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The Effects of Exergaming and Neurofeedback on Working Memory in Children with Attention-Deficit/Hyperactivity Disorder

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1. Round 1

1.1. Reviewer 1

Reviewer:

The Introduction contains several broad statements about working memory, including the sentence, “Working-memory deficits may be especially disruptive for children with ADHD because many classroom activities require the simultaneous processing and retention of information.” The authors should strengthen this section by defining the specific working-memory model adopted in the study and distinguishing working memory from short-term memory, attention, response inhibition, and general executive functioning. Because the N-Back Task was used as the sole outcome measure, the theoretical rationale should explain which component of working memory the task primarily measures, such as continuous updating, monitoring, and temporary maintenance, and why this component is expected to be sensitive to neurofeedback and exergaming.

In the Introduction paragraph beginning, “Treatment of ADHD commonly involves pharmacotherapy, behavioral interventions, parent training, educational accommodations, cognitive rehabilitation, or combinations of these approaches,” the literature review becomes overly broad and includes medication, dietary interventions, yoga, neurofeedback, cognitive rehabilitation, and exergaming. The authors should improve conceptual focus by organizing the literature around the study’s two principal interventions and the shared mechanisms relevant to working memory. Material on diet, pharmacological

guidelines, and unrelated neurofeedback applications should be shortened unless it directly establishes the clinical need for the two interventions examined. A more focused Introduction would improve coherence and make the identified research gap more convincing.

In the paragraph stating, “Recent developments have expanded neurofeedback beyond conventional ADHD protocols,” the manuscript cites studies on depression, anxiety, mindfulness, and sport performance. These references demonstrate the broader use of neurofeedback but are only indirectly relevant to children with ADHD and working memory. The authors should explicitly justify why evidence from these populations is informative for the present study or reduce this discussion. More space should instead be allocated to methodological controversies in ADHD neurofeedback research, including protocol specificity, expectancy effects, sham-control design, rater blinding, transfer effects, and the distinction between improvements on trained tasks and generalized executive-function outcomes.

In the Study Design and Participants paragraph, the manuscript states, “The required sample size was estimated using GPower version 3.1, and 52 eligible boys with ADHD were recruited.” The authors should provide the complete a priori power-analysis parameters, including the statistical test selected in GPower, expected effect size, alpha level, desired statistical power, number of groups, number of repeated measurements, assumed correlation among repeated measures, and nonsphericity correction. It should also be clarified whether the calculated sample size included an allowance for attrition. Without these details, the adequacy of the sample cannot be independently evaluated, especially for detecting the interaction effect and the pairwise differences between the two active interventions.

In the same participant paragraph, the authors report that participants were “matched as closely as possible in terms of intellectual functioning” and then “randomly assigned” to four groups. This sequence requires clarification because matching and complete randomization are distinct allocation procedures. The authors should state whether stratified randomization, block randomization, matched-pair randomization, or simple random assignment was used. They should also identify who generated the allocation sequence, how allocation concealment was maintained, whether group assignment occurred after baseline assessment, and whether the assessor was blinded to intervention condition. These details are essential for assessing selection bias and the integrity of the experimental design.

The sham neurofeedback paragraph states that “the audiovisual feedback presented during the computerized exercises was not systematically contingent on the child’s own moment-to-moment EEG activity.” This description is insufficiently precise. The authors should explain whether sham feedback came from a prerecorded session, another participant, a random signal, or a delayed version of the participant’s own EEG. The credibility of the sham condition should be evaluated by reporting whether participants, parents, and outcome assessors were blinded and whether treatment expectancy or perceived group assignment was assessed. Without a manipulation check, it is difficult to determine whether the sham procedure adequately controlled for expectancy and treatment credibility.

In the exergaming protocol, the manuscript describes Shape Up activities such as jumping, running, punching, and simulated weight lifting, but it does not report a standardized session structure. The authors should specify the warm-up duration, active gameplay duration, rest periods, cool-down, games or modules selected, number of repetitions, progression criteria, and method used to ensure comparable training exposure. Exercise intensity should be reported using heart rate, perceived exertion, movement counts, or another objective indicator. Safety monitoring and adverse-event procedures are also necessary because the sample consisted of young children performing repeated whole-body movements.

Authors revised the manuscript and uploaded the document.

1.2. Reviewer 2

Reviewer:

The Methods state that the participants had “an average intelligence quotient of approximately 94.5,” but the manuscript does not identify the intelligence test used or provide group-specific IQ distributions. The authors should name the instrument, describe its administration and scoring, report its validity and reliability for the target population, and specify the IQ inclusion threshold. Because intellectual functioning was reportedly used to homogenize the groups, baseline comparability should be

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demonstrated statistically rather than asserted. Group-specific age and IQ means and standard deviations, as well as socioeconomic and educational characteristics, should be reported in the results.

In the eligibility description, the manuscript states that children with "serious neurological disorders, severe sensory or motor impairments, or medical conditions that could interfere with neurofeedback or physical gaming activities were not included." The inclusion and exclusion criteria should be more operationally defined. The authors should report how psychiatric comorbidities, neurological conditions, learning disorders, epilepsy, uncorrected visual or hearing difficulties, and prior experience with neurofeedback or exergaming were assessed. Medication status is particularly important: the manuscript should state whether participants were medication-naïve, maintained on a stable dose, asked to suspend medication before testing, or permitted to change treatment during the trial.

The Data Collection Tool paragraph describes the N-Back Task as presenting "100 visual stimuli" and requiring participants to compare each stimulus with "the immediately preceding item." This appears to represent a one-back condition, but the manuscript should state this explicitly and provide the nature of the stimuli, target frequency, stimulus duration, interstimulus interval, number of practice trials, scoring method, and software version. It is also unclear whether the primary outcome was the number of correct responses, accuracy percentage, omission errors, commission errors, reaction time, or a composite score. The authors must define the exact dependent variable used in the statistical analyses and explain the direction of scoring.

The manuscript states that the N-Back Task is "relatively independent of language and cultural background," but no psychometric evidence is provided for its use among Persian-speaking children aged seven to ten years with ADHD. The authors should report reliability, construct validity, criterion validity, and test–retest evidence for the exact version used. Because the same task was administered at three time points, the possibility of practice effects should be addressed. If parallel forms were not used, this limitation should be acknowledged, and the authors should explain how the control and sham groups helped distinguish intervention effects from repeated-testing effects.

In the neurofeedback protocol, the manuscript reports that "the active electrode was placed at the F4 location," but it does not identify the EEG frequency bands being reinforced or inhibited. A reproducible neurofeedback protocol requires the authors to report the targeted frequency bands, reward and inhibit thresholds, threshold-adjustment procedure, sampling rate, impedance criterion, artifact-rejection rules, feedback modality, number and duration of training blocks, rest intervals, and whether the protocol was individualized. The rationale for selecting F4 should also be supported in relation to working memory and ADHD. Merely naming the electrode site and software does not provide sufficient information for replication.

In the paragraph describing SmartMind Neurofeedback Software, the manuscript lists broad claims that the software strengthens "attention, concentration, problem-solving, working memory, response inhibition, decision-making, and cognitive flexibility." These statements should be presented cautiously unless supported by independent validation studies. The authors should distinguish between the software manufacturer's intended functions and empirically established treatment effects. They should also report whether the software was commercially licensed, whether the investigators had any relationship with its developer, and how training fidelity was monitored across participants and sessions.

Authors revised the manuscript and uploaded the document.

2. Revised

Editor's decision: Accepted.
Editor in Chief's decision: Accepted.

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