



Impaired Face Perception in Individuals with Autism Spectrum Disorder: Insights on Diagnosis and Treatment

Taiyong Bi¹ · Fang Fang²

Received: 28 August 2017 / Accepted: 9 October 2017 / Published online: 9 November 2017
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Autism spectrum disorder (ASD) is a neurodevelopment disorder characterized by impaired social interaction and communication along with restricted and repetitive behavior. For a long period of time, ASD was considered to be a rare mental disorder, with a prevalence of less than 1/100,000. However, the prevalence of diagnosed ASD has increased rapidly in recent years to approximately 1/100 in the USA. Relative epidemiological investigations have not yet been performed across China because of the complex public health situation and insufficient public awareness. ASD children are usually considered peculiar and suffer prejudice. Unfortunately, this disorder is very hard to cure and continues to develop during adolescence and adulthood [1]. As a result, ASD has become a serious public issue in our society and deserves much more attention from scientists in revealing the mechanisms underlying the disorder and developing effective treatments.

Hereditary factors have been shown to be important in the pathogenesis of ASD [2]. Evidence from twin studies has shown that the risk of an individual having ASD is > 90% if the monozygotic twin is also diagnosed as having ASD [3]. Biologists and geneticists have worked tirelessly to reveal the underlying genetic mechanism of ASD, and achieved many significant findings. For example, *Ambra1* deficiency has been shown to result in autism-like phenotypes in female mice, and suggests a role of

autophagy deregulation in the pathology of autism [4]. However, this work remains far from fully elucidating the heritable causes of ASD. To our knowledge, ASD is a complex genetic disorder with abnormalities in thousands of genes, copy number variants, and linkage regions [5]. As such, a tremendous amount of research is needed to find the determinant gene changes and develop an effective method of diagnosis and treatment based on these findings. Psychologists and psychiatrists address the issue from another perspective. It should be noted that ASD individuals usually have multiple cognitive and behavioral deficits. For example, restricted and repetitive behaviors are typical indicators of ASD. In particular, the “twin” nonapeptides oxytocin and arginine-vasopressin, which play regulatory roles in social behaviors, have been associated with specific autistic symptoms [6]. Accordingly, sensorimotor systems were found to be abnormal in individuals with ASD [7]. Similar dysfunctions have also been found in the language system [8]. Given these findings of specific impairments in ASD, we may expect to establish an effective and efficient screening system for ASD. Furthermore, relevant training programs may also be developed to improve these functions.

Most individuals with ASD have problems in social interaction and social communication. One of the reasons for this difficulty might be the impaired face perception that usually accompanies ASD. Human faces contain information critical to interpersonal interaction, such as face identity, facial expression, and gaze direction. Numerous studies have revealed that perceptions of the face and facial affect, as well as their neural processing, are largely impaired in ASD individuals [9]. A typical task to test face perception is the face recognition task. In such a task, one or more face stimuli are first presented to the observer. Seconds or minutes later, another face stimulus is

✉ Fang Fang
ffang@pku.edu.cn

¹ School of Management, Zunyi Medical University, Guizhou 563000, China

² School of Psychological and Cognitive Sciences, Peking University, Beijing 100871, China

presented. Observers are then instructed to indicate whether the face stimulus is novel or not. This task has been shown to be very reliable and sensitive in identifying individuals with selective impairments in face processing and thus might be a promising test in ASD diagnosis [10].

Our neural system has specific circuitries to process face stimuli. For example, the circuitry used to process face identity includes the lateral occipital cortex, fusiform area, and anterior temporal cortex. The emotional information of the face may be processed by the superior temporal cortex, amygdala, and insula. The normal functioning of each region and interregional connection forms the basis of face perception. Given that face perception is selectively impaired in ASD, it follows that neurophysiological studies have found corresponding dysfunctions in the human visual system. Recently, a functional magnetic imaging (fMRI) study investigated this issue using the paradigm of repetition suppression (RS) [11]. RS is the effect that arises when the response of the human brain to repetitively presented stimuli is weaker than its response to unrepeatable stimuli. RS is often used to measure the response selectivity of human visual areas [12]. Ewbank *et al.* [11] found that in the fusiform gyrus region, the RS effect of face stimuli was much weaker in the ASD group than in the control group, showing a selective impairment of face processing in this area. Similarly, Kleinhans *et al.* [13] investigated the RS effect to fearful faces and found reduced RS effects in the fusiform area and amygdala. Meta-analysis studies have shown that the function of the left fusiform area is most consistently found to be atypical in the face identity processing of ASD individuals [14] and that the function of subcortical structures, such as the amygdala, hypothalamus, and basal ganglia, is usually abnormal in facial emotion processing [15].

The question remains whether we can discriminate ASD individuals from others based on these neurophysiological abnormalities. Recent studies have made preliminary efforts on this issue. As previously mentioned, Kleinhans *et al.* [13] found a reduced RS effect in the amygdala and fusiform gyrus. They then tried to discriminate ASD individuals from typically developing controls based on the RS effects. The response in the left amygdala showed the strongest discriminability, with an accuracy of 71%. From a more data-driven aspect, Chanel *et al.* [16] measured the activation pattern of the whole brain to face and body stimuli and used machine learning techniques to classify the ASD and control groups. The overall accuracy of classification was 69% based on the response to static faces and 92% based on the response to dynamic bodies. Although the discrimination accuracies are far from applicable in the clinical diagnosis of ASD, these preliminary results have shed light on a possible way of diagnosing ASD effectively and efficiently. Furthermore,

searching for effective biomarkers is important and challenging in the field of ASD research [17]. These results also indicate candidate biomarkers in ASD. Further studies may examine different tasks and analyses to improve discrimination performance.

Given that face perception is the core feature of interpersonal interaction, it is important to find a way to improve the impaired functioning in this skill among ASD individuals. Indeed, it is possible to improve the ability to recognize faces with training. One of the most effective ways of training is perceptual learning. Perceptual learning is the phenomenon that training can improve the discrimination and recognition of visual features or objects. For example, Bi *et al.* [18] asked healthy participants to discriminate the viewpoint of faces. Every participant was trained to perform this task one thousand times each day for a total of eight days. With such intensive training, they found that their ability to discriminate face viewpoints increased by $\sim 40\%$ relative to their performance before training. Similar results have been obtained in face recognition tasks [19], face detection tasks [20], and facial expression discrimination tasks [21]. Importantly, the behavioral improvement in face discrimination was shown to be accompanied by improvement in the functioning of the human fusiform area [22]. Thus, this might be a reliable method to improve both behavioral performance and brain functions. Future studies should investigate how to apply this approach to ASD groups.

In conclusion, face perception is impaired in individuals with ASD. Neurophysiological evidence shows a selective dysfunction in the neural circuitry that processes face information. Current studies on impaired face perception indicate several possible ways to recognize and treat ASD individuals. However, these findings are far from serving as clinical diagnosis and treatment. Further research is needed on these topics.

Acknowledgements This perspective review was supported by the National Natural Science Foundation of China (31400960).

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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