Available online **www.ijpras.com**

International Journal of Pharmaceutical Research & Allied Sciences, 2023, 12(1):156-162
https://doi.org/10.51847/gnEpVY5YIX

Review Article

ISSN : 2277-3657
CODEN(USA) : IJPRPM

Study of Dysfunction in the Neural Systems in Autism Spectrum Disorders: A Review Article

Florica Voiţă-Mekereş[1,2], Larisa Bianca Galea-Holhoş[1], Gabriel Mihai Mekeres[2,3*], Razvan Parvan[1]

[1]Department of Morphological Discipline, Faculty of Medicine and Pharmacy, University of Oradea, 410087 Oradea, Romania.
[2]County Clinical Emergency Hospital of Oradea, 410087 Oradea, Romania.
[3]Department of Medical Disciplines, Faculty of Medicine and Pharmacy, University of Oradea, 410087 Oradea, Romania.

***Email:** mekeres_gabriel@yahoo.com*

ABSTRACT

One of the worst developmental abnormalities, autism spectrum disorder, is often identified before the age of three. All forms of autism impair people's capacity to communicate with others, despite the fact that each person's symptoms and degree of severity vary. Despite the fact that there is no known cure for autism, children who receive prompt and serious treatment see significant improvements in their quality of life. The deficiencies in social functioning seen in individuals with autism spectrum disorders may be brought on by diseases of the neurological systems responsible for processing social information, according to research in the field of social neuroscience. This study examined the available evidence on the neurological underpinnings of autism spectrum disorders. The outcomes demonstrated aberrant activity in sections of the mirror nerve system and its three interrelated regions that are engaged in social perception, areas related to action observation, and regions that are involved in theory of mind. These findings point to faulty social information processing in autism spectrum disorders, which are characterized by flaws in the neurological systems responsible for social perception, action comprehension, and theory of mind. These results emphasize the involvement of the posterior superior temporal sulcus as a common location in all three systems and offer a framework for understanding the brain processes underlying social deficiencies in autism spectrum disorders.

Key words: *Neural systems, Autism spectrum disorders, Social neuroscience, Developmental abnormalities*

INTRODUCTION

Autism spectrum disorder (ASD), which manifests as inadequate, delayed, or aberrant functioning in one of the domains of social interaction, language used in social communication, and creative or symbolic play. A child with autism spectrum disorder lives in his inner world, and since establishing appropriate social communication requires receiving and processing sensory information correctly and adopting appropriate behavior based on this information, his connection with the outside world is cut off, and the lack of receiving and understanding external sensory stimuli disrupts his learning process and appropriate social communication [1,2].

Cognitive neuroscience has begun the study of neural structures and circuits underlying the processing of social information and the social brain in humans. Particularly, the discipline of social neuroscience is expanding quickly, and its primary study subfields have aided in describing the distinct elements of both healthy and disordered social information processing [3,4]. Therefore, it seems necessary to describe the abnormal performance of the key systems of social information processing in autism spectrum disorders by reviewing the research that has examined the neural mechanisms of these systems.

The neural system of social perception

People are naturally sociable beings. Due to its efficiency and reflective character, social perception skill is described as the capacity to interpret the mental states of others based on fundamental behavioral cues [3,5]. This capacity is thought to be evolutionary advantageous. Numerous efficient and explicit mechanisms that develop later in the course of transformation require social awareness to function [6]. Research on primates is seen as a helpful model for understanding social perception in humans since similar social behaviors have been seen in monkeys [7,8]. For instance, chimpanzees are able to comprehend what their peers are aware of in the context of competition for food. They can assist their fellow humans by using their knowledge of others' motivations [9,10]. According to research, Rhesus monkeys may estimate what other people are thinking based on what they hear and observe [11,12]. The fusiform gyrus (FFG), amygdala (AMY), orbitofrontal cortex (OFC), and posterior superior temporal sulcus (PSTS) all need to be active for dynamic social perception. In both humans and monkeys, these regions are selectively responsive to social cues and are linked in the primate brain [13,14].

In the network of social perception, PSTS is crucial. This region is directly connected to the major visual and auditory centers in both monkeys and humans, and it participates in the representation of information in both areas [15,16]. PSTS selectively activates against static social stimuli (such as faces) and dynamic and complex social information (such as changes in gaze direction or facial emotions) [16,17]. PSTS is sensitive to social stimuli that people interpret as deliberate [16] and is activated against static social stimuli (such as faces).

In comparison to non-target acts, PSTS exhibits more discriminating behavior toward intentional human behaviors that have social significance. The processing of emotional speech via PSTS is crucial in the auditory domain.

The FFG is comprised of a number of different but connected areas that are engaged in the visual facets of social perception along the ventral-temporal cortex. They include the fusiform face area (FFA), which responds to facial cues, and the fusiform body area (FBA), which only responds to physical stimuli. The FFA is sensitive to distinct fixation patterns and simple eye movements during implicit face processing [18]. In addition, FFA in facial identity recognition and goal-directed actions is involved [19]. AMY encodes the emotional significance of social information, especially when such information requires rapid and reflexive processing [20]. For example, the amygdala enhances gaze orientation toward facial features that contain socially relevant information, such as eyes, especially when facial expressions are associated with fear [21]. The OFC is related to the reward encoding of environmental sensory cues, which is a fundamental aspect of behavioral planning in humans as well as in primates [22]. Paying attention to socially rewarding stimuli, determining personal interest in social interactions, and responding to social cues [23] requires the activity of this area due to its central role in value-based decision-making.

Our knowledge of the social development and social deficiencies of people with autism spectrum disorders has been improved by studies that look at social perception in these diseases. Compared to normal children, children with autism spectrum disorders pay less attention to social cues such as voices and faces [24]. Children with autism spectrum disorders tend to place more emphasis on physical and non-social relationships than their typical classmates do at this age, failing to recognize the social significance of biological functions [25].

Social difficulties seen in autistic spectrum diseases in young children continue throughout adulthood. Autistic adults with high activity have difficulty inferring the mental states of others, vocalization, and emotional facial expressions [26]. According to these results, there is compelling evidence of aberrant cortical and subcortical social perception processing for somatosensory, auditory, and visual inputs. The AMY FFC and PSTS brain regions, which are involved in social perception, are less active in autistic children than in their non-autistic siblings when they are seen making displays or motions, according to studies in the domain of visual signals [27]. In particular, it appears that autism spectrum disorders show less selective PSTS area performance in social perception. Compared to normal people, the function of this area in people with autism spectrum disorders is less specific to evaluate the inconsistency of the actions of the characters in a show with their displayed preferences at the beginning. In the auditory domain, those with autism spectrum disorders have the same pattern of activity as the control group for non-vocal sounds, but the sound selection regions in PSTS become inactive in response to vocal sounds. In terms of somatosensory signals, individuals with high levels of autism features had decreased activity in the OFC and PSTS regions in response to a light touch of the arm [28,29].

The nervous system of action observation

While social perception is concerned with comprehending and interpreting the outward behaviors of others in order to infer their underlying intentions, the function of the perceiver is not entirely obvious. Another process that significantly depends on the perceiver himself is active when individuals react to the behaviors of others. An individual who is observing the behaviors of others may be attempting to comprehend what such actions would entail if he were to carry them out himself. Therefore, the role of a self-perceiver is important, and understanding the actions of others is to some extent self-based. This is the mechanism of the nervous system of perception or action observation. Perceivers must go beyond simple decoding in order to correctly match their behaviors with those that are being watched [30]. The perceiver must first see another person's activity in order to grasp it, and only then can they mentally mimic it. As a result, imitation and action perception are strongly connected. Mirror neurons, a subclass of visuomotor neurons first identified in the prefrontal cortex of monkeys, have received the majority of attention in studies investigating the neurological basis of action perception and observation. Mirror neurons have been identified in humans and monkeys in response to action observation and execution. Three interconnected brain regions make up the mirror nerve system in humans [31,32]: the parietal mirror neuron region, which contains the front section of the inferior parietal lobule (IPL) and offers low-level motor description of other people's movements; the PSTS area, which serves as an intra-visual area of the dynamics of other people's actions; High-level motor plans are created in the frontal mirror neuron area, which comprises the ventral premotor cortex (PMC) and posterior inferior frontal gyrus (IFG). The process of action perception in the mirror nervous system is a crossroads process [31].

The IPL and the IFG receive the data encrypted in the PSTS. The data is subsequently sent via the IFG to the IPL and PSTS. As a result, PSTS functions as both an input and an output area in the mirror nervous system, enabling comparison between seen activities and those that have been carried out. The study of action observation is still relatively new but is expanding quickly. While some studies have found that autistic children perform poorly in imitation activities or exhibit delayed development when compared to their typical counterparts, the question of whether there is a problem in the imitation process in autism is still up for dispute [33]. Other studies have reported the same performance in the field of imitation both in autistic children and in the control group [34, 35].

The mirror neuron system in autism disorder has been the subject of several neuroimaging investigations, with varying degrees of success. On the one hand, the outcomes of functional magnetic resonance imaging (MRI) studies suggest that kids with autism spectrum disorders display aberrant activity in particular areas of the mirror nerve system, such as TFG and IPL, when watching facial expressions or hand motions [36]. According to the electroencephalography (EEG) results, mu rhythm attenuation is typically observed in people going through normal neurodevelopment during observation and execution of hand movements. People with autism spectrum disorders do not exhibit mu rhythm suppression when watching an action. The neural activity of regions of the brain related to the mirror nervous system in persons with autism spectrum disorders and those in the control group, on the other hand, has not been observed to vary in other investigations [37,38]. It is interesting to note that research showing aberrant neural activity of the mirror nervous system typically employ emotional stimuli, whereas studies showing normal activity of the mirror nervous system typically utilize non-emotional stimuli [39]. There is a developing tendency in the research of the mirror nervous system, and work is still being done to rectify the way that the distinct roles played by the mirror nervous system's various brain regions are recognized.

Theory of mind and malfunction of neural systems

In the last two decades, theory of mind (also known as mentalizing or mental state reasoning) research has shed light on both typical and pathological social behavior. The capacity to anticipate connections between the internal states of the mind and the exterior conditions of circumstances is referred to as the theory of mind. To be able to do this, one must be able to distinguish their own reality from what others see [40]. Contrary to what is seen by others and what may be observed in the act of reasoning about mental states, it is thought to be a human-only ability that calls for significant cognitive resources and high levels of attention. People can successfully navigate the challenging social environment if they have the capacity to comprehend and forecast the mental states of others [41].

Wimmer and Perner conducted the famous Sally-Anne experiment on young toddlers in 1983 to test the theory of mind [42]. Children watch Sally and Anne, two dolls, as part of this exam. After placing the stone in her basket, Sally exits the room. She removes the stone from Sally's basket and places it in her box while she is not there. Participants in this test are required to respond to the following question : Where will Sally seek her stone when she enters the space again ? The children will answer that Sally will seek the rock in the basket that she placed it in if they are able to appreciate Sally's perspective, or, to put it another way, if they comprehend that Sally has a mistaken notion about the position of the rock. The clear grasp of another person's incorrect belief is a developmental milestone that children acquire around the age of four, according to developmental psychology experts who have used this test or variants of it. The second-level false belief tests are successfully completed by typical youngsters between the ages of 6-7 [43]. The development of more sophisticated mental-state reasoning, including moral judgment, occurs between puberty and maturity.

According to research, those who suffer from autism spectrum disorders exhibit deficiencies in their theory of mind. Even though they were approximately five years older than the other test subjects, children with autism spectrum disorders who completed Sally's task could not recognize Sally's incorrect notion [44]. According to the results of various studies that have compared mentalization skills in normal and abnormal children, failure to recognize false beliefs is considered a sign of more fundamental social deficiencies in autism spectrum disorders [45, 46]. Although those people with autism spectrum disorders who have medium or medium to high IQ learn to solve simple false belief tasks during the transformation, their performance in more advanced tests that are combined with complex social emotions and natural feelings shows that their shortcomings in the field of inferring mental states are stable in adulthood. Adults with high-functioning autism can understand false beliefs when tested, but they are not able to spontaneously predict false beliefs based on behavior [47]. An increase in knowledge about inferences about the mental states of both persons with these illnesses and healthy individuals has resulted from extensive study on the theory of mind in autism spectrum disorders utilizing a range of activities. Numerous neuroimaging studies have concentrated on the deficiencies in theory of mind in people with autism spectrum disorders. Studies that have investigated mentalization using static tasks have concluded that MPFC and TPI activity in people with autism spectrum disorders show a decrease compared to normal people, and the more severe the symptoms of these disorders are, the greater the decrease in the activity of these areas [48]. However, in another study, no difference was found between the neural activities during the story-oriented theory of mind task in these subjects compared to the subjects in the control group [49].

Overall, a vast number of recent studies suggest that individuals with autism spectrum disorders have atypical spatial activity patterns and lower activity of the fundamental mentalization regions, including TPJ and MPFC, while assuming the mental states of others.

CONCLUSION

The posterior superior temporal sulcus AMY, orbitofrontal cortex, and fusiform gyrus are among the brain regions involved in social perception. The results of studies that looked at the neural mechanisms of social information processing in the brains of people with autism spectrum disorders suggest that these individuals are in these regions as well. They exhibit decreased activity in the regions involved in action observation, such as the mirror nervous system and its three interconnected regions, the posterior cingulate cortex/pericaneus, inferior frontal gyrus, and inferior parietal lobule, as well as in the regions dedicated to theory of mind, such as the middle prefrontal cortex, temporal-parietal junction, PSTS, posterior cingulate cortex/pericaneus, and anterior temporal lobe. As a hub connecting these three systems, PSTS is particularly significant and plays a crucial part in the temporal integration of indicators of others' behavior from the senses of sight, sound, and touch, as well as intentional representation [50].

The capacity to create and integrate information throughout time into a cohesive whole in order to comprehend and predict when events will occur is known as temporal integration. This area must be active in order to forecast the temporal encoding of others' conduct [51], and improper activity in ASD makes it difficult to predict others' future behavior based on their past behavior, which is consistent with the recently proposed theory of poor temporal prediction in ASD [52]. Predictive impairment in autism (PIA) is a theory that claims ASD is linked to an erroneous state-by-state conditional probability estimate for an observed temporal sequence. The PIA hypothesis is significant because it offers a framework for comprehending some characteristics of ASD, such as sensory abnormalities, a preference for monotony, difficulties interacting with dynamic objects, difficulties with the theory of mind, and an aptitude for strictly rule-based disciplines like math, music, and computers. In light of this, it is intriguing to speculate that PSTS plays a role in the temporal integration of the essential components of the dynamic stimulus environment, particularly the integration of the visual and auditory systems. Future research should therefore focus on further examining PSTS's temporal integration and how it relates to the PIA hypothesis.

ACKNOWLEDGMENTS : None

CONFLICT OF INTEREST : None

FINANCIAL SUPPORT : None

ETHICS STATEMENT : None

REFERENCES

1. Samadi SA, McConkey R. Impacts on Iranian parents who have children with an Autism spectrum- disorder (ASD). J Intellect Disabil Res. 2014;58(3):243-54.
2. Alshammari ST, Turkistani HA, Almatar YI, Alhuraish AM, Hefni ST, Bagabir RA, et al. An Overview on Endodontic Irrigation Solution Role in Management. Int J Pharm Res Allied Sci. 2022;11(1):17-20.
3. Mcarthur LZ, Baron RM. Toward an ecological theory of social perception. Psychol Rev. 1983;90(3):215-38.
4. Manea TM, Khan FS, Alsharyufi RM, Alghamdi KM, Alzahrani MK, Alzubaidi FM, et al. An Overview on Thalassemia Diagnosis and Management Approach, Literature Review. Int J Pharm Res Allied Sci. 2021;10(2):103-7.
5. Morcy HM, Almatrafi ND, Bedaiwi AA, Almijlad AA, Bedaiwi SK, Alsharif NA. Overview on Screening and Prevalence of Ovarian Neoplasms in Saudi Arabia. Arch Pharm Pract. 2022;13(3):98-104.
6. Low J, Perner J. Implicit and explicit theory of mind: state of the art. Br J Dev Psychol. 2012;30(1):1-13.
7. Call J, Tomasello M. Does the chimpanzee have a theory of mind? 30 years later. Trends Cogn Sci. 2008;12(5):187-92.
8. Alruwaili SA, Alanazi YM, Alhumaidan RI, Alqahtani MM, Alasmari KA, Banh AG, et al. An overview on diagnostic & management approach of kidney stones. Pharmacophore. 2021;12(6):19-22.
9. Melis AP, Warneken F, Jensen K, Schneider AC, Call J, Tomasello M. Chimpanzees help conspecifics obtain food and non-food items. Proc Biol Sci. 2011;278(1710):1405-13.
10. Almudayni HK, Alhowaish RK, Alotaibi BM, Alshehri AM, Alqahtani AM, Tmraz SF, et al. An Overview on Hyperthyroidism, Evaluation and Management Approach in Primary Health Care Centre. Arch Pharm Pract. 2021;12(2):134-9.
11. Flombaum JI, Santos LR. Rhesus monkeys attribute perceptions to others. Curr Biol. 2005;15(5):447-52.
12. Awang ABC, Mutalip SSM, Mohamed R, Nordin M, Siew JSK, Dasiman R. A Review of the Effects of Vitamin E in Ovarian Cancer. Int J Pharm Res Allied Sci. 2022;11(2):81-5.
13. Ku SP, Tolias AS, Logothetis NK, Goense J. fMRI of the face-processing network in the ventral temporal lobe of awake and anesthetized macaques. Neuron. 2011;70(2):352-62.
14. Ali SI, Shahnaz S, Mumtaz T, Swaleh MM. Estimation of quality characteristics for sustained releasing and acting formulation of Domperidone. Pharmacophore. 2021;12(1):57-64.
15. Kreifelts B, Ethofer T, Shiozawa T, Grodd W, Wildgruber D. Cerebral representation of non-verbal emotional perception: fMRI reveals audiovisual integration area between voice- and face-sensitive regions in the superior temporal sulcus. Neuropsychologia. 2009;47(14):3059-66.
16. Jastorff J, Popivanov ID, Vogels R, Vanduffel W, Orban GA. Integration of shape and motion cues in biological motion processing in the monkey STS. Neu-roimage. 2010;60(2):911-21.
17. Gobbini MI, Haxby JV. Neural systems for recognition of familiar faces. Neuropsychologia. 2007;45(1):32-41.
18. Morris JP, Pelphrey KA, McCarthy G. Face processing without awareness in the right fusiform gyrus. Neuropsychologia. 2007b;45(13):3087-91.
19. Shultz S, McCarthy G. Goal-directed actions activate the face-sensitive posterior superior temporal sulcus and fusiform gyrus in the absence of human-like perceptual cues. Cereb Cortex. 2012;22(5):1098-106.
20. Adolphs R. The social brain: neural basis of social knowledge. Annu Rev Psychol. 2009;60:693-716.
21. Adolphs R. Fear, faces, and the human amygdala. Curr Opin Neurobiol. 2008;18(2):166-72.
22. Watson KK, Platt ML. Social signals in primate orbitofrontal cortex. Curr Biol. 2012;22(23):2268-73.
23. Wallis JD. Cross-species studies of orbitofrontal cortex and value-based decision-making. Nat Neurosci. 2012;15(1):13-9.
24. Chawarska K, Macari S, Shic F. Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism spectrum disorders. Biol Psychiatry. 2013;74(3):195-203.
25. Klin A, Lin DJ, Gorrindo P, Ramsay G, Jones W. Two-year-olds with autism orient to non-social contingencies rather than biological motion. Nature. 2009;459(7244):257-61.

26. Baron-Cohen S, Wheelwright S, Hill J, Raste Y, Plumb I. The “reading the mind in the eyes” test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. J Child Psychol Psychiatry. 2001;42(2):241-51.
27. Kaiser MD, Hudac CM, Shultz S, Lee SM, Cheung C, Berken AM, et al. Neural signatures of autism. Proc Natl Acad Sci USA. 2010;107(49):21223-8.
28. Gervais H, Belin P, Boddaert N, Leboyer M, Coez A, Sfaello I, et al. Abnormal cortical voice processing in autism. Nat Neurosci. 2004;7(8):801-2.
29. Voos AC, Pelphrey KA, Kaiser MD. Autistic traits are associated with diminished neural response to affective touch. Soc Cogn Affect Neurosci. 2013;8(4):378-86.
30. Williams JHG, Whiten A, Singh T. A systematic review of action imitation in autistic spectrum disorder. J Autism Dev Disord. 2004;34(3):285-99.
31. Iacoboni M, Dapretto M. The mirror neuron system and the consequences of its dysfunction. Nat Rev Neurosci. 2006;7(12):942-51.
32. Almisfer AN, Alabbad HA, AlHudaithy HAA, Alsultan NH, Alobairi OK, Ansari SH. Dental Students and Dentists’ Awareness in Handling Pediatric Patients Having Systematic Diseases In Riyadh. Ann Dent Spec. 2021;9(2):33-8. doi:10.51847/5asKbDAz77
33. Young GS, Rogers SJ, Hutman T, Rozga A, Sigman M, Ozonoff S. Imitation from 12 to 24 months in autism and typical development: a longitudinal Rasch analysis. Dev Psychol. 2011;47(6):1565-78.
34. Press C, Richardson D, Bird G. Intact imitation of emotional facial actions in autism spectrum conditions. Neuropsychologia. 2010;48(11):3291-7.
35. Kuchyn LI, Vlasenko MO, Gashenko AI, Mykytenko VP, Kucherenko II. Creating the Informational and Educational Environment of the University Based on the Distance Learning Platform LIKAR_NMU. Arch Pharm Pract. 2021;12(2):66-74. doi:10.51847/5zZerOAbwA
36. Martineau J, Andersson F, Barthelemy C, Cottier JP, Destrieux C. Atypical activation of the mirror neuron system during perception of hand motion in autism. Brain Res. 2010;1320:168-75.
37. Dinstein I, Thomas C, Humphreys K, Minshew N, Behrmann M, Heeger DJ. Normal movement selectivity in autism. Neuron. 2010;66(3):461-9.
38. Dehaghi AA, Dolatshahi B, Taremian F, Pourshahbaz A, Ansari H. Acceptance and Commitment Therapy with Islamic Aspects as A Treatment for Scrupulosity in A Case Study. J Organ Behav Res. 2022;7(2):95-108. doi:10.51847/Fa3ED8HrzB
39. Hamilton AFD. Reflecting on the mirror neuron system in autism: a systematic review of current theories. Dev Cogn Neurosci. 2013;3:91-105.
40. Blakemore SJ, den Ouden H, Choudhury S, Frith C. Adolescent development of the neural circuitry for thinking about intentions. Soc Cogn Affect Neurosci. 2007;2(2):130-9.
41. Wan C. Shared knowledge matters: culture as intersubjective representations. Soc Personal Psychol Compass. 2012;6(2):109-25.
42. Wimmer H, Perner J. Beliefs about beliefs: representation and constraining function of wrong beliefs in young children’s understanding of deception. Cognition. 1983;13(1):103-28.
43. Perner J, Wimmer H. John thinks that Mary thinks that – attribution of 2ndorder beliefs by 5-year-old to 10-year-old children. J Exp Child Psychol. 1985;39:437-71.
44. Baron-Cohen S, Leslie AM, Frith U. Does the autistic child have a “theory of mind”? Cognition. 1985;21(1):37-46.
45. Baron-Cohen S, Jolliffe T, Mortimore C, Robertson M. Another advanced test of theory of mind: evidence from very high functioning adults with autism or Asperger syndrome. J Child Psychol Psychiatry. 1997;38(7):813-22.
46. Leslie AM, Thaiss L. Domain specificity in conceptual development: neuropsychological evidence from autism. Cognition. 1992;43(3):225-51.
47. Senju A, Southgate V, White S, Frith U. Mindblind eyes: An absence of a spontaneous theory of mind in Asperger syndrome. Science. 2009;325(5942):883-5.
48. Happé F, Ehlers S, Fletcher P, Frith U, Johansson M, Gillberg C, et al. ‘Theory of mind’ in the brain. Evidence from a PET scan study of Asperger syndrome. Neuroreport. 1996;8(1):197-201.
49. Dufour N, Redcay E, Young L, Mavros PL, Moran JM, Triantafyllou C, et al. Similar brain activation during false belief tasks in a large sample of adults with and without autism. Plos One. 2013;8(9):754-68.

50. Hagan CC, Woods W, Johnson S, Green GGR, Young AW. Involvement of right STS in audio-visual integration for affective speech demonstrated using MEG. Plos One. 2013;8(8):1-12.
51. Friston KJ, Blakemore SJ. Effective connectivity during animacy perception – dynamic causal modeling of human connectome project data. Sci Rep. 2014;4(1):6240. doi:10.1038/srep06240
52. Sinha P, Kjelgaard MM, Gandhi TK, Tsourides K, Cardinaux AL, Pantazis D. Autism as a disorder of prediction. Proc Natl Acad Sci USA. 2014;111(42):15220-5.