Journal of Associated Medical Sciences 2025; 58(1): 245-259

JAMS
Journal of Associated Medical Sciences

Scopus Indexed & Thai-Journal Citation Index Centre (TCI)

Journal of Associated Medical Sciences

Journal homepage: https://www.tci-thaijo.org/index.php/bulletinAMS/index

Understanding visual perception skills in autism spectrum disorder: A systematic review

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ARTICLE INFO

Article history:
Received 18 July 2024
Accepted as revised 4 December 2024
Available online 13 December 2024

Keywords:
Visual perceptual skills, autism, perceptual bias, visual processing.

ABSTRACT

Background: Visual perception in individuals with autism spectrum disorder (ASD) can vary, often showcasing both strengths and challenges. Many individuals with ASD excel in detail-oriented processing, allowing them to focus on fine details rather than the overall picture, which can be advantageous in tasks requiring attention to small details, such as visual search and pattern recognition. Understanding these unique aspects of visual perception in ASD is crucial for developing tailored interventions and support strategies to enhance visual processing abilities and overall social functioning.

Objective: To understand the visual perception skills in autism spectrum disorder.

Materials and methods: The systematic review was registered in PROSPERO and followed the guidelines of PRISMA. A comprehensive search was conducted through the databases (Scopus, PubMed, ProQuest, EBSCOhost, and OTseeker) and printed journals. Studies were included if they focused on visual perception skills in children with autism aged 3-12 years, were peer-reviewed, published between January 2014 and February 2024, and were available in full-text in English. The AXIS Tool for Cross Sectional Studies was used to conduct the critical appraisal.

Results: 19141 studies were derived for database search and 932 from printed journals. A total of sixteen (N=16) studies were identified within the scope of our study. AXIS Tool for Cross-sectional studies was used to evaluate the quality of the sixteen studies. Visual perception skills in ASD have yielded diverse findings, such as perceptual bias, enhanced visual processing, enhanced visual search, and differences in visual processing speed. The review suggested that visual perception impairments are commonly seen in ASD, impacting their functional independence. The review also highlights the importance of understanding the basis of visual perception impairments in this population.

Conclusion: The systematic review concludes that visual perception deficits are one of the primary deficits in autism spectrum disorder. Furthermore, the review reflects on the complex and diverse nature of visual perception skills exhibited by individuals with autism spectrum disorder. These deficits impact overall performance in everyday functioning, especially self-care, academics, and socialization.

Introduction

Autism Spectrum Disorder (ASD) is a pervasive neuro-developmental disorder characterized by persistent deficits in communication and social interaction and restricted, repetitive patterns of behavior, interests, or activities.[1,2] Visual perception is the brain's ability to receive, process, and interpret visual sensory information a person receives through their eyes.[3] Visual perception is broadly categorized into visual receptive and visual cognitive functions. The visual cognitive component

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doi: 10.12982/JAMS.2025.027
E-ISSN: 2539-6056

comprises visual discrimination, a key component of visual cognitive function that can significantly impact an individual's ability to engage in daily activities.[4] Visual discrimination encompasses objective perception, which involves recognizing specific details of objects, and spatial perception, which refers to understanding the spatial relationship between objects and oneself. Individuals with poor visual closure may struggle to identify objects or symbols when parts are missing, leading to difficulties in tasks such as reading and assembling puzzles.[4] A lack of depth perception impairs the ability to judge distances, causing challenges in navigating stairs, playing sports, or reaching for objects. Furthermore, deficits in topographical orientation hinder the ability to navigate environments or follow spatial directions, affecting independence in both familiar and unfamiliar settings.[5] A child might have normal vision yet show deficits in visual perception, impacting functional independence[6]. Visual perception helps an individual to engage in daily occupations.[7] For example, activities of daily living (difficulty in putting on shoes/clothes or tying laces, difficulty in using tools), academics (difficulty in reading, writing, and mathematics, difficulty in completing exams on time), play (difficulty in fitting puzzles or parts of toys, difficulty working with block games), and social (negative impact on self-esteem, self-identity). Visual perception develops as the child matures, with most developmental changes taking place and stabilizes by 9 years of age (figure-ground perception by 6-7 years, form constancy by 8-9 years, position in space by 7-9 years, and spatial relationships by 10 years).[7]

Abnormal visual perception is listed as a primary symptom among the behavioral markers observed in early clinical practice of ASD.[8] The major presentations of abnormal visual perception are visual avoidance, visual exploration, and visual-spatial disorientation.[9]

Children with ASD face difficulties in utilizing visual perception effectively,[8,9] and exhibit distinct patterns of visual perception compared to those without ASD.[10] Typically, children with ASD concentrate on intricate details, referred to as local structure, while struggling with processing broader, global structures such as the overall picture. Additionally, they often find it challenging to filter out irrelevant visual stimuli in their environment.[11,12] They demonstrate difficulties in performing daily tasks requiring various visual perception functions such as visual figure-ground, visual form constancy, and visual sequencing memory abilities.[13]

Studies have proposed that heightened perceptual abilities, preferences for processing local details, and intense states of focus are connected conceptually to the restricted and repetitive behavior (RRB) symptoms, particularly selective interests and resistance to shifting attention.[14,15] Visual perception in ASD is also linked to sensory sensitivity. Some individuals with ASD may experience heightened sensitivity to visual stimuli, leading to sensory overload or difficulties processing visual information in complex environments.[16] Abnormal visual perception in ASD impacts their school performance (handwriting, reading, fixation with objects, and maintaining eye contact) and social participation. Abnormal visual perception in children with ASD has a significant impact on various aspects of their daily functioning. Studies have shown that deficits in visual perception, such as difficulties with visual discrimination, figure-ground perception, and visual memory, can hinder essential skills like self-care, social interaction, and academic performance.[17] Poor visual perception abilities are also linked to challenges in processing facial recognition and understanding social cues, which can further exacerbate social communication difficulties in children with ASD.[18] Additionally, impaired motion processing, as part of abnormal visual perception, can affect how children navigate their environment and interact with moving objects, impacting their ability to perform daily tasks.[19] These deficits, when unaddressed, contribute to the broader functional limitations observed in children with autism.[20]

Occupational therapy (OT) professionals play a crucial role in improving visual perception deficits in children with ASD, which can impact their ability to perform daily tasks, including reading, writing, and engaging in social interactions.[21] Occupational therapists use evidence-based interventions, such as visual-motor integration activities, sensory integration therapy, and environmental modifications, to enhance the child's ability to process visual information. These interventions target core visual perception skills like figure-ground discrimination, spatial relations, and visual-motor coordination, essential for tasks like copying shapes, identifying objects, and navigating spaces. Through structured therapy sessions, children are supported in developing these skills in a way that promotes greater independence and participation in daily life activities.[21]

OT interventions can significantly improve visual perception abilities in children with ASD, leading to better functional outcomes. For example, a study[21] demonstrated that sensory-based occupational therapy, including activities designed to enhance visual processing, improved attention, behavior, and task performance in children with ASD. Another study emphasized the benefits of occupational therapy interventions incorporating sensory integration techniques, noting improvements in visual-motor skills and overall functional performance.[22] Both studies underscore the effectiveness of OT interventions in improving functional outcomes in children with ASD, particularly in enhancing visual processing and behavior. The previous study examined the role of sensory-based occupational therapy in improving classroom behaviors and educational outcomes.[21] The study demonstrated that children who received sensory-based OT interventions improved attention, emotional regulation, and task performance in classroom settings, with enhanced visual processing playing a pivotal role in these outcomes. Similarly, the latter focused on the efficacy of the Get Ready to Learn yoga program, a sensory integration-based OT intervention and found improvements in visual-motor skills, behavior, and overall task performance.[22] In both studies, the interventions led to better engagement,

attention, and functional performance, supporting that OT interventions targeting sensory and visual processing deficits can yield positive functional outcomes for children with ASD.

This unique nature of visual perception skills exhibited by children with ASD highlights the need for a thorough systematic review. Understanding these nuances is crucial for developing targeted interventions and support strategies that address the specific visual perceptual needs of individuals with ASD.

This systematic review aims to understand the visual perception skills in autism spectrum disorder.

The scope of this review was to systematically analyze studies focusing on visual perception skills in children with autism spectrum disorder (ASD) aged 3-12 years. It aimed to explore strengths and deficits in visual perception across various domains, such as visual memory, discrimination, and spatial relationships, and examine how these skills impact functional areas like self-care, socialization, and academic performance. The review also assessed the methodologies used in these studies, including standardized and non-standardized assessments, while identifying gaps for future research, particularly in dynamic visual perception.

Materials and methods

This systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was registered in PROSPERO with the ID CRD42024547616. PROSPERO is an international database of prospectively registered systematic reviews in health and social care, welfare, public health, education, crime, justice, and global development, where there is a health-related outcome. It aims to provide a comprehensive listing of systematic reviews registered at inception to help avoid duplication. The Center produces it for Reviews and Dissemination, University of York, York, United Kingdom, and funded by the National Institute for Health Research (NIHR).

Search procedure

A comprehensive search of studies was conducted using electronic databases, namely, Scopus, PubMed, ProQuest, EBSCOhost, and OTseeker. Additionally, studies were also searched from printed journals [American Journal of Occupational Therapy (AJOT), British Journal of Occupational Therapy (BJOT), Canadian Journal of Occupational Therapy (CJOT), Indian Journal of Occupational Therapy (IJOT), and Journal of Autism and Developmental Disabilities (JADD)].

Search strategy

The search strategy used MeSH terms and "OR" and "AND" Boolean operations.

MeSH terms	Search strategy
Visual perception	"visual perception" OR "visual perceptual" OR "vision" OR "visual perception skills" OR "visual perceptual skills" OR "visual processing" OR "global local processing" OR "visual discrimination" OR "visual motion perception" OR "visual figure ground" OR "visual form constancy" OR "visual search" OR "visual motor integration" OR "visual attention" OR "visual memory" OR "visual spatial relationships"
AND	
autism	"autism" OR "autism spectrum disorder" OR "autistic disorder" OR "aspergers syndrome" OR "pervasive developmental disorder"

Database/Journal	Database query
ProQuest AJOT BJOT CJOT JADD OTseeker IJOT	"visual perception" OR "visual perceptual" OR "vision" OR "visual perception skills" OR "visual perceptual skills" OR "visual processing" OR "global local processing" OR "visual discrimination" OR "visual motion perception" OR "visual figure ground" OR "visual form constancy" OR "visual search" OR "visual motor integration" OR "visual attention" OR "visual memory" OR "visual spatial relationships" AND "autism" OR "autism spectrum disorder" OR "autistic disorder" OR "aspergers syndrome" OR "pervasive developmental disorder"
PubMed	"visual perception" OR "visual perceptual" OR "vision" OR "visual perception skills" OR "visual perceptual skills" OR "visual processing" OR "global local processing" OR "visual discrimination" OR "visual motion perception" OR "visual figure ground" - Search Results - PubMed (nih.gov)
Scopus	"visual perception" OR "visual perceptual" OR "vision" OR "visual perception skills" OR "visual perceptual skills" OR "visual processing" OR "global local processing" OR "visual discrimination" OR "visual motion perception" OR "visual figure ground" OR "visual form constancy" OR "visual search" OR "visual motor integration" OR "visual attention" OR "visual memory" OR "visual spatial relationships" AND "autism" OR "autism spectrum disorder" OR "autistic disorder" OR "aspergers syndrome" OR "pervasive developmental disorder" AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA, "PSYC") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "HEAL") OR LIMIT-TO (SUBJAREA, "MULT") AND LIMIT-TO (DOCTYPE , "ar") AND LIMIT-TO (LANGUAGE, "English") AND LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p") AND LIMIT-TO (PUBSTAGE, "final") AND LIMIT-TO (OA , "all")

Data extraction and data analysis

The search results were downloaded with all titles and abstracts from electronic databases in Microsoft Excel (CSV file). Two principal authors initially reviewed the titles and focused on the initial screening of the articles based on the search strategy derived. Following the title screening, abstracts of the articles were read and screened thoroughly to determine if they met the criteria for inclusion. In cases where there were disparities in opinions between the two authors regarding particular articles or when articles did not align with the inclusion criteria, an independent reviewer re-assessed them to validate the decision to exclude them. Disagreements between reviewers in selecting studies were typically resolved through a consensus process. When reviewers encountered discrepancies in study inclusion or exclusion, they engaged in discussions to review the criteria and the reasons for their differing opinions. If consensus could not be reached through discussion, an independent reviewer was often consulted to make a final decision based on the established inclusion criteria. This process ensured that the review remained rigorous and that all decisions were based on a thorough evaluation of the evidence. After the full-text review, the two primary authors independently scored the articles using the AXIS (Appraisal tool for Cross-Sectional Studies).[23] In case of disagreements or inconsistencies between the two authors' scores, all the authors reached a consensus on the final scores.

The AXIS (Appraisal Tool for Cross-Sectional Studies). Tool, comprising 20 elements with three possible answers (Yes, No, and Don't Know), was utilized to evaluate the risk of bias.[23] Two authors independently assessed the included studies' quality, resolving disagreements through consensus.

This collaborative process ensured that the review was accurate and reliable. Data was extracted based on the demographic characteristics and measures used to assess visual perception and visual perception profile of children with autism.

Inclusion and exclusion criteria

Studies were included if (1) they focused on visual perception skills in autism; (2) on children aged 3-12 years; (3) they were published between the years January 2014 and February 2024; (4) they were available in English; (5) peer-reviewed studies; (6) available in full-text. Systematic reviews, meta-analyses, case series, case reports, and expert opinions were excluded from the study.

Results

A total of 20073 records were identified through search, among which 19141 were screened through database screening and 932 records through journal search. 19813 records were identified after removing duplicates (N=260), and 19813 were screened for title and abstract screening. Thirty-one studies were included after title screening, and twenty were included after abstract screening. Studies were excluded as they did not focus on the age group selected for the present review, did not focus on children with autism, non-original articles (reviews, commercials, editorials, and opinions), and if the study was not available in the English language. A total of sixteen (N=16) studies were included for full-text review based on the scope of the current study. Figure 1 depicts the flowchart of the records screening process. Table 1 describes the detailed outline of records screened through database and journal screening. Table 2 illustrates the visual perception profile of ASD based on the included studies.

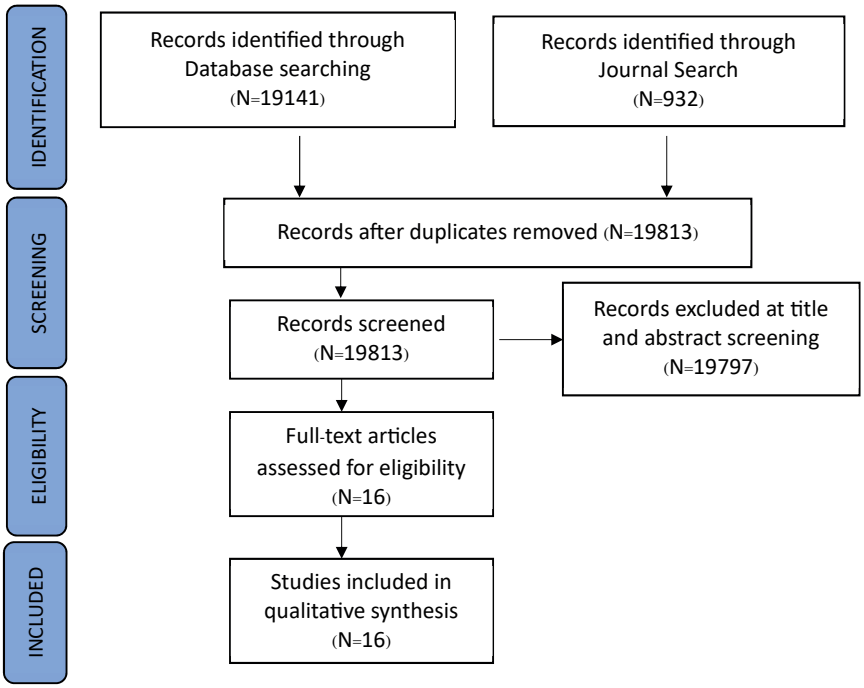

Figure 1. *PRISMA flow diagram.*

Table 1. Screening of records obtained from database and journal screening.

Database/journals	Total search	On title screening	On abstract screening	On full-text screening
Database screening				
ProQuest	3216	5	2	2
PubMed	928	8	8	8
Scopus	14318	12	10	6
OTseeker	286	0	0	0
EBSCOhost	393	0	0	0
Journal screening				
IJOT	9	0	0	0
AJOT	296	2	0	0
JADD	321	4	0	0
BJOT	190	0	0	0
CJOT	116	0	0	0

Table 2. Visual perception skills in ASD.

Year/Author	Level of evidence	Research design	Study purpose	Study participants(sample size, selection criteria, ASD screening)	Visual perception assessment	Result summary
Vetrayan J *et al.*[29]	IV	Cross sectional study	To investigate the significant relationship between visual perception and imitation in school functioning among children with ASD.	N=20, 4-9.6 years school going, diagnosed on DSM IV and CARS, have sufficient cognition skills to follow simple commands and instructions during tests, IQ on mild to moderate level on Stanford Binet Intelligence Scale	DTVP-2	The result revealed that school function of autistic children has a significant relationship with their visual perception and imitation performance. Especially the Motor-reduced Visual Perception subtest, unstructured gesture & object imitation
Hallen RV *et al.*[27]	IV	Cross sectional study	To study two visual search paradigms featuring Gaborized stimuli to evaluate the effects of task distractors and task instructions on local-global visual processing in children with ASD and TDC.	Expt. 1: 6-10 years, Dutch-speaking children, with normal or corrected-to-normal vision, N=21 diagnosed with ASD on DSM-IV-TR and ADOS-2 Expt. 2: 8-14 years, Dutch-speaking children, with normal or corrected-to-normal vision, N=26 diagnosed with ASD on DSM-IV-TR	Visual search tasks (Gaborized stimuli and local-global visual processing)	ASD did not show improved performance for the visual search tasks. Furthermore, no significant differences in their sensitivity to local versus global aspects of visual stimuli were observed.
Brown A C & Crewther DP [39]	IV	Cross sectional study	To address the inspection times (ITs) for novel global/local stimuli and recording nonlinear visually evoked potentials, specifically focusing on the magnocellular and parvocellular temporal efficiencies.	N=11, 7-11 years, male ASD recruited from primary school, diagnosed on DSM IV	Inspection time test	ASD exhibited Slower inspection time
Cherenkova L V *et al.*[38]	IV	Cross sectional study	To compare the role of various levels of magno-parvocellular channels in processing visual information and their influence on the development of cognitive and speech processes in children with typical and atypical development.	N=58 (N=19 ASD diagnosed on CARS), children pre-school department of primary school-kindergarten, right-handed, no problems with vision and hearing	Task for contrast sensitivity, global motion threshold	Deficit of global motion thresholds based on stationary object orientation was found only in ASD cases; manifestation of such deficit depended on the autistic disorder severity. In mild ASD cases, figure recognition time increased only with increasing number of locations of targets among demonstrated figures. Children with severe ASD demonstrated constant increase in detection time.

Table 2. Visual perception skills in ASD (continued).

Year/Author	**Level of evidence**	**Research design**	**Study purpose**	**Study participants**(sample size, selection criteria, ASD screening)	**Visual perception assessment**	**Result summary**
DiCriscio A S and Troiani V [30]	IV	Cross sectional study	To examine the relationship between individual differences in visual processing skills and quantitative measures of autism traits exhibiting a range of clinical features.	N=54, 5-16 years Diagnosed with autism traits, with an IQ of ≥ 69	TVPS-3	BAPQ significantly predicted figure ground subtest Linear relationship exists between figure ground and autism traits.
Jobs E N *et al.* [34]	IV	Cross sectional study	To assess Local and Global Visual Processing in 3-Year-Olds with and without ASD	N=49, 3 years old Diagnosed on DSM 5 criteria, ADOS 2, ADI-R, VABS-II, parental checklist	*Local Measures:* Children's Embedded Figures Test, Figure Ground Task, Hidden Pictures *Global Measures:* The Fragmented Picture Test, Gestalt Closure	Enhanced performance on the local task Hidden Pictures differentiated children with ASD from the other groups.
Gunal A *et al.* [25]	IV	Cross sectional study	To compare the motor and cognitive skills of children with autism to those of their typically developing peers, as well as to examine how motor and cognitive difficulties impact daily living activities and the quality of life of these children.	N=30 TDC and N=32, aged 6-12 years, diagnosed with autism on DSM-IV-TR, attending a special school, with IQ >70	LOTCA (Subtests: Orientation, Perception, Visual Perception, Thinking operations)	Children with ASD obtained lower scores than TD in perception, and visual perception domain, these deficits were further correlated with self-care and social functions.
Guy J *et al.* [28]	IV	Cross sectional study	To explore how global and local processes vary with age, while not explicitly separating the effects of interference in ASD	N=83 (N=39 ASD and N=41 TDC), diagnosed as ASD on ADOS and/or ADI-R, DSM IV (only individuals diagnosed as autistic disorder (not Asperger's), 6 -16 years	Navon task	Children and adolescents with ASD exhibit slower responses to global information compared to TD peers when there is no interference. However, when interference is present, individuals with ASD tend to show a more significant impact of local information on global processing. The reaction time trajectories in global and local conditions were compared between both groups.

Table 2. Visual perception skills in ASD (continued).

Year/Author	Level of evidence	Research design	Study purpose	Study participants(sample size, selection criteria, ASD screening)	Visual perception assessment	Result summary
Rose S A *et al.* [37]	IV	Cross sectional study	To explore selective attention in Rett syndrome, a profoundly disabling neurodevelopmental disorder resulting from mutations in the X-linked MECP2 gene.	N=28 females with Rett syndrome and N=32 age-matched typically developing children, 2-12 years Diagnosed on the Rett Syndrome Severity Scale	Search task with eye-tracking technology	Selective attention, the ability to focus on or select a particular element or object in the environment, is compromised by Rett syndrome.
Seernani D *et al.*[36]	IV	Cross sectional study	To thoroughly examine the execution of a visual search task in both typical and clinical groups (ASD, ADHD)	N=100 (ASD without comorbidities N=15, ASD with comorbidities N=18), diagnosed on ADOS, ADI-R	Visual search task	ASD+ group was particularly slow, inefficient, and had significantly longer fixations, absence of superior search
Chi I J *et al.* [26]	IV	Cross sectional study	To study the relationship between self-care and visual perception in young children with ASD.	N=132 (N=66 ASD, N=66 TDC), diagnosed on DSM 5 and CARS2-ST, aged 48-83 months	DTVP-3 TVPS-3	ASD obtained significantly lower scores for self-care performance and visual perception ability compared with TDC. Positive correlations were found between self-care performance and visual perception ability in ASD.
Wuang Y P *et al.*[31]	IV	Cross sectional study	To explore sensory integration and perceptual-motor skills in elementary school children (ages 5 to 12) with ASD in Taiwan.	N=117, 5-13 years, no serious physical or behavioral problems, diagnosed with autism	TVPS-3	The ASD participants had best performance on the visual spatial relationship, but it was still in the impaired range. The participants had significant impairments on performing form constancy, figure ground and visual closure tasks.
DiCriscio A S and Troiani V [32]	IV	Cross sectional study	to evaluate significant differences in visual-perceptual skills among children with and without ASD using TVPS	N=87 (N=48 ASD), 5-16 years Diagnosed on DSM 5	TVPS-3	A significant linear relationship between ASD features and performance on the TVPS Figure Ground subtest.
Liu C *et al.*[24]	IV	Cross sectional study	To explore the line bisection tasks in children with ASD by assessing the impacts of line length, hand use, and line end cues through two distinct experiments.	N=31 diagnosed as ASD, 5-15 years, right-handed, passed a comprehensive check, normal or corrected-to-normal visual acuity & ability to concentrate on a task for at least 15 minutes, not on antipsychotic medicine; N=20 TDC	Manual line bisection task	ASD and TD individuals show a similar preference for processing visual information on the left side. However, when asked to use their left hands to divide short lines, ASD might display a different or unusual bias pattern.

Table 2. Visual perception skills in ASD (continued).

Year/Author	Level of evidence	Research design	Study purpose	Study participants(sample size, selection criteria, ASD screening)	Visual perception assessment	Result summary
Faber L *et al.* [33]	IV	Cross sectional study	To assess and associate the motor skills, visual perception, and visual-motor integration = of children and youth with ASD in comparison to age- and gender-matched peers without ASD.	N= 67 ASD and 54 non-ASD, grade 4 to grade 9 Diagnosed as ASD on DSM 5 and autism, Asperger's or PDD-NOS on DSM IV	Beery VMI 6 (Main test and supplemental test of visual perception)	No significant differences were found between children and youth with and without ASD for VP or VMI as measured with the Beery VMI-6. Children and youth with ASD perform similar to children and youth without ASD for VP and VMI (as measured with the Beery-VMI-6).
Lin LY *et al.*,[35]	IV	Cross sectional study	To study the influence of motor-free visual perception on the connection between self-care and visual-motor integration in young children with ASD.	N=66 young children with ASD, aged 48-83 months old from Tainan, diagnosed on DSM 5 criteria and CARS, IQ ranging from 67-127	DTVP-3 TVPS-3	Self-care skills were strongly linked to abilities like visual-motor integration, visual discrimination, visual memory, and understanding visual spatial relationships. Among these, visual sequential memory and understanding spatial relationships were the most crucial factors influencing self-care skills. Sequential memory played a role in how well visual-motor integration affected self-care abilities.

Note: LOTCA: Lowenstein Occupational Therapy Cognitive Assessment, TDC: Typically developing children, ASD: Autism Spectrum Disorder, ADJD: Attention Deficit Hyperactivity Disorder, IQ: Intelligence Quotient, DTVP 3: Developmental test of Visual Perception: Third Edition, TVPS 3: Test of Visual Perception Skills: Third Edition; ADOS 2: Autism Diagnostic Observation Scale: Second Edition, ADI-R: Autism Diagnostic Inventory: revised; Beery VMI 6: Beery Buktenica Developmental Test of Visual Motor Integration: Sixth Edition, DSM: Diagnostic and Statistical Manual, CARS: Childhood Autism Rating Scale.

In this synthesis, the methodological quality of the sixteen cross-sectional studies included in the systematic review was evaluated using the AXIS tool. For 3 out of the 20 questions pertaining to statistical significance, the description of statistical methods, and the explanation of analysis studies received a "Yes" response, indicating a low risk of bias in these areas. However, for questions regarding sample size justification and non-response bias, the responses were either "No" reflecting a moderate to severe risk of bias in all studies. For the remaining questions, most studies demonstrated a low risk of bias.

All 16 studies were cross-sectional; none were longitudinal or randomized controlled trials. The 16 studies collectively highlight various findings related to visual perception and its association with self-care skills and cognitive functioning in children and adolescents with ASD. Visual perception impairments in ASD children affect cognitive and functional domains, including self-care and school performance. Local Bias is a hallmark of visual processing in ASD, with ASD participants showing better performance on local tasks but impaired global processing. Sequential Memory and Spatial Relationships are key visual-motor integration abilities that influence self-care skills. Visual processing deficits in ASD are further complicated by the severity of autism traits, which have a direct influence on performance in tasks like figure-ground perception. Despite impairments, in some areas like visual-motor integration, children with ASD perform similarly to TD peers, highlighting the complexity of visual perception and cognitive processing in ASD.

Key findings from the included studies

All 16 studies indicated impairments in visual perception in ASD. Children with ASD often show deficits in visual discrimination, figure-ground perception, visual memory, and visual-motor integration compared to typically developing (TD) peers. These deficits are linked to slower processing times, especially when processing global information, leading to difficulties in tasks requiring higher-order visual perception skills. Studies consistently found that impairments in visual perception are strongly related to problems in daily living skills, such as self-care and social functioning. Some studies suggest that while children with ASD exhibit deficits in global visual processing, they may excel in tasks requiring local visual processing, such as recognizing specific details or patterns. Although most studies suggest visual discrimination is impaired, a few findings indicate that children with ASD may show strengths in particular aspects of visual discrimination, depending on the assessment tools used and task complexity. These mixed results suggest variability in the visual perception profile of children with ASD. The studies predominantly assessed static visual perception tasks, neglecting the dynamic aspects (e.g., processing moving objects), which are crucial for navigating real-life environments. The need to determine both static and dynamic visual perception to understand the deficits in ASD was emphasized fully.

Discussion

The systematic review reflects on the complex and diverse nature of visual perception skills exhibited by children with autism spectrum disorder aged 3-12 years. While some studies suggest that visual perception is a deficit in children with ASD, characterized by impairments in tasks such as figure-ground discrimination, visual memory, and form constancy, others propose that visual perception can be a relative strength in specific areas. For instance, children with ASD often excel in tasks focusing on fine details or local visual information. This notion is supported by theoretical foundations related to ASD, i.e., enhanced perceptual functioning (EPF) and the weak central coherence (WCC) theory, which suggest that children with autism have deficits in visual perception due to the slower processing of visual input in the later stages.[13,15,16] Additionally, visual perception deficits in autism are hypothesized to be related to developmental abnormalities that occur during early life, resulting in rapid extension of the visual cortex surface area. This causes abnormal transmission of visual evoked potential.[40, 41]

When assessing visual perception skills in ASD, age and gender were found to be independent factors among the included studies. However, the complexity of stimuli significantly impacted the performance of children with ASD, placing a high cognitive demand on them and leading to severe impairment in their performance of visual perception.

Visual perception profile

Children with ASD demonstrated strong performance but in an impaired range in the spatial relationships domain.[31] This might be due to the insufficient visual-spatial processing abilities affecting the mirror neuron system and subsequently impacting imitation skills in ASD.[40]

Visual discrimination skills in children with ASD show contrasting findings across studies. Some studies propose that ASD individuals focus more on detailed parts than global parts due to their discrete attention strategy. Theories like Weak Central Coherence and Enhanced Perceptual Functioning support this perspective.[12,14,15] However, there are also studies presenting the opposite view.[23] These discrepancies could stem from demographic variations, cultural factors, and the specific measures used to assess this ability.

Figure-ground perception in autism has produced conflicting results. One study[16] suggests reduced global processing abilities, while others argue the opposite. These differences stem from variations in search strategies, such as serial search, employed by individuals with autism spectrum disorder (ASD) when locating stimuli. The choice of search strategy in ASD individuals appears to be influenced by their social impairments and individual differences[16].

Visual memory and visual sequential memory deficits are also seen in autistic children. This may be due to the difficulty in information processing and processing rapid visual stimuli.[37] Additionally, children with autism reported

having difficulty processing facial recognition as compared to object memory.[41]

Children with ASD also exhibit impairments in form constancy and visual closure abilities, which are closely tied to their visual discrimination and mental rotation skills.[40] Mental rotation involves the coordination of both the dorsal and ventral visual processing streams. Studies have shown that children with ASD have altered neural activity in the prefrontal cortex network, contributing to these challenges in mental rotation tasks and overall visual perception.[42]

Impact of visual perception skills on performance areas

A study concluded that the perception subset (visual identification of objects, overlapping figures, space position, praxis) and visual perception subset (reproduction of a two-dimensional model, puzzle, drawing a clock) of LOTCA were strongly related to the self-care skills and social function of PEDI.[35] Similar results were found in a study,[31] which stated that children with ASD performed significantly worse on communication, socialization, and daily living skills. Another study revealed that motor-reduced visual perception skills are strong contributors to school functioning (travel, maintaining and changing positions, recreational movement, manipulation with movement, using materials, setup and cleaning, eating and drinking, hygiene, clothing management, functional communication, task behavior/completion, positive interaction, and personal care awareness).[29] A study revealed a significant relationship between self-care and visual perception domains.[26] Another study revealed that visual sequential memory and visual-spatial relationships were the primary factors influencing self-care performance.[35] Sequential memory played a mediating role in the connection between visual-motor integration and self-care performance.

Impairments in visual perception skills significantly impact various aspects of functioning, including self-care, socialization, and school performance, among children with autism.[25,26,31,32] Studies have shown that children with autism heavily rely on visual instructions, enabling them to imitate and replicate tasks, thus highlighting the crucial role of visual perception abilities in their academic success.[34] Moreover, visual perception plays a vital role in learning and executing self-care activities, as children with autism often utilize visual strategies for these tasks.[44] The interrelation between visual perception and socio-cognitive deficits in autism is noted, with both aspects being linked to the superior temporal sulcus (STS).[12]

Assessment of visual perception

Among the measures used to assess visual perception, the Test of Visual Perception Skills-Third Edition (TVPS-3) was used in most studies. TVPS-3 has good internal consistency, test-retest reliability, and good criterion-related validity.[45] It has been used to evaluate the visual perceptual skills of children with different ranges of autism traits.[16] On the contrary, using various non-standardized methods to evaluate visual perception reduces the reliability of the assessment due to the absence of established psychometric properties.

Studies on visual perception in autism often focus on static constructs, neglecting the crucial aspect of integrating space and objects in motion, which is essential in real-life scenarios.[12] Children with ASD commonly experience impaired motion processing due to dysfunction in the dorsal stream of visual processing.[12,46] However, most studies reviewed here primarily assess static visual perception constructs, overlooking this dynamic component critical for understanding how these children navigate their environment and interact with moving objects. The study's major limitation was that only studies published in English were included in the systematic review.

Future scope and recommendations

To enhance the utility of the review for practitioners and policymakers, future research should focus on using standardized, validated assessment tools to ensure consistency and reliability in measuring visual perception skills. Incorporating dynamic visual tasks that simulate real-life scenarios will provide a more comprehensive understanding of how children with ASD interact with their environment. Implementing blinding techniques to minimize bias and conducting longitudinal studies to track the development of visual perception skills over time is also crucial. Developing and evaluating tailored interventions for specific visual perception deficits will also improve therapeutic and educational practices. Including studies from diverse cultural backgrounds will ensure findings are broadly applicable and culturally relevant. Lastly, fostering interdisciplinary collaboration among researchers, clinicians, and educators will integrate insights from various fields, leading to more effective approaches for addressing visual perception deficits and enhancing functional outcomes for children with ASD.

Strengths of the systematic review

The systematic review comprehensively analyzes visual perception deficits in children with autism spectrum disorder (ASD). The review explores various subdomains of visual perception challenges in ASD, such as visual discrimination, figure-ground perception, and visual memory, providing valuable insights into their diversity. It emphasizes the importance of using validated assessment tools, like the Test of Visual Perception Skills-Third Edition (TVPS-3), in clinical settings. The recommendation for standardized, evidence-based practices in assessing and treating visual perception deficits contributes to more effective interventions tailored to the unique needs of children with ASD.

Limitations

The review only included studies published in English. Most of the included studies used a cross-sectional design, which limits the ability to conclude the developmental trajectory of visual perception skills over time in children with ASD.

Conclusion

The systematic review concludes that visual perception skills are one of the crucial factors deficient in children with ASD. The range of visual perception deficits in ASD is diverse and evident, impacting their functional performance. Future studies are warranted to assess both static and dynamic domains of visual perception. Additionally, longitudinal studies are essential to explore the developmental trajectory of visual perception skills in children with ASD.

Conflict of interest

The authors declare no conflict of interest.

Funding

Nil

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Supplementary

AXIS Tool for quality appraisal of included studies.

Items in AXIS Tool	Vetrayan J *et al.*[29]	Hallen RV *et al.*[27]	Brown A C & Crewther DP[39]	Cherenkova L V *et al.*[38]	DiCriscio A S and Troiani V[30]	Jobs E N *et al.*[34]	Gunal A *et al.*[25]	Guy J *et al.*[28]	Rose S A *et al.*[37]	Seernani D *et al.*[36]	Chi I J *et al.*[26]	Wuang Y P *et al.*[31]	DiCriscio A S and Troiani V[32]	Liu C *et al.*[24]	Faber L *et al.*[33]	Lin LY *et al.*[35]
Were the aims/objectives of the study clear?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Was the study design appropriate for the stated aim(s)?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Was the sample size justified?	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
Was the target/reference population clearly defined? Is it clear who the research was about?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were measures undertaken to address and categorise non-responders?	–	–	–	–	–	–	–	–	–	–	–	–	?	–	–	–
Were the risk factor and outcome variables measured appropriate to the aims of the study?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were the risk factor and outcome variables measured correctly using instruments/ measurements that had been trialled, piloted or published previously?	+	+	+	+	+	+	+	+	–	+	+	+	+	+	+	+
Is it clear what was used to determined statistical significance and/or precision estimates? (eg, p values, CIs)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were the basic data adequately described?	–	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Items in AXIS Tool	Vetrayan J *et al.*[29]	Hallen RV *et al.*[27]	Brown A C & Crewther DP[39]	Cherenkova L V *et al.*[38]	DiCriscio A S and Troiani V[30]	Jobs E N *et al.*[34]	Gunal A *et al.*[25]	Guy J *et al.*[28]	Rose S A *et al.*[37]	Seermani D *et al.*[36]	Chi I J *et al.*[26]	Wuang Y P *et al.*[31]	DiCriscio A S and Troiani V[32]	Liu C *et al.*[24]	Faber L *et al.*[33]	Lin LY *et al.*[35]
Does the response rate raise concerns about non-response bias?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
If appropriate, was information about non-responders described?	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Were the results internally consistent?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were the results for the analyses described in the methods, presented?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were the authors' discussions and conclusions justified by the results?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Were the limitations of the study discussed?	+	−	−	−	+	+	+	−	+	+	+	+	+	+	+	+
Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Was ethical approval or consent of participants attained?	+	?	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ : *YES*, − : *'NO*, ? : *DO NOT KNOW*