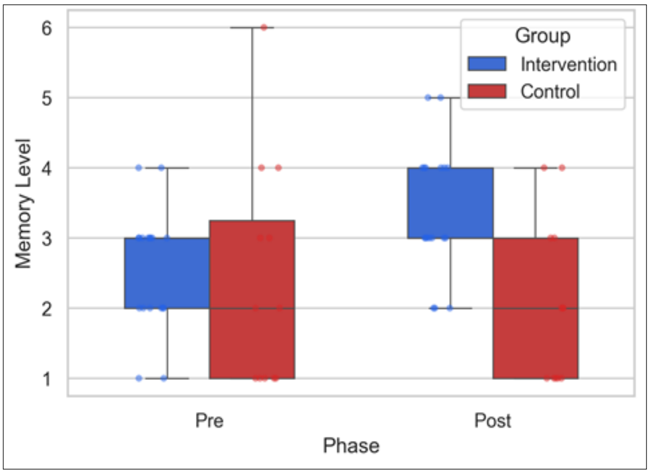

Fig 7: Box-and-swarm plot of memory level scores showing individual data points overlaid on quartile distributions

Figure 19 shows the grouped bar chart for memory level, providing a clear comparison of pre-post means across groups. The intervention group shows notable improvement while the control group remains relatively unchanged.

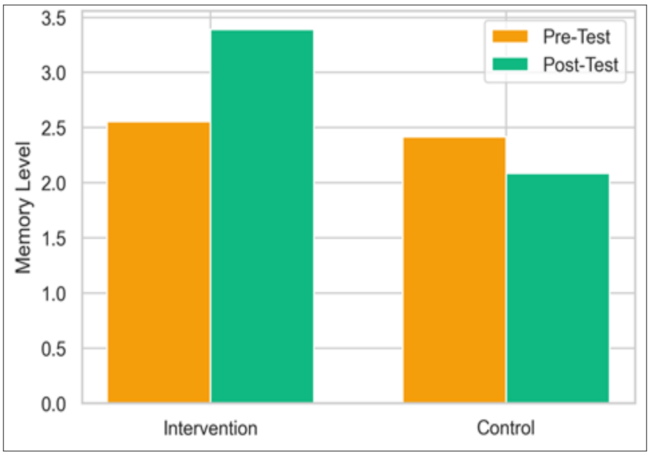

Fig 8: Grouped bar chart comparing mean memory level scores between groups and test phases

Figure 15 presents the kernel density estimation for memory time in the intervention group, illustrating the leftward shift in the distribution from pre- to post-test. This shift indicates that participants were completing the memory task more quickly after the intervention.

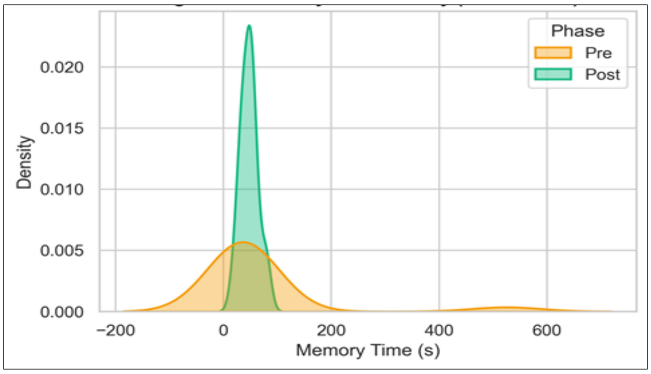

Fig 9: Kernel density estimation showing the shift in memory time distribution for the intervention group

Effect Size Analysis and Individual Responses

Effect size analysis using Cohen's d provided a standardised measure of the magnitude of intervention effects across all cognitive domains. Figure 13 presents a lollipop chart comparing effect sizes between groups, with established benchmarks (small = 0.2, medium = 0.5, large = 0.8) indicated by vertical reference lines.

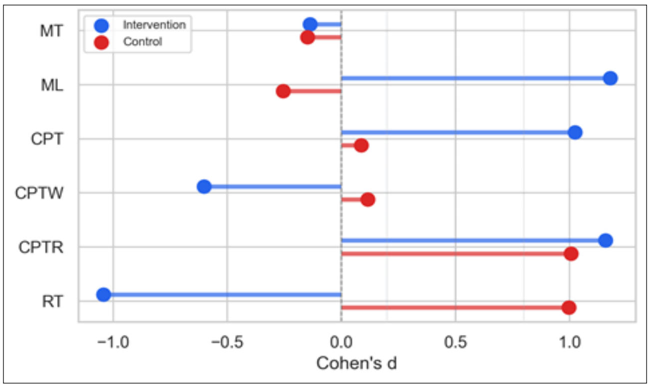

Fig 10: Lollipop chart displaying Cohen's d effect sizes for each cognitive metric by group, with benchmark thresholds

As shown in Figure 13, the intervention group consistently demonstrated larger effect sizes across all metrics compared to the control group. Reaction time and CPT measures showed particularly large effects, while memory measures showed small-to-medium effects. The control group effect sizes were negligible or near zero across all domains.

Figure 21 presents a forest plot with 95% confidence intervals for the intervention group effect sizes, providing a more precise picture of the reliability of each effect estimate. The confidence intervals for reaction time and attention measures do not cross zero, confirming statistically robust effects.

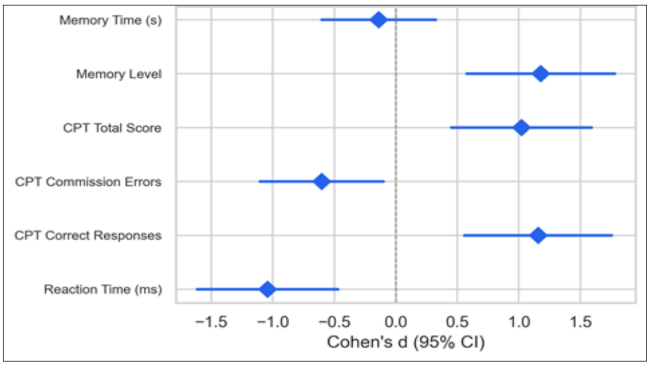

Fig 11: Forest plot displaying Cohen's d with 95% confidence intervals for the intervention group across all cognitive domains

Cognitive Profile Analysis

Radar charts were employed to visualise the holistic cognitive profile of each group before and after the intervention. Figure 9 shows the intervention group profile, revealing a noticeable expansion of the post-test polygon relative to the pre-test polygon, indicating broad-based cognitive improvement. Figure 10 shows the control group profile, where the pre- and post-test polygons largely overlap, confirming minimal change.

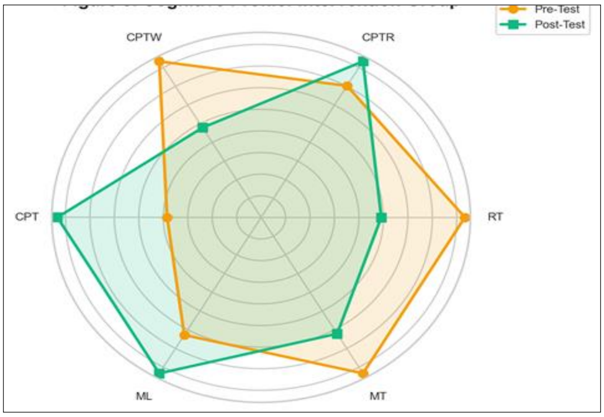

Fig 12: Radar chart showing normalised cognitive profile changes for the intervention group across all metrics

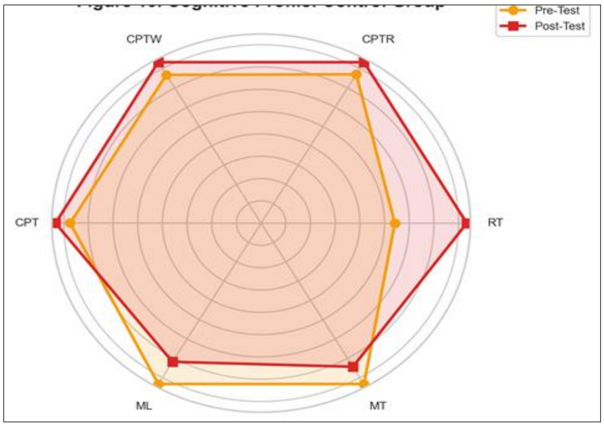

Fig 12: Radar chart showing normalised cognitive profile changes for the control group across all metrics

Interaction Effects and Comparative Analysis

Figure 16 presents a point plot with 95% confidence intervals illustrating the group-by-time interaction for reaction time. The divergent trajectories-with the intervention group decreasing and the control group increasing-constitute a classic cross-over interaction pattern, strongly supporting the causal attribution of improvements to the yogic intervention.

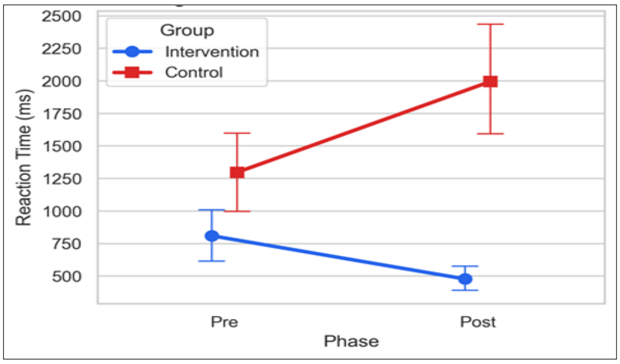

Fig 13: Point plot with 95% CI showing the group × time interaction for reaction time

Figure 17 presents a waterfall chart of individual reaction time changes sorted from most improved to least improved. Blue bars represent intervention participants and red bars represent control participants. The clear clustering of blue bars on the negative (improved) side and red bars on the positive (worsened) side provides compelling visual evidence of the differential intervention effect.

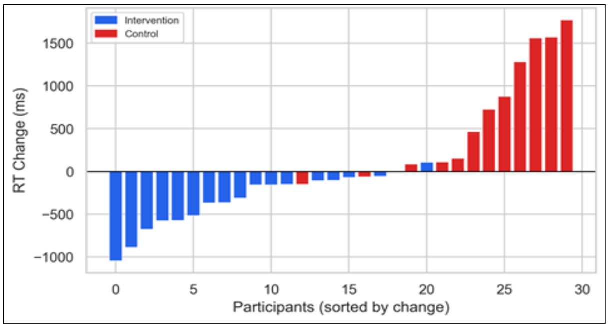

Fig 14: Waterfall chart of individual reaction time changes sorted from most improved to least. Negative = faster

Multi-Domain Relationships

Figure 18 presents a bubble chart exploring the multivariate relationship between reaction time change and CPT total change, with bubble size proportional to participant age. This visualisation reveals that intervention participants (blue) cluster in the upper-left quadrant (improved RT + improved CPT), while control participants (red) are more dispersed, with many showing no improvement or decline.

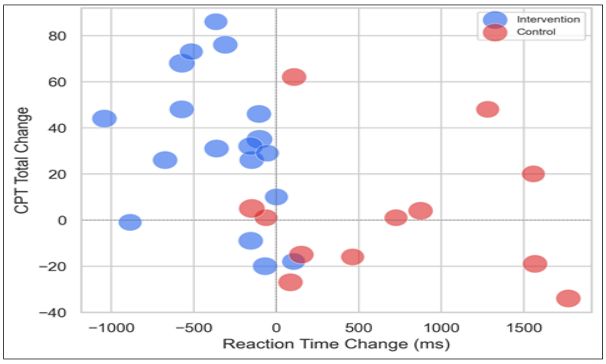

Fig 15: Bubble chart plotting reaction time change against CPT total change, with bubble size proportional to participant age

Figure 20 provides a joint plot comparing pre- and post-test reaction times with marginal histograms. Points below the diagonal line represent participants who improved (faster post-test RT). The clear separation of intervention and control group clusters, with intervention participants predominantly below the diagonal, reinforces the differential effect of the yogic intervention.

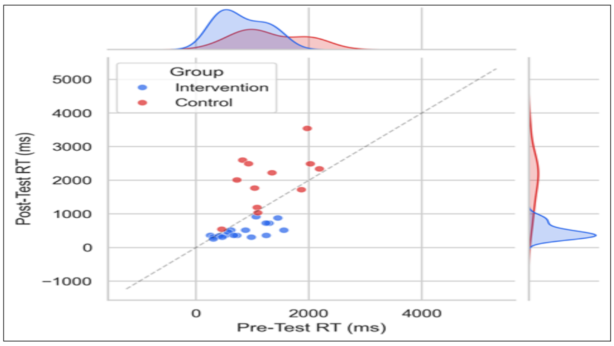

Fig 16: Joint plot with marginal histograms comparing pre- and post-test reaction times. Points below the diagonal indicate improvement

Observational Support

Teacher observations supported the quantitative findings. Improved classroom attention, increased task completion, and reduced off-task behaviour were consistently noted, particularly among students who initially exhibited lower concentration levels. Students in the intervention group reported feeling more focused and mentally clear during academic tasks following the yoga sessions. Several teachers remarked on improved hand-raising behaviour, reduced fidgeting, and better ability to follow multi-step instructions among intervention group participants.

Figure 22 presents a summary dashboard showing the pre-to-post mean trajectories for all six cognitive measures across both groups. This comprehensive overview confirms the consistent pattern of improvement in the intervention group across all domains, with the control group showing flat or adverse trajectories.

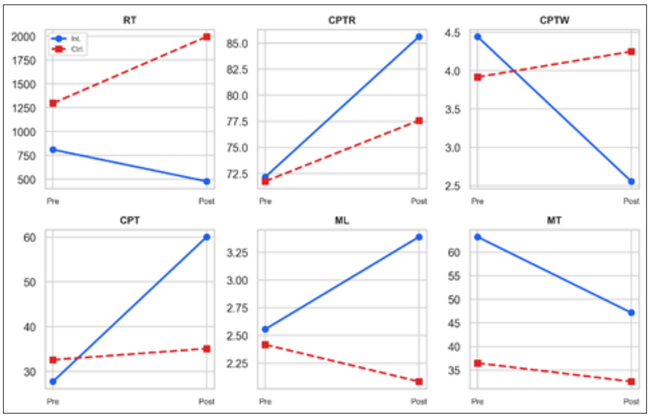

Fig 17: Summary dashboard showing pre-to-post mean trajectories for all six cognitive measures across both groups

Discussion

The present study demonstrates that an integrated yogic intervention comprising Bhramari Pranayama, Navasana, Adi Mudra, and Yoga Nidra can significantly enhance cognitive performance in children aged 8-12 years. These findings align with and extend previous research on yoga-based cognitive enhancement (Telles *et al*, 2013; Chaya *et al*, 2012; Anusuya *et al*, 2021) [1, 5, 30] by demonstrating effects across multiple cognitive domains simultaneously using objective, digital measurement tools.

The substantial improvement in reaction time observed in the intervention group is particularly noteworthy, as reaction time is considered a fundamental indicator of neural processing efficiency (Jensen, 2006) [13]. The magnitude of improvement – a mean reduction of over 300 milliseconds – suggests a meaningful enhancement in the speed at which participants could perceive and respond to stimuli. This improvement may be attributed to enhanced neural efficiency through improved oxygenation and autonomic regulation facilitated by Bhramari Pranayama (Brown & Gerbarg, 2005; Saoji *et al*, 2021; Kuppusamy *et al*, 2018) [3, 15, 25]. The rhythmic breathing and sound vibrations characteristic of this practice may activate parasympathetic pathways, reducing physiological arousal and enabling faster, more accurate cognitive responses (Streeter *et al*, 2020) [27].

Improvements in sustained attention, evidenced by increased CPT correct responses and decreased commission errors, support the hypothesis that yogic practices enhance attentional control through training of focused awareness. This is consistent with meta-analytic findings by Zhang *et al*. (2021) [36] and the theoretical framework proposed by Diamond and Ling (2020) [9], who emphasise that interventions engaging executive functions through sustained, repeated practice yield the most robust cognitive gains. The daily structure of the 56-day intervention provided precisely this type of consistent practice opportunity.

The memory improvements, while showing smaller effect sizes compared to attention and reaction time, nonetheless demonstrate a meaningful pattern of enhanced spatial working memory. The combination of improved memory level (accuracy) and decreased memory time (speed) argues against a speed-accuracy trade-off and instead suggests genuine enhancement in memory processing efficiency. Yoga Nidra may support these improvements through its role in cognitive recovery and memory consolidation (Saraswati, 1976; Vijay & Pal, 2023; Pandya, 2024) [20, 26, 32]. The deep relaxation state induced by Yoga Nidra may facilitate neural consolidation processes similar to those observed during sleep-dependent memory processing.

The correlation between improvements in reaction time and sustained attention performance across individuals suggests a common underlying mechanism, potentially mediated by enhanced autonomic regulation and more efficient allocation of attentional resources (Tang *et al*, 2020) [29]. The integrated nature of the intervention-combining breathing, physical postures, mudras, and deep relaxation-likely addresses both bottom-up physiological regulation and top-down cognitive-emotional processing, creating synergistic effects that exceed the benefits of individual components (Streeter *et al*, 2020) [27].

The negligible changes observed in the control group, despite engaging in structured activities of comparable duration and social interaction, suggest that the cognitive benefits are specifically attributable to the yogic components rather than mere engagement, novelty, or Hawthorne effects. This strengthens the internal validity of the study and supports the specific efficacy of yogic practices for cognitive enhancement in children. These findings are consistent with Hedman-Lagerlof *et al*. (2024) [12], who noted that the active components of yoga-based interventions, rather than non-specific factors, drive observed benefits.

Limitations and Future Directions

Several limitations should be acknowledged. First, the relatively small sample size (N = 30 analysed) limits statistical power and generalisability. Second, the quasi-experimental design does not permit causal inferences with the same confidence as a fully randomised controlled trial. Third, the 56-day intervention period, while sufficient to demonstrate effects, does not address long-term sustainability of cognitive gains or potential dose-response relationships. Fourth, variability in students' baseline cognitive abilities and external influences such as home environment, nutrition, and sleep quality may have affected outcomes. Fifth, the absence of an active control condition matched for physical activity intensity limits conclusions about whether the effects are specific to yogic practices or could be partially attributed to physical activity per se (Ludyga *et al*, 2020) [16].

Future research should employ larger, demographically diverse samples with randomised controlled designs. Longer follow-up periods would clarify the sustainability of cognitive gains. The inclusion of neuroimaging measures (e.g, EEG, fNIRS) would elucidate the neural mechanisms underlying observed improvements. Active control conditions matched for physical activity intensity would strengthen conclusions about the specificity of yogic effects. Finally, investigating potential moderating variables such as age, gender, baseline cognitive ability, and home environment would enhance understanding of for whom these interventions are most beneficial.

Implications

The findings of this study carry significant practical implications for educational policy and practice. Integrated yogic practices represent a cost-effective, scalable, and resource-efficient approach to enhancing cognitive performance in school-aged children. Unlike pharmacological interventions, yogic practices carry minimal risk of adverse effects and can be readily integrated into existing school schedules without requiring specialised equipment or extensive training. Given the minimal resource requirements and demonstrated effectiveness, structured yoga programmes represent a promising approach to supporting cognitive development in educational settings, particularly in resource-limited environments (Meena *et al*, 2025; Hedman-Lagerlof *et al*, 2024) [12, 19].

The specific improvements in sustained attention have direct relevance to classroom learning, as attention is a prerequisite for effective information processing, comprehension, and task completion. Similarly, enhanced working memory capacity may support improved performance in mathematics, reading, and problem-solving tasks. The faster reaction times suggest improved neural efficiency that may benefit children across a range of academic and daily activities.

Conclusion

This controlled experimental study demonstrates that an integrated yogic intervention comprising Bhramari Pranayama, Navasana, Adi Mudra, and Yoga Nidra significantly improves cognitive performance in children aged 8-12 years. Statistically significant improvements were observed in reaction time, sustained attention, and memory performance, with large effect sizes in the intervention group and negligible changes in the control group. The use of custom-built digital assessment tools provided objective, reliable measurements that strengthen the validity of these findings. These results contribute to the growing evidence base supporting the integration of structured yogic practices into educational curricula for comprehensive cognitive development, and highlight the potential of mind-body interventions as accessible, effective tools for enhancing children's learning readiness and academic potential.

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This study is part of a larger research project examining the effects of integrated yogic practices on multiple developmental outcomes in children.

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