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Comparing Face and Object Discrimination in Neurotypical Adults and Adults with Autism: A Morphing Paradigm

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Recognizing faces and objects are essential perceptual skills for human survival. Previous studies exploring face and object perception in individuals with autism spectrum disorder (ASD) reported inconclusive results. Some studies suggested that adults with ASD exhibited impaired face processing but spared object perception; in contrast, other studies showed unimpaired face processing and enhanced object perception, suggesting superior featural-based processing in ASD. However, most studies did not control the task difficulties of face and object discrimination. Hence, we adopted the morphing technique to control physical similarities among the stimuli with equated task difficulties. Using computerized morphing face/object discrimination tasks, we investigated whether adults with ASD are impaired in holistic processing or enhanced in featural processing. We also explored the correlations between individual Autism-spectrum Quotient (AQ) scores and their task performances. Twenty-four adults with ASD and 24 NT adults received the morphing face/object discrimination task, and their accuracies were measured. The results showed that: For the morphing face discrimination task, the mean accuracies were not significantly different between the two groups; however, the estimated discrimination threshold of the ASD group (33.12%) was significantly higher than the NT group (25.87%). For the morphing object discrimination task, both groups had the same mean accuracies and estimated discrimination thresholds (ASD: 21.67%; NT: 23.12%). Lastly, the trend analyses revealed a significant linear component in the ASD group for both face and object tasks, while the NT group showed linear as well as quadratic components. In sum, the present study demonstrated that, compared to neurotypical adults, adults with ASD exhibited a larger discrimination threshold for morphing face, indicating impaired holistic processing. Additionally, the linear trend suggests that adults with ASD compensatorily relied on featural-based processing when differentiating among morphing images of faces and objects.

Keywords: *autism spectrum disorder, face perception, object perception, morphing paradigm*

Extended Abstract

According to the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*–5; APA, 2013), individuals with autism spectrum disorder (ASD) exhibit difficulties with social communication and interaction, restricted interests and repetitive behaviors. Recognizing faces and objects are essential perceptual skills for human survival. Although deficient face processing is not a core clinical criterion for ASD, many studies have reported abnormalities in face processing or reduced attention to faces in individuals with ASD compared with neurotypical (NT) adults, such as difficulties in memorizing faces (Weigelt et al., 2012), difficulties in recognizing faces

(Faja et al., 2007; Gepner et al., 1996; Wilson et al., 2010), abnormal eye gazes (Senju et al., 2004; Senjuuchi et al., 2003), and atypical visual scanning of facial features (Klin et al., 2002; Osterling et al., 2002).

Unlike featural processing, which characterizes object perception, holistic or configural processing is the hallmark of face perception in humans. The face inversion effect (FIE) is commonly applied to assess the involvement of holistic/configural processing. When faces are inverted, recognition accuracy is drastically diminished because inversion greatly interrupts configural processing (Yin, 1969). Hence, the size of the FIE can be considered to indicate an individual's reliance on holistic processing. Some studies based on the inversion paradigm reported that the FIE in individuals with ASD was significantly smaller than that of NT controls (Rose et al., 2007; Tantam et al., 1989). However, other studies found that the size of the FIE in the ASD group was not different from that of NT controls, suggesting that autistic individuals use holistic processing to some extent (Bar-Haim et al., 2006; Joseph & Tanaka, 2003; Teunisse & de Gelder, 2003).

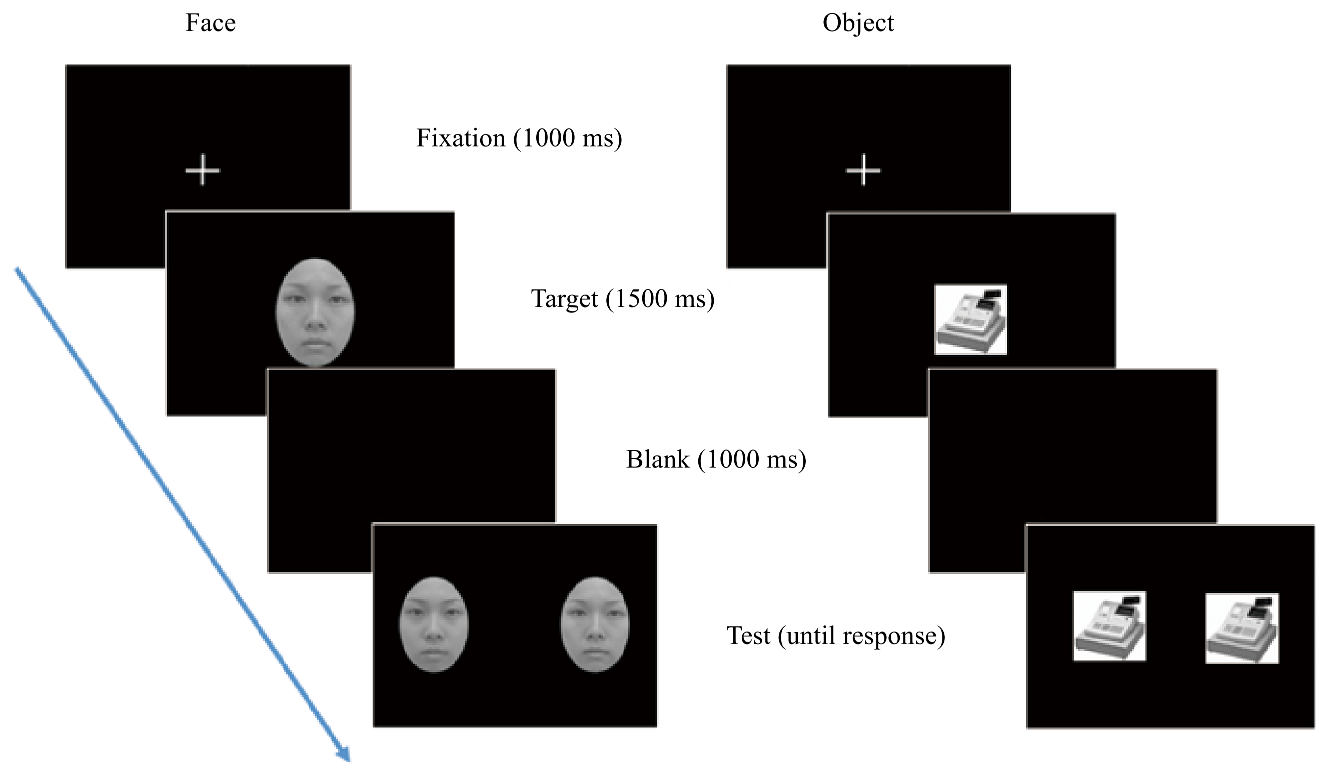
Studies exploring face and object perception in individuals with ASD have reported inconclusive results. Some studies suggested that adults with ASD exhibited impaired face processing but spared object perception (e.g., Wolf et al., 2008); other studies found unimpaired face processing and enhanced object perception, suggesting superior feature-based processing among individuals with ASD. For example, Pallette et al. (2014) used morphing techniques with object and face discrimination tasks to examine perceptual sensitivity in adolescents with ASD and their NT peers. They found that adolescents with ASD performed better than their NT peers in the object discrimination tasks, and equally well in the face discrimination task. Using a similar morphing paradigm, Hsiung and Chien (2017) designed morphing card-ordering tasks with object and face stimuli to explore fine perceptual sensitivity in adults with ASD and NT controls. Their results showed that adults with ASD were better at detecting subtle changes in the object stimuli and they performed equally well on the face stimuli. In the present study, we adopted the morphing technique to control physical similarities among face and object stimuli with equivalent task difficulties. Using computerized morphing face/object discrimination tasks, we investigated whether adults with ASD showed impaired holistic processing or enhanced featural processing. We also explored the correlations between individuals' autism-spectrum quotient (AQ) scores and their task performance.

Twenty-four adults with ASD and 24 NT adults matched for sex (ASD group: 14 men, 10 women; NT group: 13 men, 11 women), age (ASD group: 28.89 ± 5.43 years; NT group: 28.45 ± 5.09 years), and years of education (ASD group: M = 15.96 ± 1.76 ; NT group: M = 16.25 ± 1.26) participated in the study. The experimental protocols adhered to the ethical standards of the Helsinki Declaration of 1975. All participants filled out the Chinese version of the AQ questionnaire (Liu, 2008), then performed the computerized morphing face/object discrimination tasks. The AQ questionnaire has 50 questions, assessing 5 different dimensions: *social skill*, *attention switching*, *attention to detail*, *communication*, and *imagination*. For the computerized discrimination task, we used gray-scale images of four sets of faces and six sets of objects (car, plane, teapot, cash register, tennis-racket, trumpet) as the stimuli. FantaMorph (Abrosoft Co.) was used to generate the morphed images in increments of 15% for faces and 12% for objects. The procedure of the computerized task is shown in Figure 1. Each trial began with a fixation cross (1 s) followed by a single target face/object (1.5 s), and then a pair of images with a target face/object and a comparison face/object appearing side-by-side. The participants had to choose the face/object that was different from the target with a keypress response.

To check that the face and object discrimination tasks were similarly difficult for our participants, we adopted a three-way mixed analysis of variance (ANOVA) for accuracy. *Group* was the between-subjects factor; *Stimuli type* (face, object) and *Morphing level* (face 15%/object 12%, face 30%/object 24%, face 45%/object 36%, face 60%/object 48%, face 75%/object 60%) were the within-subjects factors. The *Group* main effect was not significant (p = .379; ASD: 0.79 ± 0.02, NT: 0.81 ± 0.02).

Figure 1

Illustration of the morphing face/object discrimination task. This example shows a woman (face condition) and a cash register (object condition)



The *Stimuli* main effect was also not significant (p = .721; face tasks: 0.79 ± 0.02, object tasks: 0.80 ± 0.01), suggesting that the difficulties of the face and object tasks were comparable. The main effect of *Morphing level* was significant ($F(4, 184) = 56.438$, $p < .001$).

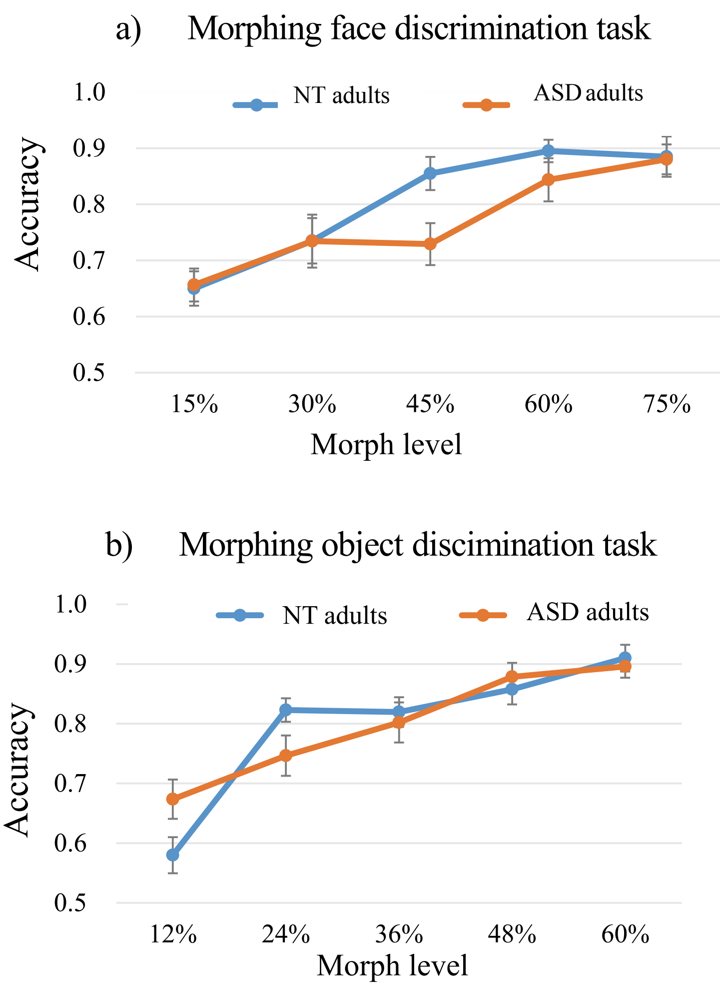
To reveal the overall task performance for the two groups, we separately conducted two two-way mixed ANOVAs for accuracy for the face and object discrimination tasks, with *Group* as the between-subjects factor and *Morphing level* (face: 15%, 30%, 45%, 60%, 75%; object: 12%, 24%, 36%, 48%, 60%) as the within-subjects factor. For face discrimination (see Figure 2a), the *Group* main effect was not significant (p = .134; ASD: 0.77 ± 0.12, NT: 0.81 ± 0.11). The main effect of *Morphing level* was significant ($F(4, 180) = 2.892$, p = .024, $\eta^2 = 0.060$). The mean accuracies from 15% to 75% were 0.66 ± 0.15, 0.74 ± 0.21, 0.80 ± 0.18, 0.88 ± 0.15, and 0.89 ± 0.15, respectively. The two-way interaction was not significant. For object discrimination (see Figure 2b), the *Group* main effect was not significant (p = .944; ASD: 0.80 ± 0.08, NT: 0.80 ± 0.09). The main effect of *Morphing level* was significant ($F(4, 180) = 2.395$, p = .052, $\eta^2 = 0.051$). The mean accuracies from 12% to 60% were 0.63 ± 0.16, 0.79 ± 0.14, 0.81 ± 0.14, 0.87 ± 0.12, and 0.90 ± 0.10, respectively. The two-way interaction was significant ($F(4, 180) = 3.613$, $p = .007$, $\eta^2 = 0.074$), suggesting that the two groups exhibited different accuracies as the morphing level increased.

We also conducted separate one-way trend analyses for the object and face conditions to explore whether the ASD and NT groups adopted different strategies for the discrimination tasks. For the ASD group, the results of the face discrimination task showed that only the linear component was significant ($F(1, 23) = 37.165$, p <

Figure 2

Performance on the morphing face/object discrimination task

a) Mean accuracies for the morphing face discrimination task for both groups. b) Mean accuracies for the morphing object discrimination task for both groups



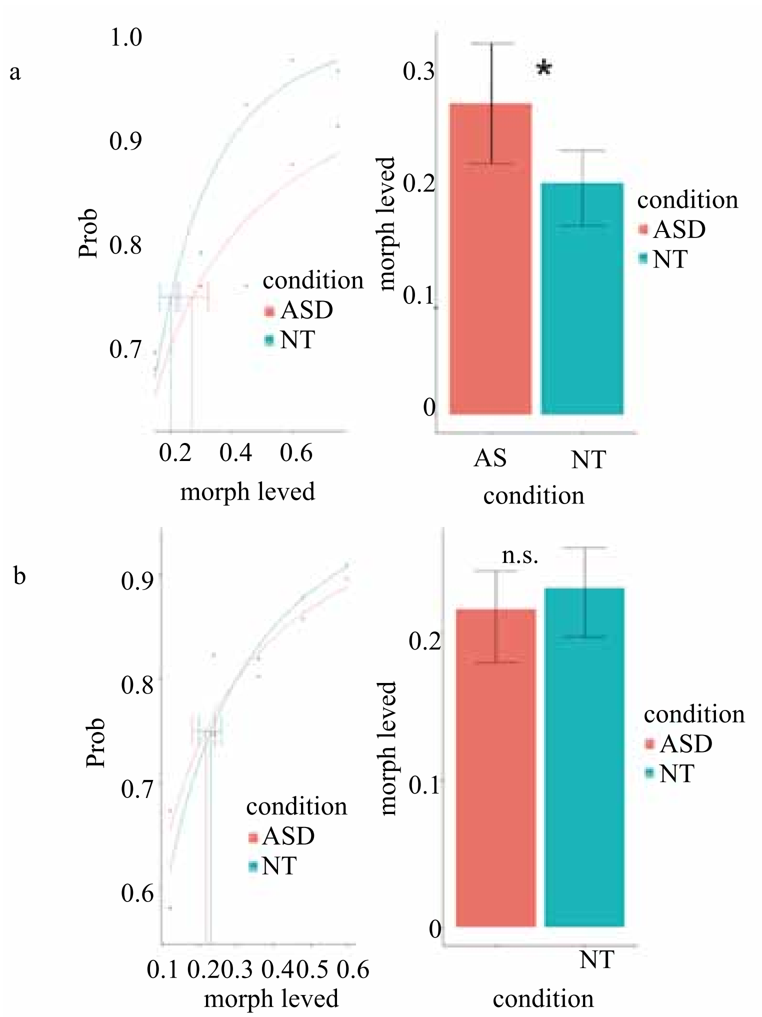
.001, $\eta^2 = 0.618$; no other components were significant. Likewise, in the object discrimination task, only the linear component was significant ($F(1, 23) = 60.064$, $p < .001$, $\eta^2 = 0.723$); no other components were significant. The NT group showed a significant linear component ($F(1, 23) = 60.186$, $p < .001$, $\eta^2 = 0.724$) and quadratic component ($F(1, 23) = 11.042$, $p = .003$, $\eta^2 = 0.324$), but no cubic or fourth-order component for the face discrimination task. Similarly, they exhibited a significant linear component ($F(1, 23) = 79.591$, $p < .001$ $\eta^2 = 0.776$) and quadratic component ($F(1, 23) = 16.224$, $p = .001$, $\eta^2 = 0.414$), but no cubic or fourth-order component for the object discrimination task. In other words, as the morphing level increased, the discrimination accuracy of the ASD group increased linearly for both the face and object tasks. However, the NT group exhibited both linear and non-linear trends as the morphing level increased. For example, when the morphing level exceeded 45%, the increase in the mean accuracy slowed and approached saturation.

Finally, as the morphing level can be treated as a continuous variable, we also separately estimated the

Figure 3

Curve fitting results of the morphing face/object discrimination

a) Threshold estimation of accuracy on the morphing face discrimination task b) Threshold estimation of accuracy on the morphing object discrimination task. The red bar denotes the ASD group and the green bar denotes the NT group



group discrimination threshold of the psychometric functions using Weibull curve fitting for the ASD and NT groups. For the face discrimination task, the estimated discrimination threshold of the ASD group (33.12%) was significantly higher than that of the NT group (25.87%), meaning that the ASD group required a greater difference than the NT group did to tell the difference between two faces. For the object discrimination task, the estimated discrimination thresholds were similar for both groups (ASD: 21.67%; NT: 23.12%).

In conclusion, compared with NT adults, adults with ASD required a larger discrimination threshold for morphing faces. Both groups had a similar discrimination threshold for morphing objects. This pattern of results supports the notion that individuals with ASD have impaired holistic processing for faces. Additionally, the results for adults with ASD showed only a linear trend, suggesting that they compensated with piecemeal or feature-based processing when differentiating among morphing images of faces and objects. In contrast, the NT adults exhibited both linear and non-linear components trends, suggesting that they processed both faces and objects in a flexible manner.