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The Effect of Inversion on the Anger Superiority Effect in Children with and without Autism Spectrum Disorders

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Abstract

Previous studies have demonstrated that angry faces capture humans' attention more rapidly than emotionally positive faces. This phenomenon is referred to as the anger superiority effect (ASE). Despite atypical emotional processing, adults and children with Autism Spectrum Disorders (ASD) have been reported to show ASE as well as typically developed (TD) individuals. In this study, we tested ASE in children with and without ASD using upright/ inverted schematic faces to explore the face-processing style employed by them during detection of emotional faces. The results revealed that faster detection of angry faces over happy faces was observed in both TD and ASD children. Interestingly, however, the effect was stronger in children with ASD compared to TD children when faces were inverted. These findings suggest that different face-processing style would be employed or different mechanisms of emotional processing would underlie the quick detection of angry faces in children with and without ASD.

Keywords Autism spectrum disorders; Anger superiority effect; Inversion; Children; Face-in-the-crowd; Visual search; Emotion

Introduction

The detection of threatening social stimuli quickly and modifying our behaviors according to the context is beneficial for avoiding social conflict. Our visual system is, therefore, thought to have evolved to be more sensitive to threatening faces than to other facial expressions [1,2]. Angry faces are universally treated as signals of potential threat. They are processed rapidly and efficiently, and are particularly efficient in capturing attention [3]. This phenomenon is defined as the anger superiority effect [ASE]. ASE has been studied using a visual search paradigm in which participants searched for discrepant angry or happy faces in a crowd of distractor faces [4-6]. Several studies have confirmed that ASE can be observed with schematic-faces as well [1,7-10]. By using schematic faces it is possible to eliminate many low-level perceptual variations found in photographs of emotional expressions, and to better control experiment variables.

ASE has recently been tested in participants with Autism Spectrum Disorders [ASD] using the same face-in-the-crowd paradigm in adults, as well as children and adolescent [11-13]. ASD are neurodevelopmental disorders characterized by social communicative difficulties and restricted behaviors and interests. Previous studies have reported that they show specific difficulties in social and emotional information processing [14]. In particular an atypical pattern of face processing has often been reported: while TD individuals tend to use a configural style for face processing [15], individuals with ASD have been shown to have difficulties in configural processing and to focus more on local features in faces [16]. These findings are compatible with the framework, termed weak central coherence, which posits that a fundamental problem in autism is the difficulty in drawing together or integrating individual pieces of information [perceptual or conceptual] to establish meaning with the resultant reliance on piecemeal, local informationrather than on the overall context[16-18]. Also, recent studies revealed that individuals with ASD showed atypical emotional responses to faces, in which undifferentiated affective responses were observed to different facial emotions in event-related potentials [ERPs] responses [19] as well as facial Electromyography [EMG] activities [20-22].

Contrary to their atypical cognitive processing and emotional responses to facial emotions, however, recent studies have revealed that ASE exists in the most of population with ASD as well as TD individuals [11-13]. Interestingly though, it has been reported that individuals with ASD did not show the effect when the large number of distractor faces [crowd size] was presented [11,12]. In addition, Isomura (submitted) found the age differences in the ASE only in ASD but not in TD. These findings suggest that individuals with ASD employed different mechanisms that might be learned/ acquired in their development. To explore the difference in cognitive mechanisms, testing ASE under conditions of face-inversion would be one of the possible approaches.

Face inversion effect is well established phenomena where face inversion reduces holistic/ configural aspects of face-processing [23-25]. The majority of studies reported that configural information plays a more prominent role in face identity recognition, and inverted faces disrupt the performance of that [26]. In individuals with ASD, however, behavioral and neuroscience studies have reported that they are not affected by inversion of a face as TD individuals, which is consistent with the idea that individuals with ASD may process feces in a more feature-based manner and attend to local aspects of faces [16,27-30].

On the other hand, the effects of inversion are less clear on emotion recognition. Previous studies reported that emotional expressions were recognized even when the stimuli were inverted [26]. In the visual search task, many studies have reported that the faster detection of angry faces over happy faces still persists when faces are inverted

[1,11,31-,33], but some studies showed that the effect disappeared or the effect became weaker when faces were inverted [7,8]. So far, few studies have tested the inversion effect on the anger superiority effect in individuals with ASD.

In this study, we tested the anger superiority effect with upright and inverted schematic face stimuli in children with and without ASD to explore the differences of face-processing style employed by them during detection of emotional faces. We hypothesized that TD children would show faster detection of angry schematic faces than happy schematic faces (i.e., ASE) regardless the orientation of faces, because the ASE is evolutionarily preserved mechanisms and even young children would show this effect, and this effect would persist when faces are inverted. In children with ASD, on the other hand, we hypothesized that they would show ASE only with upright face stimuli. When faces were inverted, we predicted that children with ASD would show a diminished or reverse pattern of ASE because they may extract facial information using a different level of processing compared to TD children (e.g., at the feature configure level versus the holistic level). If they only focus on local feature in faces (eyebrows or mouth), then happy faces would have local features of anger (i.e., a down-turned mouth and v-shapedeyebrows) in inverted condition, and vice versa.

Material and Methods

Ethics note

This study was ethically reviewed by the institutional ethics committee of experiments for human participants prior to the study (permission number, #H2012-05). We adhered to the Declaration of Helsinki and the institutional guidelines for experiments with human participants.

Participants

Twenty-two children with ASD (18 male and 4 female) and 22 typically developing children (18 male and 4 female) participated in this study. The participants in the ASD group were diagnosed either with Autism Spectrum Disorder, Asperger's syndrome, high functioning autism, or Pervasive Developmental Disorder- Not Otherwise Specified based on either DSM-IV or ICD10. Subjects have been participating in the Developmental Disorders and Support for Acquiring Reading and Writing Skills project at the Kokoro Research Center in Kyoto University. Children with no history of any psychiatric condition were recruited via the local community as a control group.

Intelligence Quotient (IQ) was measured using the Japanese version of the Wechsler Intelligence Scale for Children (either WISC-Ⅲ or WISC-IV). Subjects' parents answered the Japanese version of the Autism Spectrum Quotient (AQ). To be included in the ASD group, participants had to meet the criteria of AQ with a score more than 20, and to be included in the TD group, they had to meet the criteria of AQ with a score less than 20. Additionally, participants had to meet the criteria of IQ with a score of 70 or higher for both groups. Two individuals in the TD group were excluded from analysis because they did not meet the criteria of AQ. Consequently, 22 children with ASD (18 male and 4 female) (mean age=10.00; SD= 1.13; range= 8:5-11:9) and 20 typically developing children (16 male and 4 female) (mean age= 10.12; SD= 1.21; range= 8:5-12:5) were included in analysis. Age, AQ scores, and IQ scores are listed in Table 1. Independent samples t-tests showed that the groups were matched for age (t (40)= 0.332, ns.), and Full-scale IQ (t(40)= 0.948, ns.). AQ scores showed a significant difference between the groups (t (40)= -11.35, p<0.001). The parents of all the participants gave written informed consent to participate in this study, which was conducted in accordance with the institutional ethics provisions.

	TD (male = 16; female = 4)	ASD (male = 18; female = 4)	t-value; p-value
Age	10.12 (1.21)	10.00 (1.13)	t(40) = 0.332
	(8:5 - 12:5)	(8:5 - 11:9)	p = 0.742
full-scale IQ	108.0 (14.69)	103.59 (15.06)	t(40) = 0.948
	(89 - 148)	(73 - 124)	p = 0.349
AQ	13.30 (4.13)	29.48 (5.16)	t(40) = -11.30
	(7 - 19)	(22 - 40)	p<0.001

Table 1: Mean (SD; range) chronological age, IQ scores, and AQ scores for ASD and TD group

Apparatus

Visual stimuli were presented on a15-inch touch-sensitive monitor with a resolution of 1024 by 768pixels (Mitsubishi, RDT151TU or TSD-AT1515-CN), controlled by custom-written software under Visual Basic 2010 (Microsoft Corporation, Redmond, Washington, USA) running on a personal computer (HP Compaq 6730b/CT or Panasonic CF-SX2).

Stimuli

Each trial included the presentation of a self-start key, a fixation picture, and face stimuli. A light-blue-coloured rectangle(179 (W) x136(H) pixels: 5.3 cm x 4.1 cm on screen (7.6˚ x 5.9˚ of visual angle) was used as the self-start key, which was presented at 1.5 cm (2.1˚ of visual angle) above the bottom of the screen. In the middle of the rectangle, a trial number was presented so that participants could know how many trials they had completed. Fixation pictures were presented at the center of the screen and covering the whole stimulus area of faces. Twenty-four types of pictures of popular cartoon characters were used for the fixation pictures. The face stimuli were schematic pictures portraying angry, happy, and neutral facial expressions (Figure 1A-E). Each emotion had two types of faces which were different in the angle of eyebrows and flatness of mouth. They were created with reference to previous studies (11,34). The faces were drawn in black against a white background. All lines in the face drawings were of 2 pixel width. The individual faces were 48 (W) by 54 (H) pixels (1.4 cm x 1.6 cm on the screen (2.0˚ x 2.3˚ of visual angle). The face stimuli were presented inside a stimulus area of 268 x 218 pixels (8.0 cm x 6.5 cm on the screen(11.4˚ x 9.3˚ of visual angle). The stimulus area was divided into 4 x 3 grids. We randomized positions of face stimuli for each trial. First we randomly chose a grid for each face stimulus and then alter its position within a grid in a range of +- 8 pixels from the center of the grid in both vertical and horizontal dimensions. This procedure resulted in a moderately irregular arrangement of the stimuli, intended to eliminate possible supra stimulus cues to the target's position (34,35). An example of stimulus displays is shown in Figure 1F.

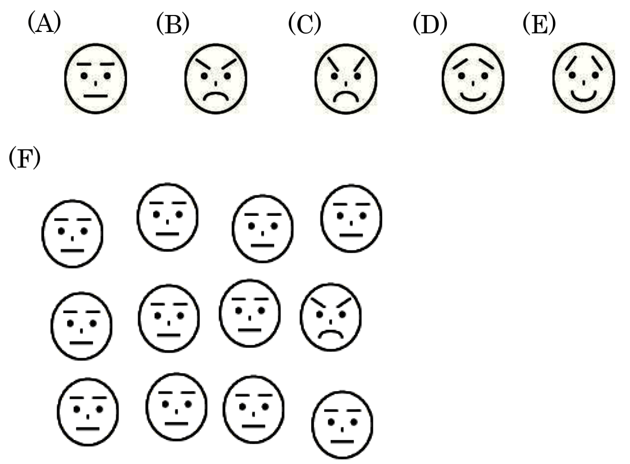

Figure 1: (A)-(E) Stimuli used in this study. Neutral face **(A)**, Angry faces **(B, C)** and Happy faces **(D, E)**. **(F)** Examples of matrix in the search: One angry face and 11 distractor neutral faces

Procedure

Participants were given 36 trials of a face-in-the-crowd task (i.e., visual search task) with upright face stimuli (upright condition), and 36 trials of that with inverted face stimuli (inversion condition). The order of the given condition was counterbalanced across participants. They were seated approximately 40 cm from the monitor with eye level at the center of the screen, and instructed to touch a discrepant object as quickly and accurately as possible. Each trial started when participants touched the self-start key, after which a fixation picture was presented for 500 ms to keep the children's attention on the screen, and then the face stimuli were displayed. Face stimuli consist of one emotional face (target) and 11 neutral faces (distractors). The face stimuli were presented until a response was made. When the participants responded correctly, a high tone sounded and a cartoon picture which indicated a correct response was presented, whereas a low tone sounded and a picture which indicated an incorrect response was presented when they made an incorrect response. Emotion-type (Angry/ Happy) was varied with a pseudorandom sequence. Target position was also controlled by pseudorandom sequences.

Results

Upright Condition

As our tasks were designed to produce no or very low numbers of errors, the response times were used for analyses. We conducted a General Linear Model (GLM) repeated measures on the response times with two factors: Emotion (Angry vs. Happy), and Group (TD vs. ASD). The results revealed that there was a main effect of Emotion ($F(1,40) = 35.84$, $p < 0.001$, $\eta 2p = 0.473$), indicating that angry faces were detected more quickly than happy faces (Figure 2A). Neither main effect of Group ($F(1,40) = 0.728$, $p = 0.398$, $\eta 2p = 0.018$) nor an interaction between two factors was found. ($F(1,40) = 0.521$, $p = 0.475$, $\eta 2p = 0.013$).

Inverted Condition

As with the upright condition, a GLM repeated measures on the response times was conducted with two factors: Emotion (Angry vs. Happy), and Group (TD vs. ASD). The results revealed that there was a main effect of Emotion ($F(1,40) = 50.90$, $p < 0.001$, $\eta 2p = 0.560$), and an interaction between Emotion and Group ($F(1,40) = 8.95$, $p = 0.005$, $\eta 2p = 0.183$). Subsequent analysis (Bonferroni correction) revealed that inverted angry faces were detected more quickly than inverted happy faces both in TD ($F(1, 40) = 8.19$, $p = .007$, $\eta 2p = 0.170$) and in ASD ($F(1,40) = 53.84$, $p < 0.001$, $\eta 2p = 0.574$), but the difference between emotions was significantly bigger in ASD than that in TD (Figure 2B). There were no significant differences between groups on the response times to detect inverted angry faces ($F(1,40) = 0.063$, $p = 0.803$, $\eta 2p = 0.002$), as well as to detect inverted happy inverted faces ($F(1,40) = 0.874$, $p = 0.355$, $\eta 2p = 0.021$).

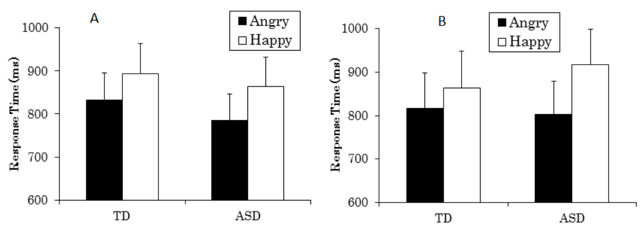

Figure 2: Mean response times in the detection of angry/ happy targets by TD and ASD children in upright condition (A) and in inverted condition (B). Black bar represents mean response time to detect angry faces, and white bar represents mean response time to detect happy faces. Error bars: 95% CI.

Discussion

The current study showed that angry schematic faces were detected more quickly than happy schematic faces (i.e., ASE) by both typically developing children and children with ASD. This result is consistent with previous studies [2,3,7-9,11]. Moreover, as we had hypothesized, TD children showed this effect even when faces were inverted. Consistent with previous studies, our results revealed that schematic emotional faces preserve their emotional effect even under the inverted condition. Surprisingly, however, the results revealed that children with ASD showed even bigger effect of the anger superiority in inverted condition compared to TD children. This is against our prediction where we had expected that they would show a diminished or reverse pattern of ASE. To note, we have tested the same participants with ASD (except 2 children who participated in the current study) with another visual search task, where the participants were asked to find one line which has a different angle from the others, and found that there was no difference between ASDs and TDs. Therefore, the difference between ASD and TD found in the current study would not be caused by any of the followings; different level of understanding of the task, different level of concentration on the task, or difference of any other physical problems between ASD and TD.

The results in the current study suggested several possibilities. First, children with ASD may show some level of configural face processing. If they only focus on local-features to detect emotional faces as referred to by many studies as "feature-based face-processing style" [16,18,37], reverse pattern or diminished effect would have been observed for inverted faces. Thus, the findings here could propose that children with ASD would show some level of configural face processing, at least with simple schematic face stimuli used in this study, or under this implicit condition where they were not required to recognize emotional expressions of stimuli but they just needed to find a discrepant object. Second, face-processing style may not be sufficient to explain emotional processing. There may be another processing mechanisms of emotional expressions that are unaffected by inversion and is distinct from featural and configural processing as suggested by Bomberi et al. [26].

Previous study revealed that adults with ASD did not show the ASE to schematic emotional faces under the inverted condition, while TD individuals showed it as well as in upright condition [11]. They concluded that even though people with ASD showed ASE (with upright faces), they may still be processing faces using a different cognitive style or different level offace-processing compared to controls. It is consistent with our study in that the group difference was shown only in inverted condition, but not in upright condition. However, we found the opposite effect where children with ASD showed stronger ASE than TD children in inverted condition. This may be because there would be some developmental changes on processing emotional faces from children to adults in individuals with ASD, or because the difference of methodology would affect more strongly to individuals with ASD compared to TD individuals. Further studies are needed to clarify this inconsistence. Especially, in the current study, we did not find any particular effect such that ASD children detected inverted angry faces more quickly than TD children, or that ASD children detected inverted happy faces more slowly than TD children. Further investigations with larger sample sizes, with real face stimuli, and using eye-tracking will help to understand the detailed mechanisms how TD and ASD children process emotional faces rapidly.

Conclusions

This study demonstrated that schematic angry faces were detected more quickly than schematic happy faces both in children with ASD and TD children. When faces were inverted, they still showed the same effect, however, the effect was stronger in children with ASD compared to TD children. These findings suggest that different face-processing style would be employed or different mechanisms of emotional processing would underlie the quick detection of angry faces in children with and without ASD.

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