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The Impact of Augmented Reality Technology on Visual Perception in Preschool Children at Risk of Specific Learning Disorder

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1. Round 1

1.1. Reviewer 1

Reviewer:

The literature-review paragraph beginning “Given the importance of early diagnosis and intervention in improving visual perception, the use of modern technologies can play a significant role” is overly broad and contains material that is somewhat peripheral to the study’s central research question, particularly the extended discussion of teacher self-esteem support, blended learning, and educational technology in general. The authors should consider restructuring this section so that the argument progresses more directly from visual-perceptual difficulties, to technology-mediated perceptual training, to the distinctive affordances of augmented reality, and finally to the specific research gap. The present version introduces several theoretical and pedagogical concepts without subsequently operationalizing them in the intervention. For example, if Zaraii Zavaraki’s blended learning model genuinely constitutes a theoretical basis for ARCHIN, the Methods section should explicitly

demonstrate how each relevant component of that model informed intervention design rather than merely mentioning the model retrospectively.

The manuscript's review of prior studies is extensive, but the paragraphs describing computer-assisted rehabilitation, digital games, multimedia, virtual reality, and augmented reality currently function largely as a catalogue of studies. For example, the paragraph beginning "In the field of computer-assisted interventions and cognitive rehabilitation" sequentially summarizes Captain's Log, Sound Smart, and other computer-based programs without critically synthesizing their methodological quality or explaining precisely how ARCHIN differs from them. The authors should reorganize this review analytically rather than chronologically or descriptively. A stronger synthesis would compare participant age, diagnostic/risk status, intervention modality, outcome measures, treatment dosage, control condition, and methodological rigor, thereby demonstrating exactly which unanswered question the present study addresses. This would also make the novelty claim regarding preschool-aged children and AR considerably more persuasive.

The final paragraph of the Introduction states that "the present study aims to fill this gap by examining the impact of augmented reality technology on the visual perception of preschool children at risk of specific learning disabilities." The research gap is generally clear, but explicit research hypotheses should be stated immediately after this paragraph. The Discussion refers to "one main hypothesis and five sub-hypotheses," yet these hypotheses are not formally presented at the end of the Introduction. The authors should specify the primary outcome and secondary outcomes prospectively: for example, whether total visual perception was the primary outcome and the five Frostig components were secondary outcomes. This distinction is particularly important because six inferential tests are subsequently performed, creating a multiple-testing issue that should be addressed statistically.

In Section 2.1, the manuscript states that "The statistical population consisted of all preschool children at risk of specific learning disorders who attended preschool centers in Darab," but screening was apparently conducted among only 80 children "in one of the preschool centers in Darab." This creates an inconsistency between the defined target population and the actual accessible sampling frame. The authors should clearly distinguish the target population, accessible population, screened cohort, eligible cohort, and randomized sample. If only one preschool center participated, the phrase "all preschool children at risk … in Darab" is too broad and should be revised. The authors should also describe how this preschool center was selected, whether it was public or private, the approximate socioeconomic characteristics of enrolled families, and whether the screened 80 children represented all age-eligible children at that center.

Table 1 and the paragraph describing the eight-session program show an uneven allocation of intervention dosage across Frostig dimensions: eye-motor coordination receives one dedicated session, figure-ground one session, constancy of shape one session, while position in space and spatial relationships each receive two sessions. This raises an important interpretive issue because improvement across subdomains may partly depend on exposure duration rather than the inherent suitability of AR for each perceptual construct. The authors should explain the pedagogical rationale for this unequal session distribution and clarify whether session content was based on a validated protocol or expert consensus. The intervention also incorporates repeated practice, feedback, review, task completion symbols, and possibly reward mechanisms; therefore, attributing observed changes exclusively to "augmented reality technology" is conceptually too broad. The manuscript should define the intervention as a multicomponent AR-mediated training program and acknowledge the inability to isolate AR-specific effects.

The Methods section should report intervention fidelity and adherence. The manuscript states that children received eight 30-minute sessions, but does not indicate whether all eight participants completed every session, whether any sessions were interrupted, repeated, shortened, or missed, or whether actual exposure time was recorded. It is also unclear who delivered the intervention, what training the facilitator received, whether the same facilitator worked with all children, whether sessions were individual or group-based, and whether implementation was monitored using a checklist. These details are critical because the participants were only 5.0–5.9 years old and may vary substantially in attention, engagement, and ability to operate AR tasks. Reporting attendance, completion rates, adverse events or cybersickness, technical failures, and treatment-fidelity procedures would materially improve reproducibility and internal validity.

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1.2. Reviewer 2

Reviewer:

The eligibility criterion stating that children had to "fail to obtain a passing score on all six visual-perception subtests of the Captain's Log software" requires much stronger justification. This is an unusually stringent operational definition that may select children with particularly severe or generalized perceptual difficulties rather than preschool children broadly "at risk of specific learning disorder." The manuscript should provide empirical or normative evidence supporting the specified cutoffs of 8/10 or 7/10 and explain whether these thresholds are age-standardized, validated in Iranian preschool children, or derived solely from manufacturer documentation. The authors should also clarify whether failure on all six tests was defined a priori or introduced during participant selection. Because eligibility depends heavily on Captain's Log, the reliability, sensitivity, specificity, and construct validity of these subtests for this population should be reported.

The paragraph describing the three excluded children should be expanded because exclusion after initial risk identification may introduce selection bias. The manuscript states that three children were excluded because they "were unable to complete the individually administered Captain's Log assessment (e.g., due to inattention or refusal to continue the tasks)." Difficulty sustaining attention or completing computerized assessment may itself characterize children at developmental or learning risk and could also influence responsiveness to an AR intervention. Excluding these children may therefore create a more compliant or technologically tolerant sample. The authors should report the characteristics and, where available, Steele scores of these excluded participants, clarify whether exclusion criteria were established before recruitment, and discuss this potential selection mechanism as a limitation.

The allocation procedure described as "a sex-stratified computer-generated sequence … using the RAND() function … implemented by the first author" is more rigorous than simple convenience allocation, but the manuscript should provide additional information about allocation concealment. Because the first author apparently conducted eligibility screening and implemented the random sequence, it is unclear whether assignment could have been anticipated or influenced. The authors should report who generated the allocation sequence, who enrolled participants, who assigned participants to groups, and whether group assignments were concealed until enrollment was complete. If concealment was not implemented, this should be acknowledged explicitly. Given that individual participants were randomly allocated after purposive recruitment, the authors should also reconsider whether describing the study simply as "quasi-experimental" is methodologically accurate or whether it is better characterized as a small randomized controlled pilot study with nonprobability recruitment.

The description of the Frostig Advanced Visual Perception Test raises an important psychometric concern. The manuscript reports Cronbach's $\alpha = .67$ and strikingly small criterion-related correlations for the total score with mathematics, reading, dictation, and their mean ($r = .031$, .024, .054, and .007). These values appear to indicate weak internal consistency and minimal criterion validity for the total score in the cited Iranian standardization evidence. The authors should not simply describe this instrument as well established without critically addressing these psychometric results. Please verify that these coefficients have been transcribed correctly, explain what specific form/version of the Frostig test was administered, report its scoring range and age norms, and provide evidence of reliability for the present sample if feasible. Measurement error is especially important here because the study's conclusions depend entirely on this single outcome instrument.

In Section 2.3, the sentence "The ARCHIN augmented reality application was developed using the Unity engine for Android devices running version 8 or higher" is insufficient for intervention reproducibility. The authors should provide substantially more technical and instructional detail regarding ARCHIN, including device specifications, screen dimensions, AR framework or tracking technology, marker-based versus markerless operation, interaction modality, task difficulty progression, feedback mechanisms, number of trials per task, success criteria, adaptive features, and whether equivalent activities were administered to all participants. The application appears to be a central contribution of the study, yet its development and validation process is not reported. The manuscript should state whether content validity, usability, developmental appropriateness, technical stability, and expert review were evaluated before implementation, and whether pilot testing was conducted with preschool children.

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2. Revised

Editor's decision: Accepted.
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