Original Article

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Enhancing Visual Perception in Children Ages 4-12 Years: A Systematic Review of Technology-based Interventions

Physical Medicine and Rehabilitation Section

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ABSTRACT

Introduction: Visual perception plays a pivotal role in a child's overall development and learning. Occupational therapists often employ interventions to support children in enhancing their visual perception skills, with technology-based approaches gaining prominence in recent years. This review intends to highlight the significance of visual perception interventions, especially those involving technology.

Aim: To systematically synthesise the literature on the effectiveness of technology-based interventions on visual perception in children with disabilities aged 4-12 years.

Materials and Methods: A comprehensive search of studies was conducted using electronic databases (Scopus, PubMed, ProQuest, and OTseeker). Additionally, studies were also considered through manual searches from printed journals (American Journal of Occupational Therapy, British Journal of Occupational Therapy, Canadian Journal of Occupational Therapy, and the Australian Journal of Occupational Therapy) to identify existing technology-based visual perception interventions in children aged 4-12 years. Risk of Bias was conducted through guidelines for systematic review by the American Occupational Therapy Association (AOTA). Data extraction was reported by tabulating author(s) and year, sample characteristics, outcome measures used, study design, intervention details (experimental, comparator, study setting, duration), and outcomes of the studies.

Results: In the present review of 13 studies, two studies used iPad interventions, while 11 used computer-based interventions, targeting various clinical groups like developmental delays, dyslexia, cerebral palsy, hearing impairment, down syndrome, hydrocephalus, and special needs. Occupational therapists led most studies, with some involving physiotherapists, educators, and multidisciplinary teams. iPad interventions focused on visual skills with structured apps, while computer methods included games and software like Microsoft Office and Computerised Visual Perception Training (CVPT) for visual training. Positive effects were seen on visual perception and motor skills across different conditions with these technology-based interventions.

Conclusion: Visual perception interventions, particularly those incorporating technology, have become invaluable in the field of paediatric occupational therapy. As technology continues to evolve, occupational therapists must remain adaptive and innovative in their strategies to provide the best possible support for children with visual perception difficulties.

Keywords: Computer-assisted training, Learning applications, Serious games, Visual training

INTRODUCTION

In everyday life, people engage in a variety of visual perception-related activities, including those related to education, work, entertainment, and social interactions [1]. Health professionals such as occupational therapists focus on individuals' engagement in daily living activities, education, work, and recreation. The emphasis on visual perception and its impact on performance skills becomes crucial [2]. Interventions targeting visual perception can be broadly categorised into traditional and computerised interventions within clinical settings. Traditional visual perceptual training programs encompass activities such as copying figures, matching shapes, block constructions [3], puzzles [4], paper-and-pencil exercises [5], and origami [6]. While these programs can be beneficial for individuals with visual perceptual dysfunctions, they are often characterised by repetition and may lack elements to keep individuals motivated [7]. This becomes particularly challenging for children with disabilities, who may struggle with repeated practice of functional activities due to inherent factors such as short attention spans and cognitive impairments.

The utilisation of computer-based interventions offers the advantage of delivering various sensory stimuli and prompt feedback concurrently. This approach aims to boost intrinsic motivation and facilitate the automatic learning process in children. Research shows that computerised training for visual perception and visual motor integration in children is more effective than traditional paper-and-pencil methods [8-10]. Technology-based interventions have the additive advantage of making the intervention fun and enjoyable, and aided in the efficacy of the intervention [11].

The current body of literature lacks a comprehensive synthesis and critical analysis of interventions designed to enhance visual perception and visual-motor integration in children. Despite the growing recognition of the pivotal role these skills play in academic achievement, cognitive development, and overall wellbeing, there exists a gap in understanding the effectiveness of various intervention strategies. This research aims to systematically review and evaluate existing interventions, identifying their methodological strengths and weaknesses, providing a nuanced understanding of evidence-based practices for optimising visual perception and visual-motor integration in children through technology-based interventions.

MATERIALS AND METHODS

This systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses PRISMA [12] guidelines. The review was further registered on PROSPERO International prospective register of systematic reviews with the ID CRD42023460783. A comprehensive search of studies was conducted using electronic databases (Scopus, PubMed, ProQuest, and OTseeker). Additionally, studies were also considered through manual searches in printed journals (American Journal of Occupational Therapy, British Journal of Occupational Therapy, Canadian Journal of Occupational Therapy, and the Australian Journal of Occupational Therapy).

Search strategy: The authors developed a search strategy with appropriate MeSH terms [Table/Fig-1].

Component	MeSH words
Visual perception	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills"
AND	
Technology-based Interventions	"perceptual motor" OR "perception training" OR "computer games" OR "apps" OR "applications" OR "virtual reality" OR "assistive technology" OR "occupational therapy" OR "intervention" OR "early intervention" or "Kephart approach" OR "perceptual motor task" OR "visual perception frame of reference" OR "acquisitional frame of reference"

S. No.	Database query	Results
PUBMED		
1	"computer games" OR "computer intervention" OR "technology based" AND "visual perception" AND "occupational therapy"	47
2	"virtual reality" AND "visual perception" OR "visual perception skills" OR "visual motor integration" OR "visual motor skills" AND "occupational therapy"	76
3	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" AND "occupational therapy" AND "Kephart approach"	0
4	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" AND "occupational therapy" AND "assistive technology"	1
SCOPUS		
5	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" AND "computer games" AND "occupational therapy" AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English"))	52
6	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" AND "virtual reality" AND "occupational therapy" AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "final"))	276
7	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" OR "occupational therapy" or "Kephart approach"	0
8	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" AND "occupational therapy" AND "assistive technology" AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English"))	110
ProQuest		
9	"visual perception" OR "visual perceptual skills" OR "visual motor integration" OR "visual motor skills" AND "sensory intervention" OR "sensorimotor" OR "sensory motor" OR "perceptual motor" OR "sensory integration therapy" OR "perception training" OR "computer games" OR "virtual reality" OR "assistive technology" OR "occupational therapy" OR "intervention" OR "early intervention" or "Kephart approach" OR "perceptual motor task" OR "visual perception frame of reference" OR "acquisitional frame of reference"	4
OTseeker		
10	'visual perception' AND (Any Field) like 'occupational therapy' AND (Any Field) like 'computer games' OR (Any Field) like 'technology based' OR (Any Field) like 'app based'	0
11	'visual perception' AND (Any Field) like 'occupational therapy'	1

[Table/Fig-1]: Search strategy for different database.

Selection Criteria

Inclusion criteria: (1) they targeted technology-based interventions on visual perception and/or visual-motor integration; (2) they focused on children aged 4-12 years; (3) they were published between May 2013 and April 2023; (4) they were available in full text in English; (5) they were 1B, 2B, and 3B (randomised control trial, two-group, case-control, one-group, non randomised control trial) [13].

Exclusion criteria: Studies were excluded if they were Level 1A, 2A, and 3A evidence (Systematic Review and Meta-analysis), Level 4 (Case Report and Case Series), and Level 5 (Expert Opinions) [13].

Procedure

The search results were downloaded with all titles and abstracts from electronic databases in a Microsoft Excel (csv file). Two main authors initially reviewed the titles and abstracts of the articles to determine if they met the predetermined criteria for inclusion. In cases where there were disparities in opinions between the two authors regarding certain articles, or when articles did not align with the inclusion criteria, an independent reviewer reassessed them to validate the decision to exclude them. After the full-text review, the two primary authors independently scored the articles using the revised tool for assessing the risk of bias, Cochrane Database of Systematic Reviews 2016 [14] and quality assessment tool for before-after (pre-post) studies with no control group was employed for intervention studies lacking a control group [15]. In case of any disagreements or inconsistencies between the two authors' scores, all the authors reached a consensus on the final scores. This collaborative process ensured that the review was accurate and reliable.

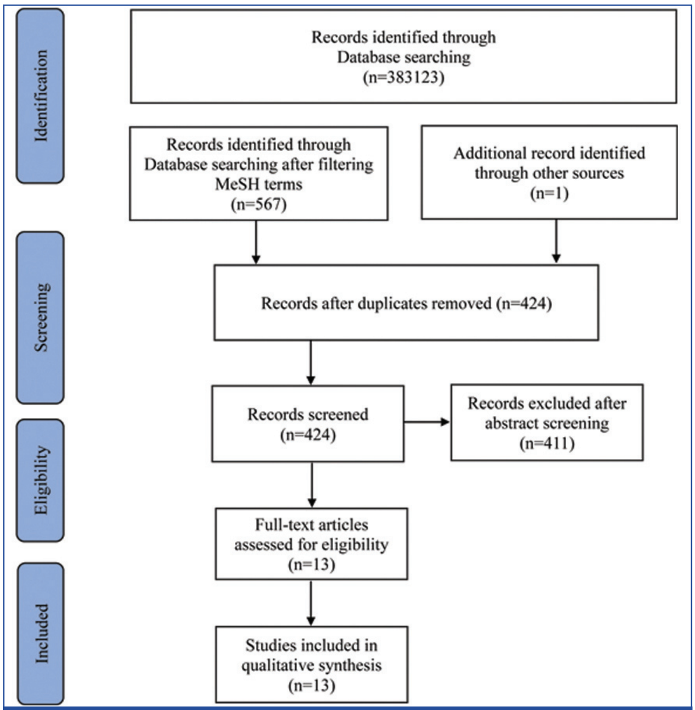
Critical appraisal: The risk of bias assessment was conducted in accordance with the guidelines for systematic review provided by the AOTA. For Randomised Controlled Trials (RCT) and non RCTs, the Cochrane Database of Systematic Reviews from 2016 was utilised [14]. Additionally, the quality assessment tool for before-after (pre-post) studies with no control group was employed for intervention studies lacking a control group [15]. This comprehensive approach ensured a rigorous evaluation of bias across various study designs, enhancing the reliability and validity of the findings. Categories for the risk of bias were as follows: Low-risk of bias (+), unclear risk of bias (?), high-risk of bias (-). Scoring for the overall risk of bias assessment is as follows: 0-3 minuses, low-risk of bias (L); 4-6 minuses, moderate-risk of bias (M); 7-9 minuses, high-risk of bias (H) for RCT and non RCT studies [14]. Scoring for the overall risk of bias assessment is as follows: 0-3 N, low-risk of bias (L); 4-8 N, moderate-risk of bias (M); 9-11 N, High-risk of bias (H) for studies with no control group [15].

Data extraction: Thirteen studies met the selection criteria of the study. The author(s) and year, sample characteristics, outcome measures used, study design, intervention details (experimental, comparator, study setting, duration), and outcomes of the studies were extracted and tabulated.

RESULTS

An electronic database search and a search of printed journals for literature resulted in a total of 567 studies after eliminating duplicates. After abstract screening, 411 studies were excluded. A total of 13 studies were included after the full-text review. The review process is visually represented in [Table/Fig-2] of the PRISMA diagram.

Characteristics of the studies: Within the scope of present systematic review encompassing 13 studies, two studies utilised iPad-based interventions, and the remaining 11 employed computer-based interventions. Furthermore, the reviewed literature encompassed a diverse range of clinical populations, with three studies focusing on children with developmental delays, two on dyslexia, three on cerebral palsy, two on hearing impairment/deafness, and one each on Down syndrome, hydrocephalus, and special needs diagnosis. The majority of the studies (n=10) were employed by occupational therapists, and one study each was employed by a physiotherapist, a special educator, and a multidisciplinary team (occupational therapists, social workers, speech therapists, psychologists, and rehabilitation nurses). Among the 13 studies, five studies specifically focused on visual perceptual skills [5,16-19], three studies focused on visual motor integration



[Table/Fig-2]: PRISMA flow diagram.

skills [20-22], and one study each on visual motor coordination [23], visual perception and cognitive functions [24], visual perception, visual attention, and motor coordination [25], visual perception and upper extremity skills [26], and visual motor integration, visual perception, and motor coordination [27]. [Table/Fig-3] summarises the characteristics of included studies through data extraction. Based on the risk of bias assessment, eight studies demonstrated a low risk of bias [4,16,20-23,25,26], two demonstrated a medium risk of bias [24,18], and three studies demonstrated a high-risk of bias [12,19,27] [Table/Fig-4,5].

Based on Intervention Type

iPad-based interventions: Within the subset of iPad-based interventions, two pivotal studies have significantly contributed to the understanding of their effectiveness [21,25]. While one study focused exclusively on visual motor skills, employing 49 iOS applications to target this specific aspect [21], the other study conducted a comprehensive evaluation of iPad-based interventions encompassing visual motor, visual attention, and visual perception skills [25]. Notably, the latter study exhibited a distinct advantage through its structured representation of applications categorised into beginner, intermediate, and advanced levels. This categorisation was tailored to target various facets of visual skills, including visual attention, visual scanning, visual memory, visual reasoning, figure-ground perception, and specific visual motor skills such as drawing, timing, handwriting, tilt, finger, finger fast, jump-up, and both hands. This nuanced approach adds depth to our understanding of the diverse elements targeted by iPad-based interventions, providing valuable insights into their potential efficacy across multiple dimensions of visual perception and motor integration skills.

Computer-based Interventions

Game-based: One study employed a Computer-based Cognitive Rehabilitation (CBCR) program named CoTras-C [24]. This program

Author(s)/ year	Level of evidence study design risk of bias	Participants inclusion criteria study setting	Intervention and control groups	Outcome measures	Results
Park JH and Park JH (2015) [24]	*Level of evidence* IB	*Participants* N=30 (M age 69.73±8.33 years EG; 71.93±8.07 years CG)	*Intervention* Computer-based Cognitive Rehabilitation (CBCR) using the CoTras-C (30 minutes; 20 sessions, 2 days/week for 10 weeks)	*Visual perception* K-DTVP-2	*Significant findings* Both groups improved significantly (visual perception and cognitive function)
	Study design Randomised control trial	*Inclusion criteria* Children diagnosed with developmental delay by paediatrician or rehabilitation physician; able to follow instructions within three repeated explanations	*Control* Conventional cognitive rehabilitation (30 minutes; 20 sessions, 2 days/week for 10 weeks)	*Cognitive* K-ABC	*Non-significant findings* None
	Risk of bias Medium	*Study setting* Clinic			
Alwhaibi, RM et al., (2020) [27]	*Level of evidence* IB	*Participants* N=54 (5-8 years, 66.7% boys)	*Intervention 1* Physical Therapy Program+Augmented Biofeedback (30+30 minutes; 3 times a week, for 3 months)	*Visual motor integration* Beery VMI 6	*Significant findings* Physical Therapy and Augmented Biofeedback yielded significant findings in VMI, VP and MC
	Study design Randomised control trial	*Inclusion criteria* Spastic hemiplegic cerebral palsy, with no history of seizures or botulinum toxin A treatments and able to understand and follow verbal commands	*Intervention 2* Physical Therapy only (60 minutes; 3 times a week, for 3 months)		*Non-significant findings* Only Physical Therapy and Augmented Biofeedback did not reveal significant scores in VMI, VP and MC
	Risk of bias High	*Study setting* Clinic	*Intervention 3* Augmented Biofeedback only (60 minutes; 3 times a week, for 3 months)		
Ahn SN (2021) [20]	*Level of evidence* 3B	*Participants* N=13 (7-13 years, 66.7% boys)	*Intervention* Conventional therapy along with virtual reality and computer game based cognitive therapy (12 sessions, 40 minutes, once a week)	*Visual perception* DTVP-2	*Significant findings* Post intervention scores revealed a significant score in BOT-2 and DTVP-2 (GVP, MRVP); moderate to strong correlation observed
	Study design Single group Pre-Post Test (Pilot)	*Inclusion criteria* Spastic hemiplegic cerebral palsy, with no history of seizures or botulinum toxin A treatments and able to understand and follow verbal commands	*Control* None	*Motor function* BOT-2	*Non-significant findings* Visual closure (MRVP), VMI did not show significant findings
	Risk of bias Low	*Study setting* Clinic			

Coutinho F et al., (2017) [21]	*Level of evidence* 1B	*Participants* N=20 (4-7.11 years, Mean 6.35 and 6.02 in EG and CG, respectively)	*Intervention* iPad interventions (Two 40 minutes session/week for 10 weeks)	*Visual motor integration* Beery VMI 5 Miller Function and Participation Scale (Visual Motor Subscale)	*Significant findings* M-FUN total raw score yielded significant scores
	Study design Randomised control trial	*Inclusion criteria* Special needs diagnosis, enrolled in academic environment, normal or/ and corrected hearing	*Control* Conventional occupational therapy (Two 40 minutes session/week for 10 weeks)		*Non-significant findings* No significant results in Beery VMI scores nor between interventions
	Risk of bias Low	*Study setting* Rehabilitation Centre			
Köse B et al., (2022) [16]	*Level of evidence* 1B	*Participants* N=138 (7-10 years)	*Intervention 1* Virtual Reality and Game Based Rehabilitation (TGGIP) (45 minutes, twice a week for 8 weeks)	*Visual perception* MVPT-3	*Significant findings* TGGIP significantly improved in VP skills than GIP
	Study design Randomised control trial single blinded	*Inclusion criteria* Specific learning disability diagnosed by child adolescent psychiatrist	*Intervention 2* Virtual Reality and Game Based Rehabilitation (GIP) (45 minutes, twice a week for 8 weeks)		*Non-significant findings* None
	Risk of bias Low	*Study setting* Home			
Chen NY et al., (2013) [5]	*Level of evidence* 1B	*Participants* N=64 (4-6.11 years)	*Intervention 1* Multimedia Visual Perceptual Group Training (40 minute session, once a week for 14 weeks)	*Visual perception* TVPS-3	*Significant findings* All three therapeutic programs produced significant differences between pretest and post-test scores Group>Individual Group>Paper
	Study design True experimental pre post-test double blinded	*Inclusion criteria* Diagnosis of Developmental Disability (DD) by a certified physician or certificate of DD	*Intervention 2* Multimedia Visual Perceptual Individual Training (40 minute session, once a week for 14 weeks)		
	Risk of bias Low	*Study setting* Rehabilitation centre	*Intervention 3* Paper Visual Perceptual Group Training (40 minute session, once a week for 14 weeks)		*Non-significant findings* No significant difference observed in the control group, between group 2 and 3; 3 and control
			Control No Intervention (40 minute session, once a week for 14 weeks)		
Harpster, K et al., (2022) [25]	*Level of evidence* 2B	*Participants* N=14 (6-16 years; 8 females)	*Intervention* iPad games (20 min, 60 min total/day, 4 times a week for 6 weeks)	*Visual perception* WASI-II 9 (Perceptual Reasoning Index) WISC-IV (Processing Speed Subtest) NEPSY-II (Visual Spatial Su btests) Perdue Pegboard	*Significant findings* Significant gains in PRI, WISC-IV (visuo motor coordination) *Non-significant findings* None
	Study design Pilot pre post-test	*Inclusion criteria* Surgically treated hydrocephalus	*Control* None		
	Risk of bias Low	*Study setting* Hospital/Centre			
Wuang YP et al., (2021) [17]	*Level of evidence* 3B	*Participants* N=60 (6-10 years, M age 7.96±1.4)	*Intervention* Kinesthetic Game Based Training System (Two 30 minute sessions per week over 8 week period)	*Visual perception* TVPS-3	*Significant findings* KBTS and TVPT differed significantly on VMI and most TVPS-3 tests (except form constancy and sequential memory); VABS-C and SFA-C (except school participation and socialisation domain)
	Study design Pre post-test experimental design	*Inclusion criteria* Impaired or delayed development of visual perception, ability to follow and comprehend simple instructions		*Visual motor integration* Beery VMI 6 *Adaptive behaviour* VABS-C	
	Risk of bias High	*Study setting* Centre	*Control* Traditional Visual Perceptual Training Program (Two 30 minute sessions per week over 8 week period)	*School function* SFA-C	*Non-significant findings* None
Nejad ZNT et al., (2019) [23]	*Level of evidence* 3B	*Participants* N=16 (M age EG 7.10 years and CG 7.9 years)	*Intervention* SHOFER computer games (driving/ racing genre) (45 minute session per week for 5 weeks)	*Visual perception* Frostig Test Continuous Performance Test	*Significant findings* Computer game increased attention and spatial perception in the experimental group.
	Study design Pre post-test experimental design	*Inclusion criteria* Hearing impaired children	*Control* None		*Non-significant findings* No significant difference was found between the groups, except in the subtest of figure-ground perception
	Risk of bias Low	*Study setting* Centre			
Sajan JE et al., (2017) [26]	*Level of evidence* 2B	*Participants* N=20 (M age EG 10.6±3.78 years and CG 12.4±4.93 years)	*Intervention* Conventional rehab program+Wii games (18 sessions, 45 minutes each, for 3 weeks)	*Upper extremity measures* Static Posturography PBS QUEST BBT	*Significant findings* The experimental group improved in upper extremity functions
	Study design Pilot RCT (Assessor Blinded)	*Inclusion criteria* Diagnosis of Cerebral Palsy undergoing care in tertiary care and teaching hospital	*Control* Conventional rehab program (36 hours/week)	*Visual perception* TVPS-3	*Non-significant findings* The control group did not differ significantly in upper extremity functions Improvements in balance, visual perception, functional mobility did not differ between both groups
	Risk of bias Low	*Study setting* Hospital		*Ambulation* Functional ambulation	

Wan YT et al., (2017) [18]	*Level of evidence* 2B	*Participants* N=76 (6-21 years; M age 13.17±4.35)	*Intervention 1* Computerised Visual Perception Training for typically developing children	*Visual perception* TVPS-3	*Significant findings* Down Syndrome intervention group had significant improvements on TVPS-3 after intervention. The fMRI results indicated more activation in superior and inferior parietal lobes (spatial manipulation), as well as precentral gyrus and dorsal premotor cortex (motor imagery) in Down Syndrome intervention group
	Study design Experimental pre post-test design	*Inclusion criteria* Down Syndrome; IQ 55-70; w/o serious behavioral and emotional disturbances	*Intervention 2* Computerised Visual Perception Training for Down Syndrome (60 minutes, once a week for 1 year)	*Imaging* functional Magnetic Resonance Imaging (fMRI)	
	Risk of bias Medium	*Study setting* Centre	*Control* No intervention		*Non-significant findings* No significant difference was found either in CRR of FPMT or in Reaction Time of two fMRI tasks between pretest and posttest
Radovanovic V (2013) [22]	*Level of evidence* 3B	*Participants* N=70 (7-10 years; 60% of boys)	*Intervention* Computer Games (15 minutes, once a week, for 5 months)	*Visual perception* acadia test: visual-motor coordination, possibility-of-sequence test	*Significant findings* Significant difference in experimental and control groups, but only in 7-year-olds
	Study design Experimental pre post-test design	*Inclusion criteria* 70 profoundly deaf students (≤81 dB in the better ear)	*Control* None		*Non-significant findings* None
	Risk of bias Low	*Study setting* School			
Gibert C et al., (2022) [19]	*Level of evidence* 3B	*Participants* N=39 (9 years; 50% of boys)	*Intervention 1* MoveR Immersive Rehabilitation Therapy (30 min per day for 5/7 days per week for 2 weeks)	*Visual perception* TVPS-4	*Significant findings* Intervention 1 improved significantly higher than 2
	Study design Experimental pre post-test design	*Inclusion criteria* Children diagnosed with dyslexia with normal vision and IQ 85-115			*Non-significant findings* None
	Risk of bias High	*Study setting* -	*Intervention 2* Visual training (30 min per day for 5/7 days per week for 2 weeks)		

[Table/Fig-3]: Characteristics of included studies [5,16-27].
EG: Experimental group; CG: Control group; K-DTVP: Korean-developmental test of visual perception; K-ABC: Kaufman assessment battery for children; Beery VMI: Beery buktenica developmental test of visual motor integration; VMI: Visual motor integration; VP: Visual perception; MC: Motor coordination; DTVP: Developmental test of visual perception; BOT-2: Bruininks-Oseretsky test of motor proficiency-second edition; GVP: Global visual perception; MRVP: Motor reduced visual perception; M-FUN: Miller function and participation scales; TGGIP: Therapist guided game based intervention program; GIP: Game based intervention program; TVPS-3: WISC-IV: Weschler intelligence scale for children IV, test of visual perception skills-third edition; WASI-II: Weschler abbreviated scale intelligence-II; NEPSY-II: Developmental neuropsychological assessment-second edition; VABS-C: Vineland adaptive behavior scale-children; SFA-C: School function assessment-children; PBS: Paediatric Berg's balance scale; BBT: Box and block test; QUEST: Quality of upper extremity skills test; IQ: Intelligence quotient; FPMT: Full picture matching test; CRR: Correct response rate

	Selection bias			Performance bias		Detection bias		Attribution bias	Reporting bias	
Citation	Random sequence generation	Allocation concealment	Baseline differences between intervention groups	Blinding of participants during the trial	Blinding of study personnel during the trial	Blinding of outcome assessment: self-reported outcomes	Blinding of outcome assessment: objective outcomes	Incomplete outcome data	Selective reporting	Overall risk-of-bias assessment
Park JH and Park JH (2015) [24]	-	?	-	-	+	?	+	+	+	M
Alwhaibi RM et al., (2020) [27]	-	?	_	-	-	-	-	+	+	H
Coutinho F et al., (2017) [21]	+	?	+	-	+	?	-	+	+	L
Köse B et al., (2022) [16]	+	+	+	-	_	?	+	+	+	L
Chen NY et al., (2013) [4]	+	?	+	+	+	+	+	+	?	L
Wuang YP et al., (2021) [17]	-	?	-	-	-	-	-	+	+	H
Sajan JE et al., (2017) [26]	+	+	+	-	+	+	+	+	+	L
Wan YT et al., (2017) [18]	-	?	-	+	-	+	_	+	+	M
Gibert C et al., (2022) [19]	-	?	-	-	-	-	-	+	+	H

[Table/Fig-4]: Risk-of-bias table: Randomised Controlled Trial (RCT) and non RCT with control group.

targeted visual perception skills, including spatial relations, spatial memory, concentration, eye-hand coordination, eye movement, and figure-ground perception in their intervention. Another study utilised six games in conjunction with biofeedback and physical therapy to improve visual motor integration skills [27]. The study utilised Wii Console VR video games along with the CoTras program for spatial

Citation	Study question or objective clear	Eligibility or selection criteria clearly described	Participants representative of real-world patients	All eligible participants enrolled	Sample size appropriate for confidence in findings	Intervention clearly described and delivered consistently	Outcome measures are prespecified, defined, valid/ reliable, and assessed consistently	Assessors blinded to participant exposure to the intervention	Loss to follow-up after baseline 20% or less	Statistical methods examine changes in outcome measures from before to after intervention	Outcome measures were collected multiple times before and after the intervention	Overall risk of bias assessment (low, moderate, high-risk)
Ahn SN (2021) [20]	Y	Y	Y	Y	Y	Y	Y	NR	N	Y	NR	1 (Low ROB)
Harpster K et al., (2022) [25]	Y	Y	Y	Y	Y	Y	Y	NR	N	Y	NR	1 (Low ROB)
Nejad ZNT et al., (2019) [23]	Y	Y	Y	Y	Y	Y	Y	NR	N	Y	NR	1 (Low ROB)
Radovanovic V (2013) [22]	Y	Y	Y	Y	Y	Y	Y	NR	N	Y	NR	1 (Low ROB)

[Table/Fig-5]: Risk of bias table for before-after (pre-post) studies with no control group.

relations, spatial memory, concentration, eye-hand coordination, eye movement, and figure-ground perception, and conventional therapy [20]. The study concentrated on employing virtual reality and game-based rehabilitation using the mobile game "Brawl Stars," both with therapist-guided and unguided interventions on visual perception skills [16]. The study focused on the application of Augmented Reality (AR), which used a Kinesthetic Game-based training system to improve visual perceptual dysfunction [17]. The study incorporated the use of SHOFER computer games for visual-motor coordination [23]. The study used Wii games (tennis and boxing) to improve visual perception and other skills (upper extremity skills and ambulation) [26]. The study used 15 online games that focused on visual motor integration skills [22]. The study used MoveR training as an immersive therapy to reinforce visual discrimination, visual attention, saccadic/vergence system, and spatial orientation catered through four different exercises: (i) Read in Motion; (ii) Battlerace; (iii) Jump in Words; (iv) Vergence movements [19].

Software-based

Study emphasised the usage of multimedia group therapy visual perception interventions in basic and advanced training using Microsoft Office 2007 PowerPoint software [5]. Study also incorporated a CVPT program using computerised Microsoft Paint software, computerised puzzle software, and computerised memory software [18].

Based on the Clinical Population

Cerebral palsy: Individuals with cerebral palsy have impairments in visual-motor integration, which in turn affects their ability to coordinate motor, visual perceptual, and visual skills effectively in functional activities. Three studies focused on interventions for children with cerebral palsy, among which studies specifically targeted the spastic hemiplegic type [20,27]. Another study conducted on the efficacy of Wii-based interactive video games as an adjunct to occupational therapy in children with cerebral palsy [26], however, no specific data is available on the type of cerebral palsy. Overall, it is evident that children with hemiplegic cerebral palsy demonstrate visual perception impairment ranging from 5-15% [28]. The results of these three studies conclude a positive efficacy of incorporating technology-based interventions in this population.

Learning disability: Two studies on children with learning disabilities [16,19] were conducted. One study incorporated the use of wearing 3D glasses along with immersive rehabilitative therapy that included four scenarios (Read in Motion, Battlerace, Jump in Words, and Vergence Movements) supervised by the therapist [16]. The other study incorporated the use of virtual reality along with game rehabilitation, with and without therapist guidance [19]. While both studies yielded positive results, the groups supervised by the therapists improved significantly greater improvement compared to the other group.

Hearing impairment: One study incorporated the use of SHOFER computer games that included racing and driving games [26]. These games have been reported to impact visual motor skills [29]. Research conducted to assess the impact of these games on different facets of health indicates that utilising them as engaging therapeutic activities leverages their motivational features [30]. Another study [22] also incorporated the use of online computer games to improve visual-motor integration. Both studies concluded a positive result on the administration of computer games in children with hearing impairments; severe to deep and profound [22].

Developmental delays: A study incorporated the use of a CBCR intervention and compared it with conventional cognitive intervention for visual perception and other cognitive domains [24]. A study previously conducted concluded that CBCR positively improves visual perception and cognitive functions [31]. Additionally, utilising a computer program contributes to the cognitive development of children by aiding their intellectual capacity, improving curiosity, and enabling creative thinking [32]. Another study utilised the application of Kinect Game-based Training System (KBTS) and compared it with Traditional Visual Perception Training (TVPT) [17].

Down syndrome: Only one study evaluated the effectiveness of visual perception interventions in children with Down syndrome who have mild intellectual disabilities through a CVPT program. This study highlighted an in-depth understanding of the neuroanatomical correlation of visual perception in Down syndrome. Children with Down syndrome significantly lacked in the dorsal and ventral stream processing, especially in the areas of the superior parietal lobe and precuneus [18].

Hydrocephalus: Only one study evaluated the effectiveness of iPad interventions on children with surgically treated hydrocephalus [25]. This element of visual perception is crucial in this population, as individuals with hydrocephalus (SBH) often encounter impaired upper limb function from childhood through young adulthood, impacting their ability to execute visually guided hand and arm movements, such as drawing. Children with SBH, especially those with higher spinal cord lesions, confront restricted mobility and limited opportunities for visual spatial and visuomotor learning. Additionally, many SBH children experience eye movement disorders linked to deficient nonverbal and visual perceptual skills. Those with higher lesions may face frequent hospitalisations for medical complications during crucial developmental periods, potentially impeding their visual perceptual development [33].

DISCUSSION

The systematic review focused on enhancing visual perception in children aged 4 to 12 years through a comprehensive analysis of technology-based interventions. The inclusion of studies within this specific age range underscores the critical developmental period when visual perception skills are foundational for various cognitive and motor functions.

Several key findings emerged from the review, highlighting the diversity of technology-based interventions and their impact on visual perception in children. The selected studies covered a broad spectrum of technological tools, including virtual reality, immersive training programs, augmented biofeedback, and interactive applications.

These interventions demonstrated the potential to address visual perception challenges across different conditions, such as cerebral palsy, hydrocephalus, developmental delays, learning disabilities, down syndrome, intellectual disabilities, and hearing impairments. The most commonly used measure for visual perception was the Test of Visual Perception Skills [5,17-19,26] (third and fourth version) and the Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery VMI) [12,17,21] (fifth and sixth version) for assessing visual-motor integration skills.

One notable aspect of the review was the varying durations of interventions across studies. While the majority of interventions were of shorter durations, a distinctive observation was made in one study [18] that extended its intervention over a year. This aspect prompts further exploration into the long-term effects and sustained benefits of technology-based interventions on visual perception skills in children. The review also shed light on the advantages of technology-based interventions, emphasising their capacity to provide immediate, predictable, and repeatable responses [34]. Moreover, the interventions offered a controlled and pressure-free environment, which is particularly beneficial for children who may face challenges in real-world scenarios [35,36].

The exploration of 13 studies, the prevalent efficacy of technology-based interventions, their application, and implementation in India appear to be notably limited. The utilisation of imaging measures, specifically functional Magnetic Resonance Imaging (fMRI), was notably limited, with only one study [18] incorporating this technology. fMRI results indicated more activation in the superior and inferior parietal lobes (spatial manipulation), as well as the precentral gyrus and dorsal premotor cortex (motor imagery) [18]. To enhance intervention effectiveness, there is a pressing need for future studies to incorporate a broader range of imaging measures. Integrating advanced imaging techniques can offer deeper insights into the neural mechanisms underlying the effects of interventions. This expansion in imaging measures can contribute to refining and optimising interventions based on a more nuanced comprehension of the neural processes involved.

Limitation(s)

Firstly, only studies published in English were included in the systematic review. Secondly, study only incorporated four databases. Thirdly, study focused on different diagnostic populations.

Clinical Implications and Future Recommendations

Occupational therapists can leverage insights from the review to tailor intervention strategies, selecting approaches based on the specific needs and conditions of children with diverse visual perception challenges. Moreover, acknowledging the interdisciplinary nature of visual perception, collaboration with professionals from neurology and technology specialties can contribute to a holistic understanding, informing comprehensive intervention plans. While cultural nuances may not be explicitly addressed, therapists are encouraged to be mindful of cultural factors influencing the acceptance of technology-based interventions, allowing for tailored and culturally sensitive approaches. This systematic review equips occupational therapists with valuable insights to optimise their practice using technology, fostering effective visual perception development in a diverse paediatric population. Further research is needed to establish which technology components are most important in improving a child's visual perception and visual motor integration skills, as well as to explore various means to increase consistency of participation and accuracy of the evaluation. Moreover, the dearth of research in specific cultural contexts warrants future investigations to establish the sustained effectiveness and cultural relevance of technology-based interventions for enhancing visual perception in children.

CONCLUSION(S)

In conclusion, the systematic review reveals a consistently positive trend. The findings underscore the efficacy of technology as a valuable tool in promoting visual perception and visual motor integration skills among the age group of 4 to 12 years. Furthermore, the review highlights additional benefits stemming from technology interventions, suggesting a broader impact beyond the targeted outcomes. This positive correlation between technology-based interventions and enhanced visual perception reflects a shifting trend towards embracing the virtual world as a constructive and beneficial platform for child development.

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