

Face-like pareidolia images are more difficult to detect than real faces in children with autism spectrum disorder

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Abstract

Background. Research on the diagnosis, treatment and pathophysiology of neurodevelopmental disorders is multifaceted, requiring the use of genetics, imaging, psychology, and artificial intelligence (AI). Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by a limited ability to communicate and a limited interest in social environments. Facial recognition is really important in daily life. Seeing faces in unusual objects, e.g., a face in a cloud, is called face pareidolia.

Objectives. Although more evidence points to a greater role of genetic factors in ASD, neuropsychological tests have an important role in diagnosing ASD. The aim of the study was to investigate how face perception is processed in children with autism using a new digital test that consists of faces and pareidolia images.

Materials and methods. Twenty typically developing (TD) children (8 male, 12 female) between 6 and 16 years of age and 21 children with ASD (14 male, 7 female) between 6 and 14 years of age were included in the study. A new neuropsychological test called the digital pareidolia test was administered to the participants. The study consisted of 2 stages: a face condition and a pareidolia condition.

Results. Our results showed that children with autism ($n = 21$) were less successful in identifying both face and pareidolia images, and were slower to react in both conditions than children from the TD group. Both children with ASD and the TD group reacted faster to face images than pareidolia images.

Conclusions. The findings in this study are in agreement with atypical and different face perceptions in autism which cause social difficulties. We demonstrated that the digital face and pareidolia test has considerable potential for use as a neuropsychological test that can specify the diagnosis and progression of autism in subclinical areas. Pareidolia faces and real faces are processed in a common way.

Key words: autism spectrum disorders, face, face perception, pareidolia, face-like images

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Background

Recent approach to neurological diseases is not unidirectional but requires multidirectional research in areas such as genetics, imaging, diagnostic testing, treatment, and disease course. For example, to cure neurological diseases, norepinephrine transporter inhibitors are used to change neurotransmitter gradients in the brain.¹ Additionally, in 1 study, researchers used a faster protocol for converting circulating monocytes to neuron-like cells which express neuronal marker genes.²

Autism spectrum disorder (ASD) is a neurodevelopmental disorder defined as the reduced ability to communicate in social environments, repetitive behaviors and limited interests.³ Many factors that affect ASD, such as the disruption of mitochondrial DNA functions, have been identified as a cause of metabolic diseases and have been investigated in relation to the pathogenesis of neurodegenerative diseases. Mitochondrial functions become less flexible under constant stress where mitochondrial functions are compromised. Neurological and psychiatric disorders have also been associated with the activation of the tryptophan–kynurenine (Trp–Kyn) pathway, which contributes to the formation of stress and inflammatory pathological conditions.⁴ The Trp–Kyn pathway, its correlation with the immune system, tolerogenic shift against low-grade inflammation, and the relation of this pathway with the autism spectrum, one of the major psychiatric diseases, have also been examined.⁵

The effects of statin therapy in patients with ASD, anxiety and many other neurological disorders, as well as the side effects of medicines are often examined for the risks they are related to in patients with autism.⁶ A study by Lee et al. indicated that maternal immune activation increases the ASD risk in rat infants.⁷ They analyzed microbiota profile, behavior, anxiety-like recurrent behavior, and myelination levels in rat infants. These rat infants had a brain–gut–microbiota axis with hypomyelination, autism-like microbiota profile, behavioral deficits,

and exhibited anxiety-like and recurring behavior.⁷ In another study, Abuaish et al. found that gastrointestinal problems and gut bacteria dysbiosis, such as *Clostridium* explosion, are related to autism.⁸ The researchers examined 2 methods to control the microbiota in an autistic rat and how they affected the rat's behaviors: 1) different fecal *Clostridium* spp. and grades and 2) hippocampal transcript levels. Their results suggest that preclinical intervention and the brain–gut axis are related to the etiology of autism.⁸ Not only gut bacteria are related to behaviors; the Pavlovian-instrumental transfer can be used to guide behaviors. Researchers conducted Pavlovian-instrumental transfers in 100 participants and found a link between outcome-specific Pavlovian-instrumental transfer and individual working memory. The most important finding is that working memory is not associated with the balance between congruent and incongruent choices. The obtained results can be interpreted for human behavior.⁹

Faces are really important in communication. Seeing faces where there are none, e.g., likening a house to a face, is called face pareidolia. When we compared the previous evidence with the new results, it became clear that neurological disorder patients adapt to social signals less than healthy people.¹⁰ Therefore, interpersonal space is very important for these patients. Such space is described as the distance people keep between themselves and other people. Candini et al. suggested a connection between neurobehavioral components of interpersonal space and fundamental physiological processes.¹¹ In a study by El-lena et al., healthy volunteers' skin conductance responses were measured when observing 3D avatar images of joyful, fearful and neutral faces getting closer.¹² It was found that responses to fearful faces were modulated by distance, yet it did not apply to joyful and neutral faces.

Although atypical face perception is not among the diagnostic criteria for ASD, a study has shown that it is common in this population.¹³ Since the recognition of a person's face is a critical aspect of everyday social interactions, it has been studied in ASD.¹⁴ For example, children with

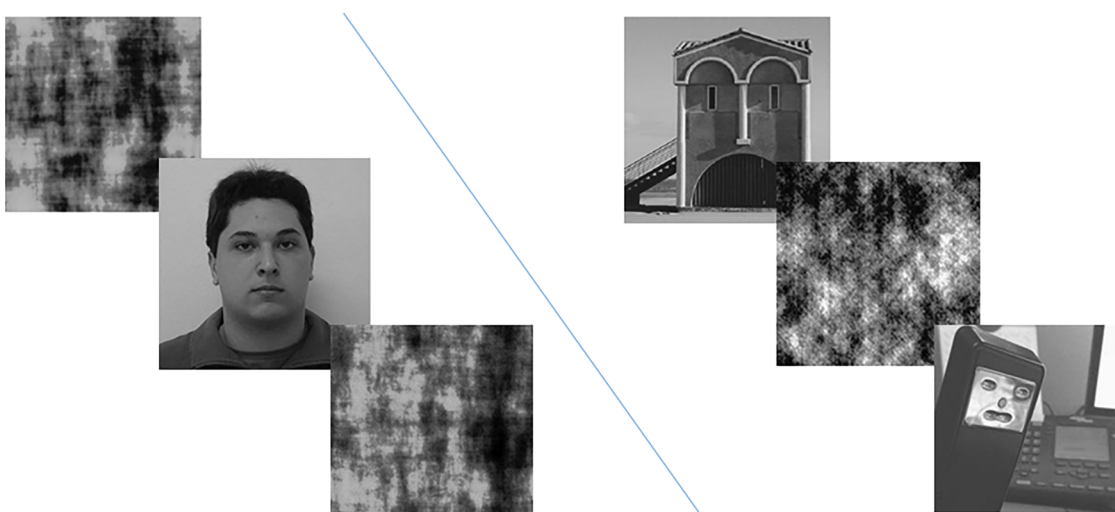


Fig. 1. Examples of presented face and pareidolia images

ASD have difficulties in recognizing facial identity, utilizing facial cues and perceiving face motion.^{15–17}

A study revealed that children with autism not only have difficulties with face perception but also with the perception of illusory faces and face-like images.¹⁸ It was observed that children and teenagers with ASD responded to face and pareidolia images less than the typically developing (TD) group and had a higher threshold in recognizing faces.¹⁹ Despite these results, studies examining the relationship between autism and pareidolia are limited.

As mentioned earlier, face pareidolia refers to confusing inanimate objects with faces.²⁰ Apart from visual pareidolia, there is also noise pareidolia, in which people hear human voices in different, nonhuman noises.²¹ Williams and Blagrove examined human voice perception from electronic voices and showed relationships between Highly Sensitive Person Scale points and detection of ambiguous stimuli which were electronic voices.²²

Objectives

A new review pointed out that not only establishing the diagnostic criteria in psychiatric disorders but also the research on neurodevelopmental disorders benefit from preclinical studies.²³ Neurological disorders such as schizophrenia and autism are connected to the lack of neuronal construction.² Although ASD can be detected using point mutations, chromosome anomalies and micro-aberrations,²⁴ new neuroimaging and neuropsychological tests should be developed for diagnosis.

We aimed to examine whether children with ASD and TD children differ from each other in terms of responses to faces and pareidolia images.

Materials and methods

Akdeniz showed that face and face pareidolia perception are processed in the early phases of visual perception.²⁵ Another study infers that pareidolia is a mirroring of the visual system which perceives human faces as well as evocative and cognitive connection.²⁰ Based on this information, we tested pareidolia in 21 children with ASD and 20 TD children, after obtaining the consent of their parents. Children in the ASD group were diagnosed by an expert clinician using the Diagnostic and Statistical Manual of Mental Disorders (DSM 5) criteria.¹ None of the children had a comorbid disorder or disease. Additionally, results of the physical and neurological examinations of all the children were within the normal ranges and none of the children used any medications. Table 1 shows the demographics of the participants. The average performance IQ of both groups was similar. Moreover, parents completed a test to determine their child's inattention and hyperactivity/impulsivity. Attention deficit was higher

Table 1. Demographics of the participants

Characteristics		TD (n = 20)	ASD (n = 21)
Age, median (Q1, Q3)		12.0 (6.25, 14.75)	10 (8, 11)
Male/female		8/12	14/7
Age at diagnosis	<2 years	–	1
	2–3 years		4
	4–6 years		11
	7–11 years		3
	>12 years		1
Performance IQ, median (Q1, Q3)		96 (80, 103)	93 (80, 101)
Verbal IQ, median (Q1, Q3)		92 (81, 102)	89 (74, 97)
Inattention, median (Q1, Q3)		2 (0, 5)	6 (1, 8)
Hyperactivity/impulsivity, median (Q1, Q3)		2 (0, 4)	5 (2, 7)
Disruptive behavior [%]		20.71	37.42

TD – typically developing; ASD – autism spectrum disorder; Q1 – 1st quartile; Q3 – 3rd quartile.

in children with autism than in healthy children, and more parents stated that these children exhibited destructive behaviors. This study was carried out with the approval of the ethics committee of the Dr. Sami Ulus Maternity and Children Training and Research Hospital (Ankara, Turkey; approval No. E-21/02-094).

Sixty photographs with equal numbers of faces, face scrambles, pareidolia images, and pareidolia scrambles were used in this study (Fig. 1). Scrambled photos were disordered versions of faces and pareidolia photos, and were prepared using MATLAB software (MathWorks, Natick, USA). Pareidolia and face images were equal in size, tone and intensity of light, and all images presented neutral faces. All photos were transformed into digital form and loaded into Google Forms platform (Google, Mountain View, USA). The study consisted of 2 stages: a face condition and a pareidolia condition. In both conditions, the photos were shown one by one as a sequence of faces and scrambles, and the children were instructed to press the button when they saw a face or face-like photo on the screen. Scrambled images were non-target stimuli; therefore, they were not included in the statistical analyses. In addition to the reaction time to face or face-like images, whether the children recognized them or not was recorded as “yes” or “no”.

Statistical analyses

All statistical analyses were conducted using IBM SPSS v. 24 software (IBM Corp., Armonk, USA). A value of $p < 0.05$ was considered statistically significant. Since the sample size was small, the Shapiro–Wilk test was used to analyze whether the participants were normally distributed. It was found that the distribution of variables departed significantly from normality. Based on this outcome, the median (1st quartile (Q1), 3rd quartile (Q3)) scores of all the data were analyzed using descriptive statistics

to report response variables and demographic information of the participants. In addition, descriptive statistics were used to detect the number of correct responses and the accuracy rate. The Mann–Whitney U nonparametric test was used to analyze whether the means of the ASD and TD groups differed significantly in face and pareidolia conditions. Differences in reaction time and accuracy rate between the face and pareidolia conditions within the groups were also investigated and compared with each other.

Results

Twenty TD children (8 male, 12 female) whose age ranged between 6 and 16 (median = 12, Q1 = 6.25, Q3 = 14.75) and 21 children with ASD (14 male, 7 female) who were between 6 and 14 years of age (median = 10, Q1 = 8, Q3 = 11) participated in the study (Table 1).

In terms of the face condition, the median (Q1, Q3) score for reaction time was 2.67 s (1.76, 3.45) in children with ASD, while it was 1.14 s (0.96, 1.27) in the TD children. For the pareidolia condition, the median (Q1, Q3) score for reaction time was 2.55 s (2.32, 3.54) in children with ASD, while it was 1.20 s (1.04, 1.57) in the healthy children (Table 2). As the mean scores for reaction time show, both children in the ASD and TD groups reacted faster to face images than to pareidolia images. However, TD children exhibited larger differences in reaction times between face and pareidolia conditions than children with ASD (Fig. 2).

The Mann–Whitney U nonparametric tests were applied to assess whether the ASD and TD groups differed significantly for the 2 conditions. The results showed that children with ASD reacted significantly later to both face images ($Z = -4.36$, $p = 0.001$) and pareidolia images ($Z = -3.47$, $p < 0.001$) than TD children (Table 2).

The accuracy rate was defined as the percentages of correct responses to each face and pareidolia image by TD children and children with ASD. Even though TD children achieved a 100% accuracy rate for each face image, just 7 out of the 15 face images were responded to with an accuracy rate of 100% by children with ASD. However, since the ASD group achieved 95.2% accuracy in other face images, there were no significant differences between the 2 groups.

For the pareidolia paradigm, the mean accuracy was 96% in healthy children, whereas the mean for children with ASD was 83%. Ten out of 15 pareidolia images were responded to by healthy children with a 100% accuracy rate. However, just the 1st pareidolia image had the greatest

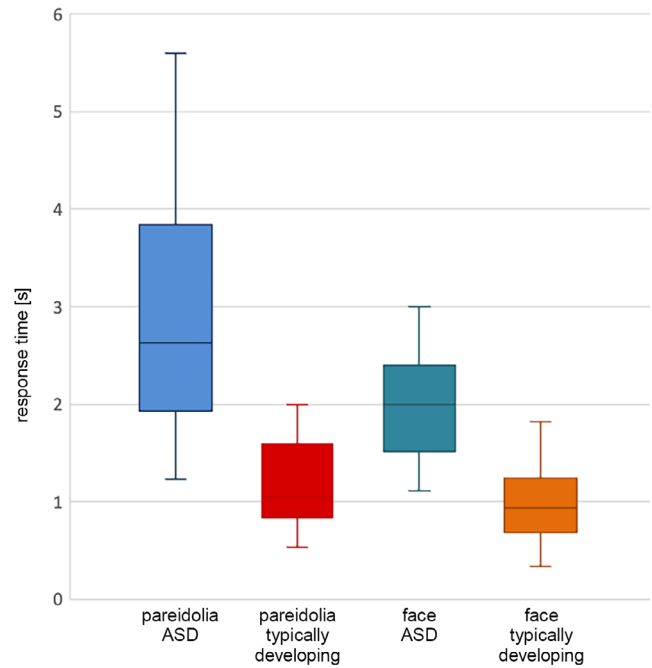


Fig. 2. Comparison of the response time of typically developing (TD) and autism spectrum disorder (ASD) groups to the first images of face and pareidolia images

accuracy rate in children with ASD, which was 90.4%. Moreover, the lowest accuracy rate was 85% in the TD group, while it was 52.3% in the ASD group. The lowest accuracy rates were related to the same pareidolia images, which were the 3rd and 12th images in the 2 groups. Regarding this, the greatest difference in accuracy rates between the TD children and the ASD group again concerned the 3rd and 12th pareidolia images (Fig. 3).

No statistically significant difference was observed when comparing ASD children's disruptive behaviors with the TD group. Responses to stimuli, such as face and pareidolia, affected the participants' performances differently. Also, the age of children with autism did not affect their responses to stimuli.

Discussion

Studies that explore how visual face processing occurs in children with autism are needed. The precise reason for the disordering of face perception in ASD has not yet been fully identified. In this study, we examined whether children with ASD differ from TD children using a new test,

Table 2. Comparison of the groups according to the reaction time for face and pareidolia images

Type of images	RT-TD, median (Q1, Q3)	RT-ASD, median (Q1, Q3)	t; Z	p-value
Pareidolia	1.20 (1.04, 1.57)	2.55 (2.32, 3.54)	-3.47*	0.001
Face	1.14 (0.96, 1.27)	2.67 (1.76, 3.45)	-4.36*	<0.001

RT – reaction time; TD – typically developing; ASD – autism spectrum disorder; Q1 – 1st quartile; Q3 – 3rd quartile; * Mann–Whitney U test (other – Mann–Whitney U nonparametric test).

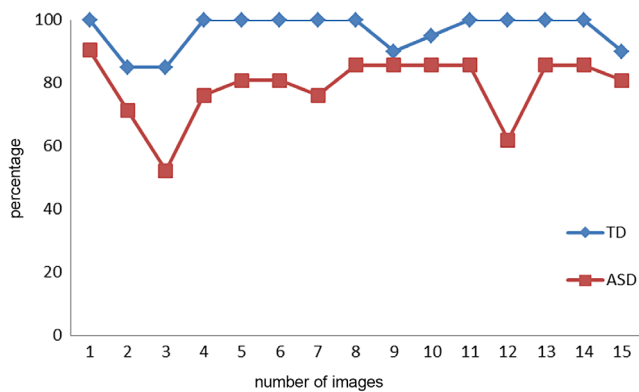


Fig. 3. Percentage of children accurately identifying each of the 15 pareidolia images

TD – typically developing; ASD – autism spectrum disorder.

which utilizes digital face and pareidolia images, to understand how face perception is processed in the brain. Our study had 2 remarkable outcomes. First, the results showed that children with ASD respond to both face and pareidolia images significantly later than TD children. Second, the ASD group had a significantly lower accuracy rate than the controls for pareidolia images, although the 2 groups did not significantly differ from each other in terms of the accuracy rate for face images.

Behaviors may be triggered by emotions. Battaglia et al. examined action control capability changes in 60 volunteers via stop-signal task, and used happy, fearful and neutral body postures in an experimental study. They found that both happy and fearful body postures improved the ability to suppress a current action compared to neutral body postures.²⁶ Emotional expressions are related to gaze cues. From the information obtained as a result of noninvasive brain stimulation, it has been shown that the perception of gaze cues occurs in the amygdala and superior temporal sulcus (STS) regions of the brain.²⁷ The gaze cue refers to communicating with the gaze direction of others that causes the attention to be directed reflexively and the spatial position of the object to be perceived more quickly.²⁷

Emotional expressions are vital for communication and behavior. Quick processing of interpersonal emotional perceptions in the brain is important in social life. Borgomaneri et al. showed happy, neutral and fearful images to healthy volunteers during transcranial magnetic stimulation. Corticospinal excitability increased in the healthy volunteers' right motor cortex when they were looking at fearful and happy images in comparison to neutral images.²⁸

In a review of ASD studies, the striatum and cerebellum were associated with changed cognitive, motor and sensory functions.²⁹ Motor functions are mostly associated with Purkinje cell loss and social dysfunction, which can help with the early diagnosis and valued perspective of the disorder.²⁹ As we learn more and more about the pathophysiology of the disorder, we can develop more efficient treatments, find ways to avoid the disorder, and more accurately

diagnose it. Considering the results of a study that classified the predominant neural endophenotypes of autism, scientists who study different aspects of ASD need to work together to obtain significant data.³⁰ Due to complexity of these studies neuropsychological tests can be considered a priority and promising area in neuroscience.

Another research on the pathophysiology of neurological disorders is a study of 52 people between 5 and 10 years of age, in which 26 people with autism and 26 healthy controls were examined for brain abnormalities using structural magnetic resonance imaging (sMRI) images from the Autism Brain Imaging Data Exchange (ABIDE) database. The findings showed white matter, gray matter volume and total brain volume increase in the Hammers Atlas of autistic participants. Using sMRI, we can identify the abnormal structural brain regions and their connection with ASD, which can help accurately diagnose autism early. We are even able to improve personal treatment by examining abnormal brain regions and seeing effectiveness of the treatment.³¹ However, it is difficult and expensive to apply sMRI in practice. For this reason, even the researchers took the images from the ABIDE database. The digital pareidolia test we recommend is usable, inexpensive and accessible.

Face and face pareidolia perception in neurological disorders is still not precisely elucidated. Poor performance in face perception tests is unlikely to be understood taking into account only divergent general cognitive abilities, but it can be understood in perceptual integration and social cognition.³² This outcome provides a novel understanding of the origins of face perception in ASD and induces neuropsychological neuroscience research. Face pareidolia is a complex visual illusion where a meaningful object is perceived as a result of seeing random patterns that resemble a face.³³ We found that the ASD group reacted to pareidolia images later and had lower accuracy rates than the TD group. Similarly, a previous study revealed that people with ASD had a significantly higher threshold to recognize face-like images. The ASD patients did not recognize the images that were easily recognized by the TD group and they gave fewer responses to faces.¹⁹ Furthermore, children with ASD could define fewer pareidolia faces than their TD peers, even though the 2 groups did not differ in terms of the number of total defined objects.¹⁸ Our results are consistent with those of the previous studies.

We found that children with autism showed poor performance in terms of face perception. These results are in line with previous studies which showed that children with ASD have different or atypical face processing. For example, Pierce revealed that subject-specific regions (e.g., frontal cortex, primary visual cortex) located opposite to the fusiform face area (FFA) that is active when looking at faces in normal individuals were activated in ASD individuals, meaning that they use different neural pathways to recognize faces.³⁴ In addition, Hadjikhani et al. observed that the right amygdala, inferior frontal cortex (IFC), STS, and face-related somatosensory and premotor cortex, which are involved in face perception,

showed hypoactivity in ASD adults.³⁵ Moreover, some researchers claimed that individuals with ASD showed an atypically weak central coherence which is required to unite sensory information in a holistic way; therefore, children with ASD perceived faces in a piecemeal manner.^{36,37} However, another recent study revealed that children with autism were able to perceive holistically face-like objects like the TD group after looking at the stimuli, even though the TD group was significantly more likely to exhibit faster response.³⁸ Our results are consistent with the previous studies.^{36,37} We believe these results can be attributed to the slower process of neural mechanisms of facial recognition in children with autism compared to the TD group.

We found that children with ASD showed poor performance in both face and pareidolia conditions. In a study consistent with our results, Rahman and van Boxtel reported that it is harder to perceive non-face stimuli as faces compared to real faces.³⁹ Findings suggest that face perception in general and in face pareidolia is not related to autism-like traits but to a person's age. Perception ability and inversion effect do not adhere to autism-like traits.³⁹ It can be explained by the fact that both real and pareidolia face perception require coaction between top-down and bottom-up processing in the FFA, frontal and occipitotemporal areas of the brain.⁴⁰ Atypical activation of areas involving face perception in ASD children may also cause the atypical perception of pareidolia faces.³⁵ On the other hand, the activation of the right prefrontal cortex (PFC) was observed during both real and illusory face processing.⁴⁰ Considering the abovementioned findings, we suppose that overgrowth and neural dysfunction in multiple brain regions may cause the early mechanisms of autism. However, some studies which are not consistent with our interpretation suggest that abnormalities in the PFC of children with ASD are mainly seen in the medial and dorsolateral parts of the brain responsible for executive functions, not processing faces.^{41–43}

In the future, our new pareidolia test should be used in adults with autism and other psychiatric disorders and the results should be compared. There are more degenerative in cognitive processes in bipolar and schizophrenia diseases.⁴⁴ Moreover, further information could be obtained if the parents or siblings of the participating children would also be tested.

Limitations

The present study has some limitations. The fact that the number of male participants was twice the number of female participants in the ASD group may have affected the results, since males have a higher risk of developing ASD than females by a ratio of 4:1.⁴⁵ Furthermore, it was suggested that males and females with ASD have different neuroanatomical abnormalities, and males with ASD have greater impairment in recognizing faces.^{46,47} Technological problems during the application of the digital test were another limitations.

Conclusions

Currently, scientists examine whether there can be spatial attention induced by gaze cues of face-like objects. The findings show that face-like objects are not just an illusion of real faces but also activate the extra face-specific attentional process.⁴⁸ Detecting facial expressions shows a positive sequential dependency. We are more likely to perceive face-like expressions on objects as the same as the previously seen expression, and this is the same for real human faces as well.⁴⁹ Pareidolia is associated with many mechanisms; for example, dysfunction of the right striatum is connected with pareidolia in patients with Parkinson's disease.⁵⁰

This study indicates that children with ASD displayed poor performance in reacting to face and pareidolia images and recognized those images less correctly when compared to their TD peers. Clinicians need new reliable and accurate noninvasive tests to specify situations during the diagnosis and treatment of autism. The digital face and pareidolia test may be a new promising neuropsychological test of the subclinical areas to be used in children.

The take-home message is understanding that the roles of expression processing and facial features are not inseparable, but pareidolia faces and real faces are perceived by the brain in a similar way.

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