J. Indian Assoc. Child Adolesc. Ment. Health 2018; 14(4):38-57

Original article

Do children with autism spectrum disorders exhibit biological motion perception deficits? Evidence using an action recognition paradigm

SudhinKaruppali

Address for correspondence: Associate Professor, Dept of Audiology & Speech Language Pathology, Kasturba Medical College, Mangalore, Manipal Academy of Higher Education. **Email:**sudhin.karuppali@manipal.edu

---

Abstract

Background: Biological motion (BM) detection tasks determine the power of bottom-up and top-down processing. An individual's performance in the perception of BM displays is highly influenced by stimuli characteristics and the way the correct responses are operationalized. Such impairments in the perception of BM displays are observed in individuals with autism spectrum disorders (ASD). The present study aimed to study the performance of children with ASD and their age-matched controls in a biological motion perception task using an action recognition paradigm.

Methods: This study followed a case-control design. Two males and two female participants with ASD (mean age 5.3, S.D. 0.9 years), and two males and two female control participants matched for language age and sex (mean language age 5.3, S.D. 0.6 years) were included in the study. Ten BM displays were video recorded using 15-point light displays mounted on an adult actor. Participants were instructed to detect the perceived BM display. Descriptive analysis was done on the type of responses generated.

Results: A considerable increase in the accuracy of the responses was noted by the age matched typically developing children when compared to the ASD group. The participants of the ASD group received a maximum of 30% accuracy scores when compared to the controls receiving 90% scores.

Conclusion: Action recognition based BM display task may help determine deficits in sensory and perceptual processing of individuals with ASD.

Keywords: autism, biological motion, display, perception, recognition

Introduction

The perception of actions and intentions of the communication partner is one of the most essential pragmatic skills. The visual system provides particularly a rich source of information in support of this ability. The detection of naturally valid stimuli such as biological motions follows the concept of the organizational competency of the human visual system. Gunnar Johansson's landmark study on biological motion perception using point-light displays (PLD) has given a wealth of information on the perceptual organization underlying the visual coherence abilities in humans [1]. The ability to perceive these biological motions such as the body parts or the entire body, conveys social meaning, and is therefore crucial to social cognition and social interaction [2]. Such PLD contain sufficient information to recognize other actions [3], such as the identification of the agent as an animal or human figure [4], to determine features such as the gender of a person, age, mental states, actions and intentions to unfamiliar individuals [5], recognition of familiar persons [6], recognition of emotions[7], and also one's peculiar walking pattern [8].

Individuals with lesions in the anterior parts of the superior temporal sulcus were found to normally detect coherence and shape from motion tasks, but demonstrated difficulty in perceiving biological motion, implicating that the perception of coherent motion and of biological motion may rely on different neural mechanisms [9]. Exploring the sensory abnormalities in individuals with autism spectrum disorders (ASD) has revealed a systematic impairment in motion perception. The first report on children with ASD exhibiting an abnormal response to visual motion was revealed by Gepner and colleagues [10]. Milne et al. [11] indicated that the research focus towards biological motion perception in autism is emerging and that its causes and implications are not fully understood. Biological motion processing may be found affected in people with ASD right from an early age [12]. Nilsson Jobs, Falck-Ytter, and Bölte [13] does propose a wide range of neuropsychological and cognitive abilities of children with ASD to differ from typically developing individuals. Children with ASD are genetically inclined to have a differential development in the first year of life with noticeable impairments around age 20 months in imitation [14] and joint attention abilities [15].

The biological motion perception impairments can result in deficits in joint attention and imitation skills, which is strongly linked to later social and language development [16]. Typically developing children are found to exhibit improved biological motion perception abilities between 5 and 12 years of age, with the 12 year-olds performing significantly better than children with ASD who reached a plateau [17]. Individuals with ASD never showed a complete absence of biological motion perception but an increased error rate or a decreased rate of correct answers [18]. Though children with ASD were able to extract social content from body motions, they were significantly less efficient than the typically developing control children [19]. It was observed that the short exposure durations of the biological motions did result in a reduced performance of ASD group when compared to the chronological and verbal age matched control group with learning difficulties [20].Moore and colleagues concluded that the biological motion perception in individuals with ASD was intact, but there existed impairment in attributing affect to human gestures. However, Bertone and colleagues [21] speculated that the abnormality in motion detection by individuals with ASD is only for second-order (contrast and flicker characteristics) and not first-order motions (spatiotemporal changes in luminance). This second-order impairment was implicated to a reduced ability to integrate complex perceptual information rather than a specific form. With little known about exactly how biologically and psychologically relevant information is encoded in visual motion patterns, studies pertaining to the processing of biological motions in Indian children with ASD and age-matched controls are essential to open a new trend of assessment methods to better understand the organization of their perceptual mechanism. Hence the present study aimed to study the performance of children with ASD and their age-matched controls in a biological motion perception task using an action recognition paradigm.

Method

Participants

The present research was a case-control study that followed a convenience sampling design. Two males and two female participants with ASD (mean age 5.3, S.D. 0.9 years), and two males and two female control participants matched for language age and sex (mean language age 5.3, S.D. 0.6 years) were included in the study. The participants of the ASD group were patients who had reported to the Department of Audiology and Speech Language Pathology, Kasturba Medical Hospital, Mangalore. The control participants were recruited from regular English medium schools following a lottery method. The study design was approved by the Institutional Ethics Committee.

The participants from the ASD group were referred from the Department of Psychiatry, KMC, Mangalore, and had received a clinical diagnosis of Autism Spectrum Disorder based on the DSM 5 criteria using the Childhood Autism Rating Scale (CARS). Appropriate standardized nonverbal cognitive tests were done to estimate the IQ of the four ASD participants. This was followed by estimating the severity of autism by the speech language pathologist using the Gilliam Autism Rating Scale (GARS) [22], which is a standardized norm-referenced tool designed to screen for ASD in individuals between the ages of 3 and 22.Participant E1 (4.1-year-old male) and Participant E2 (6.3-year-old female) were diagnosed to have a high probability of autism; Participant E3 (5.5-year-old male) had an above average probability; while Participant E4 (5.3-year-old female) had an average probability of having autism. Participant E1 was a newly diagnosed patient with no history of any speech and language therapy. Participant E2, E3, and E4 has been receiving speech and language therapy in English since 14, 5, and 2 months respectively. The native language of Participant E1, E2, and E4 was Konkani, an Indo-Aryan language spoken along the South western coast of India. Participant E3 spoke Malayalam, a Dravidian language spoken in the South Indian state of Kerala. All participants have been attending regular English medium schools (play and pre-schools), and are therefore exposed to English language. The participants in the control group were recruited from regular English medium schools within Mangalore. The typical children were ascertained to not have a history of any underlying disorder leading to speech, language, or hearing deficits. An informed consent was obtained from the parents of all participants.

The participants from both experimental and control groups were assessed for their language age using the Assessment of Language Development (ALD) [23]. Table 1 shows the demographic profile and the language age of the participants from both experimental and control groups.

Table 1: The demographic details and language age of each participant (experimental and control group)

	Experimental group				Control group			
Sex	**Participant**	**Chro age (years)**	**Lang age (years)**		**Participant**	**Chro age (years)**	**Lang age (years)**	
			RLA	**ELA**			**RLA**	**ELA**
M	E1	4.1	3.0 – 3.6	2.0 – 2.6 (scatter up to 3.0)	C1	3.3	3.0 – 3.6	3.0 – 3.6
F	E2	6.3	5.6 – 6.0	3.0 – 3.6 (scatter up to 4.6)	C2	5.8	5.6 – 6.0	5.6 – 6.0
M	E3	5.5	4.0 – 4.6	3.0 – 3.6	C3	4.5	4.0 – 4.6	4.0 – 4.6
F	E4	5.3	4.6 – 5.0	3.0 – 3.6 (scatter up to 4.0)	C4	4.9	4.6 – 5.0	4.6 – 5.0

Note: Chro age = Chronological age; Lang age = Language age

Stimuli

The task planned for the present study consisted of naming the biological motion (BM) display as indicated by Moore et al. [20]. Each BM display was prepared using an adult actor wearing a tight-fitting black suit with a set of 15 PLDs powered by 15 standard Lithium 3V battery (CR 2032) placed at different joints across the body. The selected sites were the ankles (2), knees (2), hips (2), wrists (2), elbow joints (2), clavicles (2) and shoulder joints (2) and at the midline of the forehead (1). The actor was instructed to perform 12 basic human movement patterns (actions)‘cycling’, ‘scratching’, ‘clapping’, ‘dancing’, ‘jumping’, ‘walking’, ‘pulling’, ‘rowing’, ‘running’, ‘bending’, ‘pushing’, and ‘hopping’ in the most comfortable manner [24] as possible.

Studies have found the use of action verbs to be pronounced in 2 year-olds, with a further advancement in grammatical skills evident with age [25]. Therefore, using visual action sequences as a stimuli and generating the corresponding action verb for the participants in the current study can be warranted. These selected action verbs were subjected to content validity measures by five speech language pathologists to ascertain the appropriateness of it. This was followed by each action being motorically performed in a series of recurrent gait cycles. One gait cycle indicated the initiation of the action to its termination. Each gait cycle varied from 500ms to 2000ms.Table 2 shows the duration of the gait cycles for each of the BMs.

Table-2: Details of the number and duration of the gait cycles for each BM display

Sl. No	BM PLDs	Duration of each gait cycle(ms)	Number of gait cycles
1.	cycling	1200	5
2.	scratching	450	8
3.	clapping	650	8
4.	dancing	1800	5
5.	jumping	680	5
6.	walking	850	5
7.	pulling	1100	5
8.	rowing	1750	5
9.	running	700	5
10.	bending	1950	5
11.	pushing	1050	5
12.	hopping	1550	5

The final recording consisted of a series of lights moving in a sequence depending on the activity being performed. For example, Figure 1 depicts a complete gait cycle of the biological motion of walking represented in a static form. All 12 biological motions were captured in a 3D space in a dark room using a Sony DCR 650E DVD Handycam mounted on a stable tripod. Barclay et al. [26] suggested that a minimum of two complete gait cycles were required to accurately perceive the biological motion. For the present study, all the 12 videotaped BM displays were presented in 5 - 8 gait cycles. Five typical adults (judges) viewed the recorded stimuli from a standard laptop (Lenovo L420) screen placed at a distance of 90cm in front of their eyes. The BM displays were validated by the judges who had to indicate if the viewed BM displays indicated the actual human motion of it being performed. The judges had to rate the stimuli based on the transparency of the human motion depicted. All judges rated the BM displays to accurately convey the desired human motion. Out of the 12 BM PLDs that was ready to be used for the experiment, two of the BM displays (jumping and running) were used as trials.

In order to ascertain the familiarity of the target 12 movement sequences (as shown in Table 2), the corresponding real life videos (of the actual BM displays) were collected from online sources (www.youtube.com). For example, videos consisting of an individual clapping hand (while watching a game), walking (in a park), jumping (for fun), etc. were identified. All videos consisted of motoric actions being performed with sufficient contextual support.

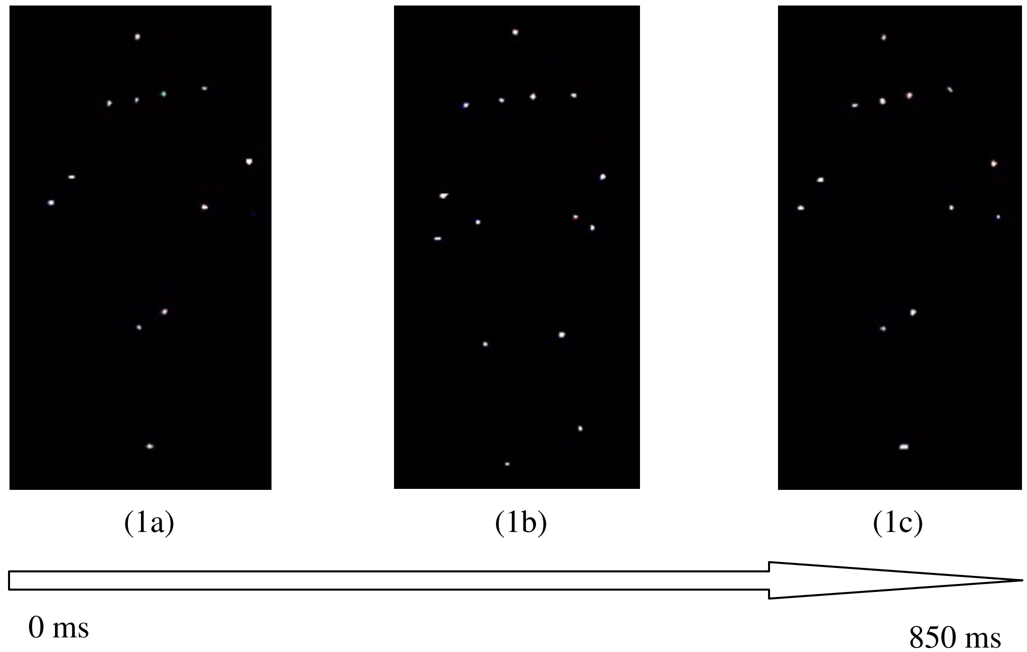

Figure 1: This figure depicts the gait cycles involved in the biological motion of walking. Fig (1a) is the beginning of the gait cycle; Fig (1b) is the midpoint of the gait cycle; and Fig (1c) is the ending of the gait cycle.

Procedure

Initially the participants were seated comfortably on a chair. Each of the participant's parents (ASD group) was present beside them during the experiment. A standard laptop (Lenovo L420) was placed at a distance of 90 cm away from the participant's eyes. Each of the participants from the control and experimental groups were shown the real life videos of the 12 target movements, and were asked to indicate what was happening in the video. All participants from the control group were able to indicate all 12 corresponding actions being performed. When considering the ASD participants, all the 4 participants were able to recognize a minimum of 8 actions (indicating 80% accuracy). This was followed by the presentation of the BM PLDs, with each stimulus being presented with its corresponding stimulus interval as mentioned in Table 2. The participants were exposed to each of the BM display for a longer duration (i.e. repeated gait cycles), as Barclay et al. [26] suggested shorter exposure times may lead to reduced performance, especially in children with autism [20]. Successive trials were separated by an inter-stimulus interval of 3000ms wherein a blank screen appeared. The experiment consisted of 10 BM displays which were presented in a random order. Participants were instructed to look at the screen during the trials and verbally generate the appropriate gerund (a verb that ends in 'ing' functioning as a noun) to the corresponding perceived action. Before the presentation of the 10 displays, the two BM displays that were selected as trials were presented so as to familiarize the participants. Any issues related to the comprehension or performance of the stimuli was addressed. This was followed by the presentation of the 10 BM displays, wherein the participants were required to name the correct action perceived. The participants did not receive any feedback on their generated responses. Each correct response was scored as one and an incorrect or no response scored as zero.

Analysis

Each participant (from the experimental and control group) was analyzed for the total number of correct responses for the identification of the BM displays. The total numbers of correctly identified BM displays were calculated for each participant. Descriptive analysis was done on the type of responses generated by the participants.

Results

Descriptive analysis was done on the responses attained by each participant. The below table (Table 3) illustrates the total number and types of correctly identified BM displays by each participant from the experimental and control group. When considering the responses generated by the participants of the experimental group, participant E1 was unable to correctly identify the

BM displays, resulting in a score of 0%. However, participant E2 and E3 attained a score of 10%; while participant E4 received a score of 20%. Participant E2, E3, and E4 was able to identify the BM display of the action 'dancing', while participant E4 perceived clapping as well. Except for participant C1, all the other 3 participants were able to effectively label the target BM display with the prescribed number of gait cycles as shown in Table 2. None of the participants of the experimental group were able to receive accuracy scores greater than 30%.Theresponses generated by the participants (experimental group) for the unidentified BM displays were mostly descriptive in nature. For example, for most of the BM displays - participant E1 mentioned that he saw moving stars instead of the displayed action. For the participants in the control group, participant C1 attained a score of 40%; while participant C3 and C4 received a score of 80%. Participant C2 attained the highest score of 90%, being able to identify most of the BM displays. There was no significant correlation observed of biological motion perception with autistic traits of the participants.

Table-3: The number and types of correctly identified BM displays

	Total no. of correctly identified BM displays/Total BM displays	**Correctly identified BM displays by the participant**
Experimental group		
Participant E1	0/10	-
Participant E2	1/10	dancing
Participant E3	1/10	dancing
Participant E4	2/10	dancing, clapping
Control group		
Participant C1	4/10	dancing, clapping, cycling, walking
Participant C2	9/10	dancing, clapping, cycling, walking, scratching, rowing, pushing, bending, hopping
Participant C3	8/10	dancing, clapping, walking, scratching, rowing, pulling, bending, hopping
Participant C4	8/10	dancing, clapping, walking, scratching, rowing, pulling, bending, hopping

Discussion

The present study was carried out to explore the visual-perceptual abilities in children with ASD (experimental group) in comparison with language and age matched typically developing children (control group). The objective of the study was to present BM displays to participants of the control and experimental groups, while they were expected to detect the type of action performed by the moving figure. As observed, none of the ASD participants attained more than 20% scores in identifying the BM displays when compared to their controls, who were able to attain a maximum score of 90%. All the participants of the control group (C1, C2, C3 and C4) did attain scores which were higher than the participants of the experimental group. Though participant C1 did attain a comparatively lower score of 40%, the overall accuracy level of the control group was 72%. This relatively less score of participant C1 could be attributed to the age disadvantage and lesser social experience compared to the older controls. The BM displays which were identified by participant C1 was dancing, clapping, cycling, and walking, which are known to be actions which the child had a social experience with, compared to actions such as pulling, rowing, hopping, etc. which were yet to be motorically experienced by the child.

The poor performance of the ASD participants in the BM identification task could possibly imply a poor organization of their visual perceptual system[27,28]. ABM display task aims to filter out contextual sources of information, which may influence the recognition of a moving figure, which was the essence of the present study. Identifying the BM display in the absence of facilitatory context was challenging in the present study, and hence does demand the recognition of the intention and mental state of the moving figure [29].The perception of the BM displays in the present study, such as the movement of whole body (for the actions of walking, jumping, pushing, rowing, dancing, pulling, running and hopping), and body parts (cycling, scratching, clapping, bending) were found to be crucial for social interaction and cognition [2,30]. Similar findings have emerged in adults with autism wherein a poor performance was noted when asked to attribute mental states to moving figures [31,32]. When considering the 10 BM displays that were presented to the ASD participants, the 'dancing' BM display was the most easily identified. The BM display of dancing included a visual display of moving dots without a consistent pattern, compared to all other BM displays which had a more sequential manner of movement. However, unlike conventional discrimination tasks, wherein walkers walked 'on the spot' while facing left or right, Murphy and colleagues [33] studied adults (ASD and typically developing adults) using a task wherein they added translatory motion to the stimulus so that the walkers physically moved across the screen (which was in line with the current study). However, there were no significant differences observed between both the groups. Murphy and colleagues did suggest that this difference may not effectively explain the differences in younger individuals (ASD and normal), as the responses tend to become better with age.

The participants (E2, E3, and E4) who did attain a better performance than E1 (newly diagnosed patient), could have had an age (language) advantage, along with the benefit of speech and language therapy (in the English language) which they have been getting on a regular basis. The therapy strategies which were focused for these individuals included activities to improve their intentional communication, functional communication, joint attention, imitation, and all pragmatic behaviors, all of which targeted to improve the social interaction and social cognition [2]of the participants. Such strategies have the potential to improve the social communication skills of children with ASD [34,35], which may indirectly influence their visual-perceptual appreciation of the BM display. To add on, the language age of participant E1 was 2.0 – 2.6, with a scatter seen up till 3.0 years, while the other participants (E2, E3, and E4) received a mean language age of 3.3 years with a scatter up to 4 years and above. This may indicate a receptive and expressive language age advantage that could have indirectly played a role in getting better BM recognition responses by the participants (E2, E3, and E4). However, when considering the native language used by the ASD participants, none of them were native speakers of the English language, with all having being exposed to English only from the time of joining school (play school and beyond). The participants of the control group were also non-native speakers of English, with all participants having Tulu and Konkani as their native tongues.

The participants in the control group effectively recognized (labeled) the BM displays, even before the completion of the stimulated number of gait cycles. For example, the cycling BM display which contained 5 gait cycles was identified within 3 gait cycles. Whereas, the ASD children could not generate any response even after the completion of all gait cycles for each BM display. When shown the BM displays, participants mentioned seeing stars moving around, while others indicated that it was night and there was light moving around. The present study contained pre-specified gait cycles for the presentation of each BM display, demanding each participant to label the action perceived [18], and not the speed of response. With the scores suggesting an increased threshold to perceive biological motions by individuals with ASD, the participants of the experimental group might have responded even better if considered to provide the stimuli with recurrent gait cycles, thereby targeting their reaction time. Such increased reaction times in individuals with ASD to identify BM displays have been observed [33,36].

The problems in social interaction and mental state attribution encountered by children with ASD have been attributed to theory of mind hypothesis [37], implying problems in imitation and joint attention skills. When considering the scores received in GARS, all participants in the experimental group received varying probabilities of having autism (from average - above average – high probability of autism). This did indicate serious deficits in the social interaction and communication domains of GARS. Imitation and joint attention skills that are strongly linked to social and language development, may be attributed to difficulties in biological motion perception [16]. Such social skills which showcase the parallel understanding of a second person's actions and intentions can be observed when considering the perception of the participants to BM displays. The ease of matching the BM display to the individual's own motor representations [38] have been explained using the common coding theory [39], and motor simulation theory[40]. The participants with ASD in the present study exhibiting difficulties in BM display recognition, does gets support from Frith's [41] 'Weak Central Coherence theory' which advocates individuals with ASD to have difficulty assimilating visual, spatial and/or temporal information, which is the basis of performing a BM recognition task.

Researchers have proclaimed that the core and causal deficits found in children with ASD may be attributed to the lower-level [42] and high-level [43] differences in sensory and perceptual information processing. The ASD participants in the present study did exhibit difficulties in stereotyped behaviors such as – avoiding eye contact, rocking back and forth while seating, and flapping hands or fingers in front of face or at sides. Studies have advocated that these sensory representations used during action perception does overlap with the motor representations used during action planning, implying that an observers own activities can influence that observer's perception of the activities of other people [38]. Mapping the perceived BM display onto the individual's own motor system does enable the observer to understand the goals underlying the action, facilitating in the prediction of actions. Studies have shown that children with ASD tend to have difficulties in comprehending these sensory representations, implicating deficits in action perception [44]. Though BM display tasks may include emotion recognition along with actions, the present study focused only on the identification of an action. None of the participants with ASD showed a complete lack of biological motion recognition except for participant E1. When considering the severity of autism and the degree of impairment in perceiving biological motions, a positive correlation between the two were not evident, unlike the study done by Blake et al. [45].

To conclude, the present study was planned to study the visual-perceptual abilities of children with ASD using a BM perception action recognition paradigm task. Comparing the individuals with ASD and their language age matched typically developing children, the former group exhibited difficulties in the perception of the BM displays in spite of performing fairly good in the recognition of real life videos of the corresponding target actions. This does imply children with ASD to have serious deficits in the sensory and perceptual processing abilities implying poor visual-perceptual skills. With researchers appreciating and advocating newer perceptual assessment methods in individuals with ASD, such methods will also pave way for the early identification of visual-perceptual deficits, directing clinicians to frame early therapeutic goals to strengthen the ASD's low and high level information pathways. Such behavioral methods used in the current study, may be promoted considering the low level resources that were used to develop such a sensitive task, especially in a country like India wherein clinical resources are difficult to obtain. Other research pertaining to the similar field may be directed to control a variety of possible influencing variables such as the native language, cognitive age, gender, comorbid conditions, and severity of autism.

Acknowledgements: None

Conflict of interest: None

References

1. Johansson G. Visual perception of biological motion and a model for its analysis. Percept Psychoph 1973, 14:201–211.
2. Okruszek Ł. It Is Not Just in Faces! Processing of Emotion and Intention from Biological Motion in Psychiatric Disorders. Front Hum Neurosci 2018, 12:48.
3. Dittrich WH. Action categories and the perception of biological motion. Perception. 1993, 22:15–22.
4. Hill H, Pollick FE. Exaggerating Temporal Differences Enhances Recognition of Individuals from Point Light Displays. Psychol Sci 2000, 11:223–228.
5. Troje NF. Decomposing biological motion: A framework for analysis and synthesis of human gait patterns. J Vis 2002, 2:371-381.
6. Westhoff C, Troje NF. Kinematic cues for person identification from biological motion. Percept Psychophys 2007, 69:241–253.
7. Pollick FE, Paterson HM, Bruderlin A, Sanford AJ. Perceiving affect from arm movement. Cognition 2001, 82:B51-61.
8. Beardsworth T, Buckner T. The ability to recognize oneself from a video recording of one's movements without seeing one's body. Bull Psychon Soc 1981, 18:19–22.
9. Alaerts K, Swinnen SP, Wenderoth N. Neural processing of biological motion in autism: An investigation of brain activity and effective connectivity. Sci Rep 2017, 7:5612.
10. Gepner B, Mestre D, Masson G, De-Schonen S. Postural effects of motion vision in young autistic children. Neuroreport 1995, 6:1211–1214.
11. Milne E, White S, Campbell R, Swettenham J, Hansen P, Ramus F. Motion and form coherence detection in autistic spectrum disorder: Relationship to motor control and 2:4 digit ratio. J Autism Dev Disord2006, 36:225–237.
12. Klin A, Jones W. Altered face scanning and impaired recognition of biological motion in a 15-month-old infant with autism. Dev Sci 2008, 11:40–46.
13. Nilsson Jobs E, Falck-Ytter T, Bölte S. Local and Global Visual Processing in 3-Year-Olds with and Without Autism. J Autism Dev Disord 2018, 48:2249–2257
14. Williams JH, Whiten A, Singh T. A systematic review of action imitation in autistic spectrum disorder. J Autism Dev Disord 2004, 34:285–299.

15. Charman T, Swettenham J, Baron-Cohen S, Cox A, Baird G, Drew A. Infants with autism: An investigation of empathy, pretend play, joint attention, and imitation. DevPsychol 1997, 33:781–789.

16. Toth K, Munson J, N. Meltzoff A, Dawson G, Meltzoff AN, Dawson G. Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. J Autism Dev Disord 2006, 36:993–1005.

17. Annaz D, Remington A, Milne E, Coleman M, Campbell R, Thomas MSC, et al. Development of motion processing in children with autism. Dev Sci2010, 13:826–838.

18. Hubert B, Wicker B, Moore DG, Monfardini E, Duverger H, Fonséca D, et al. Brief Report: Recognition of Emotional and Non-emotional Biological Motion in Individuals with Autistic Spectrum Disorders. J Autism Dev Disord 2007, 37:1386–1392.

19. Centelles L, Assaiante C, Etchegoyhen K, Bouvard M, Schmitz C. Understanding social interaction in children with autism spectrum disorders: Does whole-body motion mean anything to them? Encephale 2012, 38:232–240.

20. Moore DG, Hobson RP, Lee A. Components of person perception: An investigation with autistic, non-autistic retarded and typically developing children and adolescents. Br J Dev Psychol 1997, 15:401–423.

21. Bertone A, Mottron L, Jelenic P, Faubert J. Motion perception in autism: A '"Complex"' Issue. J Cogn Neurosci. 2003, 15:1–8.

22. Gilliam JE. Gilliam Autism Rating Scale. Austin, TX: Pro-Ed; 1995.

23. Lakshanna S, Venkatesh K, Bhat JS. Assessment of Language Development. Bakersfield, CA: Omni Therapy Services, 2008.

24. Kozlowski LT, Cutting J. Recognizing the sex of a walker from a dynamic point-light display. Percept Psychophys 1977, 21:575–580.

25. Hadley PA, Rispoli M, Hsu N. Toddlers' Verb Lexicon Diversity and Grammatical Outcomes. Lang Speech Hear Serv Sch 2016, 47:44–58.

26. Barclay CD, Cutting JE, Kozlowski LT. Temporal and spatial factors in gait perception that influence gender recognition. Percept Psychophys 1978, 23:145–152.

27. Wang Y, Wang L, Xu Q, Liu D, Chen L, Troje NF, et al. Heritable aspects of biological motion perception and its covariation with autistic traits. Proc Natl Acad Sci 2018, 115:1937–1942.
28. Franchini M, Wood de Wilde H, Glaser B, Gentaz E, Eliez S, Schaer M. Brief Report: A Preference for Biological Motion Predicts a Reduction in Symptom Severity 1 Year Later in Preschoolers with Autism Spectrum Disorders. Front Psychiatry 2016, 7:143.
29. Allison, Puce, McCarthy. Social perception from visual cues: role of the STS region. Trends CognSci 2000, 4:267–278.
30. Williams EH, Cross ES. Decreased reward value of biological motion among individuals with autistic traits. Cognition 2018, 171:1–9.
31. Blake R, Turner LM, Smoski MJ, Pozdol SL, Stone WL. Visual recognition of biological motion is impaired in children with autism. Psychol Sci 2003, 14:151–157.
32. Castelli F, Frith C, Happé F, Frith U. Autism, Asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. Brain 2002, 125:1839–1849.
33. Murphy P, Brady N, Fitzgerald M, Troje NF. No evidence for impaired perception of biological motion in adults with autistic spectrum disorders. Neuropsychologia2009, 47:3225–35.
34. Petinou K, Minaidou D. Neurobiological Bases of Autism Spectrum Disorders and Implications for Early Intervention: A Brief Overview. Folia PhoniatrLogop2017, 69:38–42. 35.
35. Dadgar H, Alaghband Rad J, Soleymani Z, Khorammi A, McCleery J, Maroufizadeh S.The Relationship between Motor, Imitation, and Early Social Communication Skills in Children with Autism. Iran J Psychiatry 2017, 12:236–240.
36. Freitag CM, Konrad C, Häberlein M, Kleser C, von Gontard A, Reith W, et al. Perception of biological motion in autism spectrum disorders. Neuropsychologia 2008, 46:1480–1494.
37. Frith U. Autism: Explaining the enigma. 2nd ed. Blackwell Science; 2003.

38. Miyawaki Y, Yamamoto T. The modulation of motor control by imitating non-biological motions: a study about motor resonance. J Phys Ther Sci 2018, 30:159–163.
39. Prinz W. Perception and Action Planning. Eur J Cogn Psychol 1997, 9:129–154.
40. O'Shea H, Moran A. Does Motor Simulation Theory Explain the Cognitive Mechanisms Underlying Motor Imagery? A Critical Review. Front Hum Neurosci 2017, 11:72
41. Frith U. Autism: Explaining the enigma. 1st ed. Blackwell Science; 1989.
42. Falck-Ytter T, Nyström P, Gredebäck G, Gliga T, Bölte S, EASE team. Reduced orienting to audiovisual synchrony in infancy predicts autism diagnosis at 3 years of age. J Child Psychol Psychiatry 2018,59:872-880
43. van Boxtel JJA, Dapretto M, Lu H. Intact recognition, but attenuated adaptation, for biological motion in youth with autism spectrum disorder. Autism Res 2016, 9:1103–1113.
44. Kaiser MD, Pelphrey KA. Disrupted action perception in autism: Behavioral evidence, neuroendophenotypes, and diagnostic utility. Dev Cogn Neurosci 2012, 2:25–35.
45. Blake R, Turner LM, Smoski MJ, Pozdol SL, Stone WL. Visual recognition of biological motion is impaired in children with autism. Psychol Sci 2003, 14:151–157.

Sudhin Karuppali, Associate Professor, Dept of Audiology & Speech Language Pathology, Kasturba Medical College, Mangalore, Manipal Academy of Higher Education.