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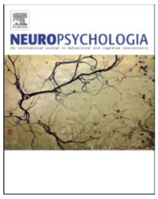

Visual integration of fear and anger emotional cues by children on the autism spectrum and neurotypical peers: An EEG study

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ABSTRACT

Communication deficits in children with autism spectrum disorders (ASD) are often related to inefficient interpretation of emotional cues, which are conveyed visually through both facial expressions and body language. The present study examined ASD behavioral and ERP responses to emotional expressions of anger and fear, as conveyed by the face and body. Behavioral results showed significantly faster response times for the ASD than for the typically developing (TD) group when processing fear, but not anger, in isolated face expressions, isolated body expressions, and in the integration of the two. In addition, EEG data for the N170 and P1 indicated processing differences between fear and anger stimuli only in TD group, suggesting that individuals with ASD may not be distinguishing between emotional expressions. These results suggest that ASD children may employ a different neural mechanism for visual emotion recognition than their TD peers, possibly relying on inferential processing.

1. Introduction

Evolutionary approach to human psychology has long associated nonverbal emotional cues with a biological need for survival (Darwin, 1872). This is especially relevant for negative facial and bodily expressions such as anger and fear. Both of these emotions are perceived as threats, and, as such, both tend to elicit intense, rapid neural responses (Meeren et al., 2005). The ability to make a distinction between the two is extremely important, as visual messages of anger and fear do not trigger the same adaptive responses in human physiology. When emotional cues signal anger, the receiver senses a direct threat from the sender, indicating a need for change, adjusted control of behavior, or aversive reaction (Pichon et al., 2009; Marsh et al., 2005). Fear cues, on the other hand, may warn of a nearby threat from other than the sender (de Gelder, 2006), or they may be an approach-oriented mechanism that facilitates affiliation (Marsh et al., 2005). Expressions of fear are typically associated with anxiety and inward-directed responses, and are less interactive than those elicited by anger cues (Pichon et al., 2009).

2. Visual communication of emotions

Visual cues, including facial expression and body posture, play an important role in an individual's perception of another's affective state, and have been shown to supersede the content of speech (Argyle, 1972). Research on visual emotional communication has centered in three areas: facial expression, body language, and the integration of the two.

Facial expression is often considered to be the primary nonverbal source for emotional communication (Eimer, 2000), and many studies of nonverbal affective perception have used faces as stimuli (de Gelder, 2009). In comparing emotional interpretation of nonverbal expressions, Mehrabian and Ferris (1967) found that typically developing (TD) participants preferentially relied on the visual emotional content of facial expression rather than other signals (such as voice tone). The importance of facial expressions in emotional communication has also been shown through studies in which targeted attention to facial features (eyes, nose, mouth) improved emotion recognition (Marsh et al., 2012).

The emotional message is also conveyed though body language. When Wallbott (1998) enlisted professional actors to read and enact sentences with high emotional content, he found that actors portrayed each basic emotion through similar body postures and movements, suggesting that the type and intensity of emotion can be communicated through body language. Additionally, body posture allows the sender to communicate emotional content over longer distances than the face

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(i.e. body posture can be visually encoded using lower spatial frequencies), providing a protective mechanism for the sender (limiting the observer's ability to identify the sender) and observer (enabling faster detection of the sender's intended actions) (de Gelder, 2009).

In the natural world, face and body cues are normally presented and processed together (de Gelder, 2009; Meeren et al., 2005). When face and body cues are received simultaneously, the observer is able to compare them for verification, so that facial and body expression are integrated into a unified emotional interpretation as body language confirms facial cues (Mehrabian, 1972). Any inconsistency between face and body is rapidly detected, since this may indicate deception, threat, or other circumstances that require immediate adaptation of action (Meeren et al., 2005).

3. Emotional communication and autism spectrum disorders (ASD)

For individuals with autism spectrum disorders (ASD), reading emotional visual cues can be difficult (Boutot and Myles, 2011). Through a series of tests, McDonald et al. (1989) found ASD adults relatively impaired to identification and expression of emotion, as compared to normal adults. Other studies have shown that ASD children focus on the upper part of the face (but not the eyes) in determining emotional state (van der Geest et al., 2002). In addition, fearful or other negative facial expressions of emotion may be avoided by ASD children (Dawson et al., 2004). Visual scanpaths of individuals viewing face stimuli indicate that, whereas neurotypical adults spend 70% of their time viewing the eyes, and most of the rest of the time viewing the nose and mouth area, ASD adults look primarily at the lower face and mouth area (Hobson et al., 1988), and may look more for individual features of the face, rather than viewing it from a holistic approach (Gauthier and Tarr, 1997).

4. Electrophysiological components of visual emotional cue processing

Electroencephalogram (EEG) signals that are recorded while photographs of human faces are presented typically show a large negative brain potential around 170 ms after stimulus onset (Eimer, 2000). This face-sensitive effect, known as the N170, almost always occurs between 140 and 230 ms post-stimulus in lateral occipito-temporal areas when faces are displayed (Meeren et al., 2005).

Some studies contest the role of the N170 as the earliest indicator of face processing, claiming that the visual P1 more accurately reflects early facial processing (Thierry et al., 2007). The P1 (or P100) peaks around 100 ms after stimulus onset, and appears to begin in the striate and extrastriate visual cortex (Clark et al., 1995; Di Russo et al., 2002). This component is sensitive to low-level features of stimuli, such as luminance, contrast, color, size, and spatial frequency (Rossion and Jacques, 2008). Amplitudes of both P1 and N170 tend to be larger in response to visually presented faces than to other objects, but differences between the categories are generally stronger in the N170 (Gofaux et al., 2003). Batty and Taylor (2003) observed that the N170 latency varied between emotions while the P1 latency remained consistent, and suggested that the P1 may index abstract, global processing of visual features in the face, while the N170 appears to reflect the integrative stage of visual feature processing for facial recognition. Van Heijsbergen et al. (2007) further compared ERPs while viewing fearful body expressions with ERPs while viewing neutral body expressions in TD participants. P1 component of ERPs to fearful expressions peaked earlier as compared to those for neutral expressions. These results suggest that early processing of emotional content in body posture is similar to that of facial expression.

Investigation of EEG responses of typically developing (TD) young adults to six basic facial expressions of emotion (Batty et al., 2011) found significant effects of emotion in the P1 component of visual ERP waveform. N170 amplitude and latency differences were observed between emotions, with fearful faces exhibiting the largest amplitude (Batty et al., 2011). Likewise, Dawson et al. (2004) found a larger early negative component (N300) in response to fearful as compared to neutral expressions in TD preschool children. In contrast, little response difference was seen between fearful and neutral facial expressions in ASD children (Dawson et al., 2004). Hadjikhani et al. (2009) fMRI studies of ASD and TD adult participants, who viewed fearful or neutral body postures with faces blocked, indicated little discrepancy between the two groups when viewing neutral poses. However, TD participants showed significantly more activation in the regions of the frontal, motor, and temporal cortices when viewing fearful postures. In contrast, ASD group activation patterns differed little when viewing fearful vs. neutral body postures. Ashwin et al. (2007) found that, when viewing fearful facial expressions, the TD group showed activation in the left amygdala and left orbito-frontal cortex, while ASD group showed activation in the anterior cingulate gyrus and superior temporal cortex. Based on these studies, authors theorized that ASD individuals use a different cognitive strategy than TD participants when processing facial cues.

5. Hypotheses

In order to learn more about development of visual emotion processing mechanism during late childhood and early adolescence, the present study examined ASD behavioral and ERP responses to emotional expressions of anger and fear, as conveyed by the face and body, in children and adolescents with ASD diagnosis, and their neurotypical peers (TD group). Previous studies in TD populations (Meeren et al., 2005) indicated that participants who were shown incongruent emotions in composite pictures of faces and bodies had slower response times, as they attempted to differentiate between or rectify the two emotions. Given known difficulties in emotion processing in ASD group, we hypothesized that:

Hypothesis #1: For the ASD group, no differences between fear and anger responses will be observed in EEG waveform morphology.

Hypothesis #2: If feature integration mechanism is different between TD and ASD groups, the results for the processing of incongruent stimuli will differ, both behaviorally and in EEG waveforms.

As behavioral data on its own would not provide sufficient information about neural processing mechanism, the present study focused on examining neurophysiological components of visual emotional cue processing in ASD and TD children, and on clarifying the neural mechanism of the ASD-associated impairment in processing face- and body-based emotional cues.

6. Methods

6.1. Participants

Fifteen individuals with diagnoses of high-functioning autism spectrum disorder (ASD) such as Aspergers and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), as provided by psychological assessment, were recruited from a private special-needs school. Fifteen healthy typically developing (TD) age and gender-matched subjects were recruited through flyers. The Test of Pragmatic Language-2 (TOPL-2, Phelps-Terasaki and Phelps-Gunn, 2007) was administered to each participant, and parents were asked to evaluate their children's communicative abilities using the Pragmatic Language Observation Scale (Newcomer and Hammill, 2009). Scores from the two tests were combined, and only participants scoring at or above average (i.e., 100+) were assigned to the TD group. The ASD group included participants with a psychological diagnosis of Asperger Syndrome, PDD-NOS, or high-functioning ASD and a TOPL-2 score below 100. EEG data from two of the ASD participants was unusable because of artifacts, and data from two additional ASD participants was excluded from the analysis because their TOPL-2 test score was over 100. Data from one TD participant was discarded because test scores were below 100, bringing the total number of participants to 11 individuals with ASD (2 F, age $M = 13.7$, $SD = 2.2$, range 10–16) and 14 TD participants (3F, age $M = 13.4$ years, $SD = 2.1$, range 10–17).

The study was approved and conducted in accordance with the ethical standards of the University of Texas at Arlington Institutional Review Board, and the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All parents and children provided their written informed consent/assent prior to their inclusion in the study.

7. Materials

We adopted the set of face-body photographic stimuli displaying angry and fearful expressions previously used in EEG (Meeren et al., 2005; Stekelenburg and de Gelder, 2004) and fMRI experiments (Hadjikhani and de Gelder, 2003; de Gelder et al., 2004). Body stimuli consisted of 20 Gy-scale photographs from the Bodily Expressive Action Stimulus Test (de Gelder and van den Stock, 2011); facial stimuli were 20 Gy-scale photographs from the NimStim database (Tottenham et al., 2009). Each of ten models (five male and five female) was photographed in a fearful pose and an angry pose. The emotions fear and anger were selected because, as threats, these two emotions tend to elicit stronger and faster neural responses (Meeren et al., 2005). For all emotional representations, the position of the arms varied from slightly to fully bent; hands were typically extended; fear poses had palms pointing or opening outward (defensive posture), while anger poses showing hands flexed in fists and pointing inward (aggressive posture).

Face-body compound stimuli were included since faces and bodies are typically integrated when encountered in everyday life, and inconsistencies between the two may indicate deception (Meeren et al., 2005). To date, there has been no systematic investigation into how facial expressions and emotional body language interact in human observers, and the underlying neural mechanisms are unknown. Compound conditions consisted of two congruent compounds matching facial and bodily expressions (fearful faces with fearful bodies, angry faces with angry bodies) and two incongruent compounds with mismatched facial and body expressions (angry faces with fearful bodies and fearful faces with angry bodies) (see Fig. 1). A total of 20 congruent photos and 20 incongruent photos were presented to participants in random order.

Faces and bodies were also presented to participants in isolation as a control condition. These stimuli were shown in the same size and position on the screen as the compound stimuli. Isolated body stimuli maintained a gray-filled outline of the head, with no facial features visible. In isolated face stimuli, no outlines of the bodies were visible. Examples of isolated stimuli are shown in Fig. 2; these were also presented to participants in random order. Overall, each of the 4 conditions (body-only, face-only, face and body congruent, face and body incongruent) accounted for 25% of presented stimuli for a balanced 2 × 4 design. Incongruent face-body composites were assigned to the angry or fearful category based on face emotion.

8. Procedure

EEG testing was conducted on the campus of the University of Texas at Arlington. During the session, participants were seated comfortably in a sound-attenuating booth approximately 80 cm from the computer screen. (The stimuli subsumed, on average, 2° visual angle vertically, and 1.5° horizontally). While wearing an EEG cap, each participant was asked to keep his eyes on the screen, and to decide as accurately and quickly as possible whether the stimulus photograph expressed fear or anger. When the face-body compound stimuli were presented, participants were told to judge the emotion by the expression of the face. Stimuli were presented for 1000 ms, followed by a black screen for 2000 ms, for an inter-trial interval totaling 3 s. The hand assigned to Fear/Anger response (and, therefore, correct response button) was counterbalanced among participants. Before beginning the testing, procedures, materials, and task expectations were thoroughly introduced to each participant. Participants were then trained and both ASD and control participants practiced the task for 10 correct trials of each task category.

The study consisted of 4 blocks. In 2 separate blocks, participants viewed 10 trials each of isolated fear faces, isolated anger faces, isolated fear bodies, and isolated anger bodies. In the other 2 blocks,participants viewed 10 trials of compound fear faces/fear bodies, 10 trials of compound anger faces/anger bodies, and 10 trials of compound fear faces with anger bodies, and 10 trials of anger faces with fear bodies. Each block/category consisted of 40 stimulus trials, for a total of 160 trials. The order of block presentation was counterbalanced, so that half of the participants viewed a face-only or body-only block first, and half viewed a block with composite stimuli first. Of those who first saw an isolated stimulus block, half started with the isolated faces block, and half started with the isolated bodies block. The order of the composite stimuli that followed was also counterbalanced, so that each possible order of presentation was presented to equal numbers of participants.

9. EEG recording

Scalp EEG was recorded from 32 Ag/AgCl electrodes mounted in an electrode cap (Wavegard, ANT Inc.) with an average mastoid reference. Electrodes were positioned according to the standard 10–20 system. A pair of bipolar electrodes were used to record vertical eye movements. Electrode impedances were maintained below 10 kΩ during recording. The EEG analog signal was digitized at a 512-Hz sample rate. Electroencephalography data were analyzed using ASA 4.6 (ANT, Inc.). EEG was filtered with a band-pass filter of .1–30 Hz, allowing to avoid usage of additional baseline correction (Malaia and Newman, 2015). Time points in the filtered data at which the absolute amplitude of the EEG exceeded ± 150 µV were marked as EEG artifact or blink artifacts. Trials containing EEG artifacts (such as blinks, horizontal eye movements, or muscle movement) were rejected from further analyses, as were trials containing incorrect behavioral responses for all stimuli. This was done in order to ensure that EEG data only contained the epochs during which the task was carried out correctly. Number of accepted trials per condition, by group, is reported in Table 1.

Data was then averaged in epochs from 100 ms pre-stimulus onset to 1000 ms post-stimulus onset using the timestamps of stimuli recorded concurrently with behavioral and EEG data. Averages were baseline corrected using the 100-ms pre-stimulus epoch.

10. Data analysis

Incorrect trials were excluded from behavioral data analyses. Behavioral data were analyzed for accuracy (number of correct responses out of number of total responses) and reaction time. Repeated measures ANOVA using within-subject factors Stimulus type (Face, Body, Congruent, Incongruent) and emotional expression (Fear, Anger), and between-subject Group (ASD, TD) factor was conducted using SPSS software.

The temporal windows for P1 component was identified at occipital sites (O1 and O2) as the first prominent positive deflection between 80 and 140 ms after onset of the picture. The temporal window for N170 component was identified at occipital sites (O1 and O2) as the maximal negative peak in the time period from 140 to 230 ms. Peak amplitude and latency were measured for these components at occipital electrodes O1 (left) and O2 (right).

The data were analyzed using repeated measures ANOVA, with diagnosis as a between-subject factor, and emotion (Fear, Anger),

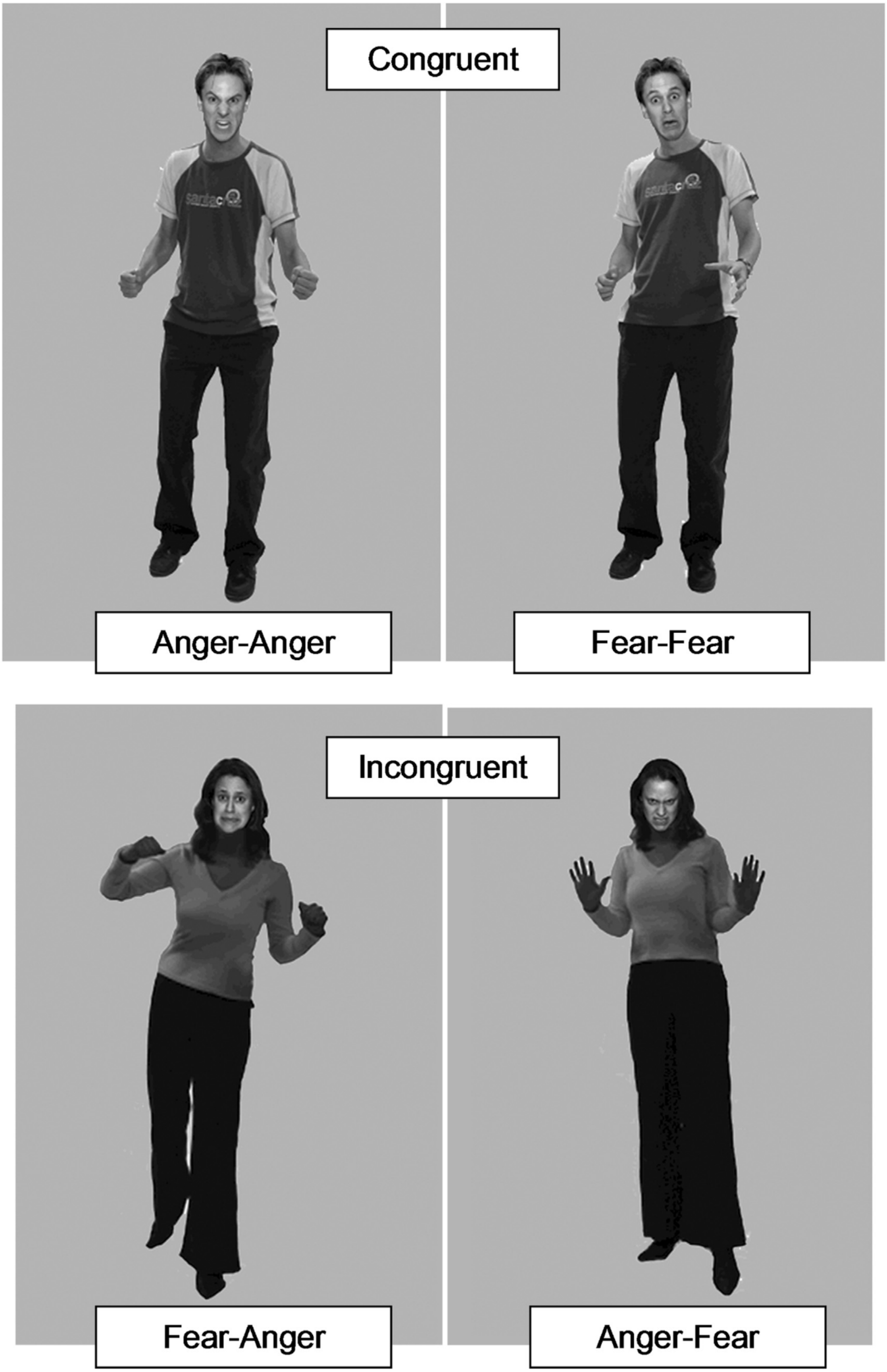

Fig. 1. Sample compound stimuli for Congruent and Incongruent conditions with condition labels (not present during the experiment).

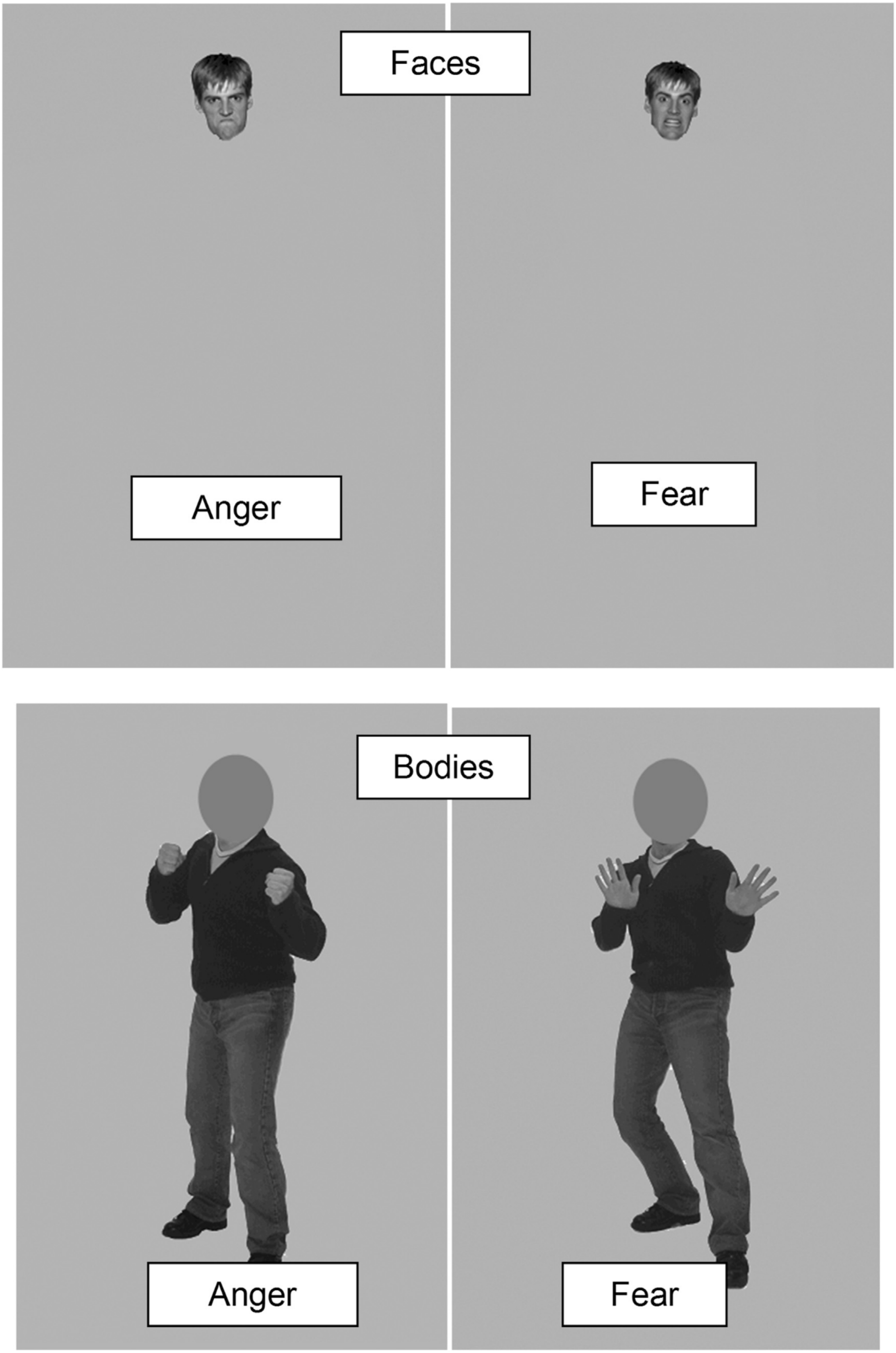

Fig. 2. Sample isolated stimuli, Face only and Body only, with condition labels.

Table 1
Remaining trials after artifact correction/rejection per condition, by group.

	TD participants				ASD participants			
	Body M (SD)	Face M (SD)	Congruent M (SD)	Incongruent M (SD)	Body M (SD)	Face M (SD)	Congruent M (SD)	Incongruent M (SD)
Anger	85% (5%)	88% (5%)	90% (3%)	81% (4%)	92% (7%)	89% (3%)	88% (5%)	80% (4%)
Fear	80% (8%)	93% (7%)	91% (5%)	82% (5%)	95% (7%)	87% (5%)	85% (5%)	89% (6%)

stimulus type (Face, Body, Congruent, Incongruent), hemisphere (left, right), and anteriority (anterior, posterior). When group differences were identified using omnibus ANOVA, step-down ANOVAs were performed for stimuli that used both carriers (face and body) vs. one carrier (face or body only). Within-subject factors for the face-body compound stimuli included emotion (Fear, Anger), congruence (Congruent, Incongruent), hemisphere (left, right), and anteriority (anterior, posterior); within-subject factors for separate face and separate body stimuli included carrier (face, body), emotion (Fear, Anger), hemisphere (left, right), and anteriority (anterior, posterior). Greenhouse-Geisser correction was used to correct for sphericity.

11. Results

11.1. Behavioral results

Separate ANOVAs were carried out for response time and accuracy analyses. A significant main effect of stimulus type (Face, Body, Congruent, Incongruent) was seen for accuracy ($F(1, 25) = 39.6$, $p < .001$) (see Fig. 3).

In the omnibus ANOVA, the ASD group's responses were also significantly faster for fear stimuli than for anger stimuli, as compared to the control group (Emotion x Group response time, $F(1, 25) = 4.23$, $p < .05$). The ASD group responses were also less accurate for fear than for anger, as compared to the control group (Emotion x Group accuracy, $F(1, 25) = 4.594$, $p < .042$).

Within-group step-down ANOVA on accuracy and response times for combined stimuli with factors Emotion (Fear, Anger) revealed the effects of emotion on the TD group's accuracy ($F(3, 39) = 83.630$, $p < .001$), with fear recognized with more accuracy than anger (Fear $M = 76\%$, Anger $M = 60\%$).

Within-group step-down ANOVA on response times for combined stimuli in ASD group showed an effect of emotion ($F(1, 12) = 11.745$, $p < .005$), with slightly faster responses to anger stimuli (Fear $M = 745$ ms, Anger $M = 715$ ms), as well as interaction of emotion and stimulus type ($F(3, 36) = 3.052$, $p < .041$), with fastest responses to body stimuli expressing anger (Body Anger $M = 683$ ms, Incongruent $M = 705$ ms). There was an effect of emotion on ASD group's accuracy ($F(1, 12) = 9.092$, $p < .011$), with more accurate responses to Anger stimuli (Anger $M = 76\%$, Fear $M = 67\%$), and interaction of emotion and stimulus type ($F(3, 36) = 3.602$, $p < .023$), with least accurate responses to incongruent stimuli with Fear facial expression (Fear Face $M = 13\%$).

11.2. Interim summary

Behavioral results indicate that ASD group participants responded more quickly than TD controls to all stimuli categories. In addition, fear stimuli elicited faster and less accurate behavioral responses in both groups.

12. EEG results

Results of omnibus ANOVA with factors Group (TD, ASD), Emotion (Fear, Anger), stimulus type (StimType - Face, Body, Congruent, Incongruent), hemisphere (left, right), on P1 and N170 amplitude and latency are summarized in Table 2.

As Table 2 and the summary indicate, the omnibus ANOVAs indicated the differences between the TD and ASD participants that were trending in significance over both components. This included Group × StimType × Emotion × Hemisphere and Group × Emotion interactions over P1 and N170 components, Group × StimType × Hemisphere over the N170 component, as well as Group × Emotion interaction over P1 component. To identify the sources of these interactions, step-down ANOVAs for each group were performed separately to investigate the specifics of stimuli responses in each population. Overall, the morphology of the waveforms in TD population had more pronounced components (see Fig. 4).

Additionally, there was a significant main effect of StimType observed in both groups, such that P1 latency was shortest in the Incongruent condition, followed by Congruent and Body conditions, with Face condition eliciting longest latency (Face only condition, $M = 106$ ms; $SD = 10$ ms; Body only condition, $M = 102$ ms, $SD = 18$ ms; Congruent condition, $M = 102$ m, $SD = 14$ ms; Incongruent condition, $M = 99$ ms, $SD = 18$ ms).

13. TD group EEG analysis

Significant results of within-group ANOVA on the TD population, with factors Emotion (Fear, Anger), Stimulus type (Face, Body, Congruent, Incongruent), and hemisphere (left, right), on P1 and N170 amplitude and latency data are summarized in Table 3.

There were significant main effects of emotion observed over both components in the TD group. N170 amplitude was more negative in

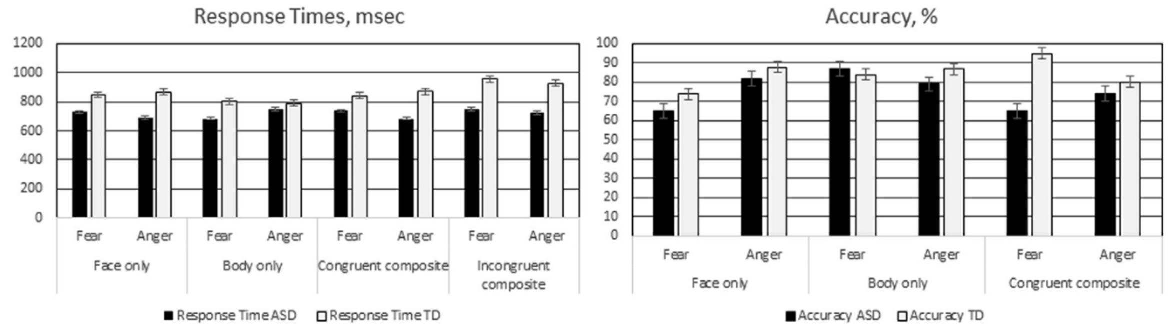

Fig. 3. Comparison of (A) response times, and (B) accuracy across stimuli categories in TD and ASD groups (error bars indicate SEM).

Table 2
Significant effects and interactions revealed by between-group analysis of variance.

Component	Contrast	F (24, 1) =	p <	η^2_p
N1 amplitude	Emotion × Group × StimType × Hemisphere	3.034	.045	.117
N1 latency	StimType × Hemisphere × Group	2.281	.028	.136
P1 amplitude	Emotion × Group × StimType × Hemisphere	3.562	.024	.134
P1 latency	Emotion × Group	7.142	.014	.237
	StimType	3.031	.040	.116

Anger condition (Fear, $M = 8.25$ µV; $SD = 13$ µV; Anger, $M = 3.56$ µV; $SD = 19$ µV). P1 peak was earlier and less positive in Anger condition (P1 latency, Fear, $M = 106$ ms; $SD = 11$ ms; Anger, $M = 101$ ms, $SD = 17$ ms; P1 amplitude, Fear, $M = 14$ µV; $SD = 13$ µV; Anger, $M = 10$ µV, $SD = 15$ µV).

Table 3
Significant effects and interactions revealed by analysis of variance in TD group.

Component	Contrast	F (10, 1) =	p <	η^2_p
N1 amplitude	Emotion	6.939	.021	.348
P1 amplitude	Emotion	4.348	.057	.251
P1 latency	Emotion	5.086	.042	.281

Table 4
Significant effects and interactions revealed by analysis of variance in ASD group.

Component	Contrast	F (10, 1) =	p <	η^2_p
N1 latency	StimType × Hemisphere	3.556	.036	.262

14. ASD group EEG analysis

Significant results of within-group ANOVA on ASD population, with factors Emotion (Fear, Anger), Stimulus type (Face, Body, Congruent, Incongruent), and hemisphere (left, right), on P1 and N170 amplitude and latency are presented in Table 4.

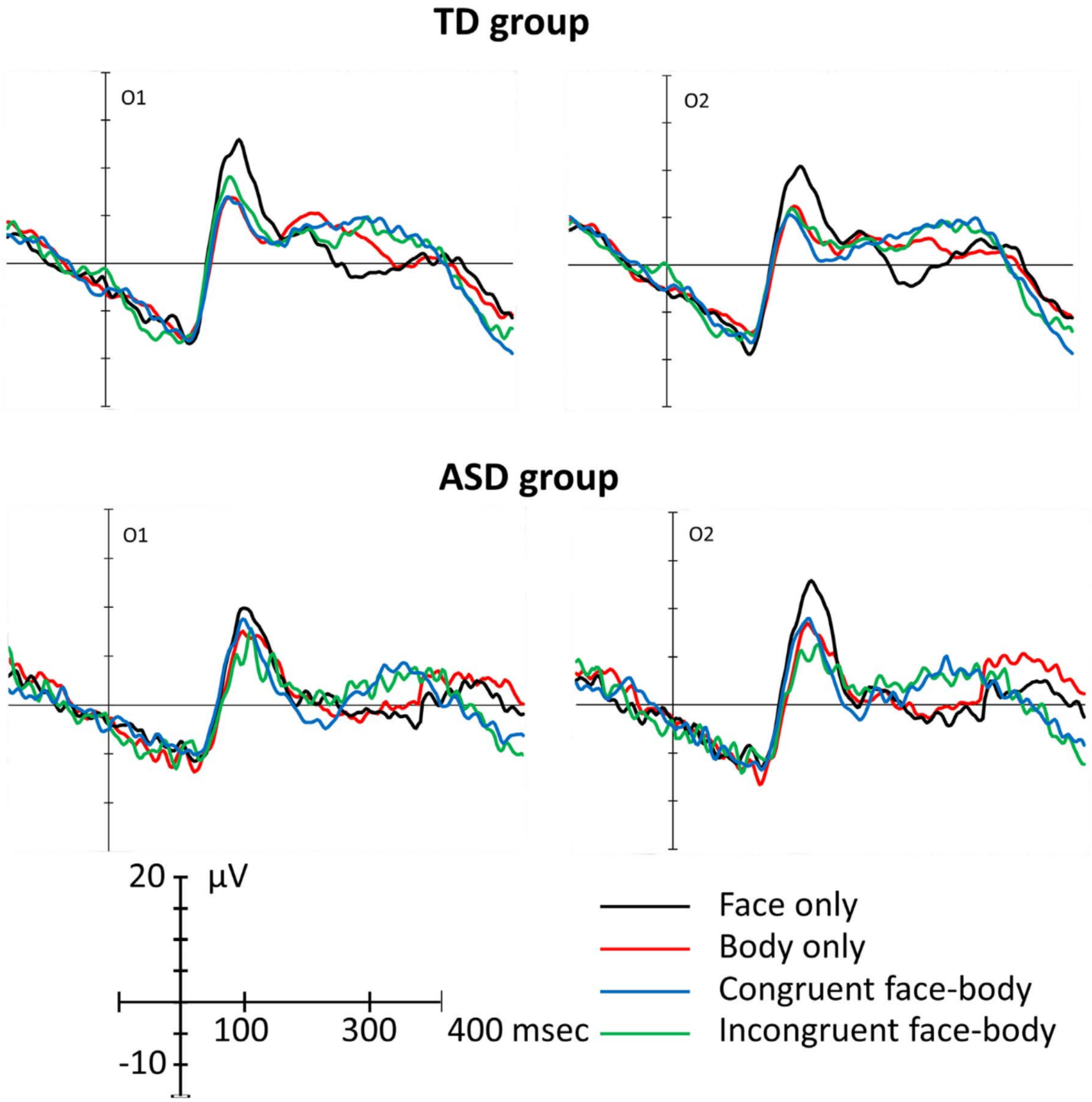

Fig. 4. ERPs elicited over O1 and O2 electrodes in TD and ASD groups by Face only, Body only, Congruent, and Incongruent stimuli, illustrating overall diminished component response in ASD group. Positive potentials are plotted upward.

There was a significant interaction between stimulus type and hemisphere for N170 latency in the ASD group, such as N170 latency was shorter on the left for Face condition, but on the right for Incongruent condition (Face only condition, left hemisphere *M* = 138 ms; *SD* = 36 ms; right hemisphere *M* = 153 ms; *SD* = 34 ms; Body only condition, left hemisphere *M* = 151 ms; *SD* = 36 ms; right hemisphere *M* = 152 ms; *SD* = 36 m; Congruent condition, left hemisphere *M* = 148 ms; *SD* = 36 ms; right hemisphere *M* = 153 ms; *SD* = 33 ms; Incongruent condition, left hemisphere *M* = 152 ms; *SD* = 37 ms; right hemisphere *M* = 148 ms; *SD* = 36 ms).

14.1. Interim summary

In both groups, the type of stimulus affected the latency of P1 component, such that P1 latency was shortest in Incongruent condition, followed by Congruent and Body conditions, with Face condition eliciting the longest latency. In the TD group, the mechanisms of processing fear and anger stimuli differed at the level of both the N170, and P1 components. In ASD group, no differences between processing fear and anger stimuli were reflected in EEG waveform morphology. However, the stimulus type affected the latency of the N170 component, such that its latency was shorter on the left for Face condition, but on the right for Incongruent condition.

15. Discussion

The present study compared ASD and TD behavioral and ERP responses to isolated face, isolated body, and combined face/body emotional expressions. Behavioral results showed faster response times for the ASD group in all categories, with significantly faster times for processing of fear, but not for anger, in all stimuli categories. In addition, significantly faster and less accurate behavioral responses were seen for fear stimuli. This finding is in agreement with other studies of emotional recognition (Farran et al., 2011; Kuusikko et al., 2009) which find that individuals with ASD show poorer performance than TD when identifying fear, but not other happiness or other emotions. A meta-analysis of 48 behavioral studies (Uljarevic and Hamilton, 2013) that focused upon emotion recognition in ASD concluded similarly, finding a lowered ability to recognize fear as compared with the other basic emotions (happiness, anger, disgust, sadness, surprise). Further, EEG results indicated that neither N170, nor P1 components reflected differences between fearful and angry expression processing in ASD group. Hypothesis 2 concerning differences in processing of incongruent stimuli by ASD and TD groups was correct, although behavioral data failed to show the differences between the groups. However, EEG data indicated an earlier right-lateralized N170 response to incongruent stimuli in ASD group, but not TD group.

Baron-Cohen et al. (2000) suggested behavioral studies of fear in ASD as a test for the amygdala theory of autism. Amygdala theory suggests, in general, that an abnormal neural network interactions involving the amygdala may result in the social deficits commonly seen in ASD individuals. This theory is supported by neurophysiological studies of individuals whose brain damage was limited to the amygdala (Adolphs et al., 1994; Broks et al., 1998). Results from these studies suggest that the amygdala response is required for identifying fear, and that damage to this neural area, or its connections, can lead to very specific requirements for recognizing emotions. In addition, in behavioral studies comparing persons with bilateral amygdala damage with a control group, Calder (1996) found deficits only when identifying fear. These studies indicate that appropriate connectivity of the amygdala may be required for processing fear, which might necessitate the use of a different strategy or neural pathway when processing fear in ASD populations (Harms et al., 2010). In contrast to these studies, Castelli (2005) found little difference between ASD and TD recognition of the six basic emotions, suggesting that the ASD deficit may not be related to identifying fear, but instead to the complexity required to decipher trustworthiness and approachability.

The ASD group's N170 latency for incongruent stimuli was significantly earlier on the right – an opposite patter from what was observed for the face only condition (where N170 latency was shorter on the left). This may indicate that ASD participants may not have registered the mismatch between face and body emotions, and relied on the body-signaled emotion instead. Note that TD group response times on the incongruent condition were slower than those of the ASD group. The combination of EEG and behavioral evidence suggests a possibility that TD participants were slowed as they interpreted the mismatched emotions presented on faces and bodies for incongruent stimuli. This could have been accomplished by engagement of a rapid neural mechanism sensitive to the agreement between face and body language, supporting previous suggestions that face and body may be processed as a single unit (Meeren et al., 2005, Malaia et al., 2012).

Comparable accuracy between ASD and TD groups on the isolated stimuli indicate that the two groups were similar in their abilities to accurately identify isolated face and body cues. In contrast, presentations of combined stimuli resulted in significant accuracy differences between the TD and the ASD group when identifying fear vs. anger. It is possible that the presentation of incongruent face and body stimuli may provide unusual information that is difficult to process via heuristic mechanisms (but can be processed via pattern-recognition algorithms that quantify stimulus-to-brain information transfer, cf. Malaia, 2017; Malaia et al., 2016). For example, ASD individuals may be identifying emotion information contained in the facial expression through a mechanism that looks for patterns to deduce visual meaning, rather than by employing the limbic system (cf. Barsalou et al., 2007; Malaia et al, 2015, Malaia et al., 2016).

Social communication and emotional processing deficits are hallmarks of ASD (Cockerham and Malaia, 2017). In order to increase the effectiveness of interventions for this population, we must obtain additional information about neural substrates that underlie ASD social and emotional processing. In our modern, highly interactive, social-network-based communities, interventions that improve the understanding of social and emotional communication will improve the lives of individuals with ASD.

16. Limitations

The isolated face condition was the only condition that did not have the complete outline of the person. The face photos including a grayed-in outline of the body would be a spatial-frequency equivalent comparison to the body condition with the grayed-out faces. Lack of grayed-in outline of the body/face in the isolated condition meant that participants had less visual contrast information in this condition. Also, three of four stimuli conditions included the face (Face, and both Composite stimuli), and participant instructions specifically drew attentional focus to the face; only a quarter of the stimuli were body-only. This could have led to lower amplitude of N170 in the body-only condition.

In addition, we accepted the school's IQ measures available for the students, in lieu of conducting an IQ test for each participant. Future studies should assess IQ when the study is conducted so that a single standard assessment method is used.

Conflict of interest

The authors declare that they have no conflict of interest.

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References

Adolphs, R., Tranel, D., Damasio, H., Damasio, A., 1994. Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. Nature 372 (6507), 669–672.

Argyle, Michael, 1972. Non-verbal communication in human social interaction. In: Hinde, R.A. (Ed.), Non-verbal Communication. Cambridge University Press, Oxford, England.

Ashwin, C., Baron-Cohen, S., Wheelwright, S., O'Riordan, M., Bullmore, E.T., 2007. Differential activation of the amygdala and the 'social brain'during fearful face-processing in Asperger Syndrome. Neuropsychologia 45 (1), 2–14.

Baron-Cohen, S., Ring, H.A., Bullmore, E.T., Wheelwright, S., Ashwin, C., Williams, S.C.R., 2000. The amygdala theory of autism. Neurosci. Biobehav. Rev. 24 (3), 355–364.

Barsalou, L.W., Breazeal, C., Smith, L.B., 2007. Cognition as coordinated non-cognition. Cogn. Process. 8 (2), 79–91.

Batty, M., Taylor, M.J., 2003. Early processing of the six basic facial emotional expressions. Cogn. Brain Res. 17 (3), 613–620.

Batty, M., Meaux, E., Wittemeyer, K., Rogé, B., Taylor, M.J., 2011. Early processing of emotional faces in children with autism: an event-related potential study. J. Exp. Child Psychol. 109 (4), 430–444.

Boutot, E.A., Myles, B.S., 2011. Autism Spectrum Disorders: Foundations, Characteristics, and Effective Strategies. Pearson Education, Upper Saddle River, NJ.

Broks, P., Young, A.W., Maratos, E.J., Coffey, P.J., Calder, A.J., Isaac, C.L., Roberts, N., 1998. Face processing impairments after encephalitis: amygdala damage and recognition of fear. Neuropsychologia 36 (1), 59–70.

Calder, A.J., 1996. Facial emotion recognition after bilateral amygdala damage: differentially severe impairment of fear. Cogn. Neuropsychol. 13 (5), 699–745.

Castelli, F., 2005. Understanding emotions from standardized facial expressions in autism and normal development. Autism 9 (4), 428–449.

Clark, V.P., Fan, S., Hillyard, S.A., 1995. Identification of early visual evoked potential generators by retinotopic and topographic analyses. Hum. Brain Mapp. 2, 170–187.

Cockerham, D., Malaia, E., 2017. Neuroscience-supported approaches to teaching students on the autism spectrum. Zeitschrift Psychologie, Special Issue Educ. Neurosci. 224 (4), 290–293.

Darwin, C.R., 1872. The expression of the emotions in man and animals 2nd ed. Retrieved from ⟨http://darwin-online.org.uk⟩.

Dawson, G., Webb, S.J., Carver, L., Panagiotides, H., McPartland, J., 2004a. Young children with autism show atypical brain responses to fearful versus neutral facial expressions of emotion. Dev. Sci. 7 (3), 340–359.

de Gelder, B., 2006. Towards the neurobiology of emotional body language. Nat. Rev. Neurosci. 7 (3), 242–249.

de Gelder, B., 2009. Why bodies? Twelve reasons for including bodily expressions in affective neuroscience. Philos. Trans. R. Soc. 364, 3475–3484.

de Gelder, B., Snyder, J., Greve, D., Gerard, G., Hadjikhani, N., 2004. Fear fosters flight: a mechanism for fear contagion when perceiving emotion expressed by a whole body. Proc. Natl. Acad. Sci. USA 101, 16701–16706.

de Gelder, B., van den Stock, J., 2011. The bodily expressive action stimulus test (BEAST). Construction and validation of a stimulus basis for measuring perception of whole body expression of emotions. Front. Psychol. 2, 1–5.

Di Russo, F., Martinez, A., Sereno, M.I., Pitzalis, S., Hillyard, S.A., 2002. Cortical sources of the early components of the visual evoked potential. Hum. Brain Mapp. 15, 95–111.

Eimer, M., 2000. The face-specific N170 component reflects late stages in the structural encoding of faces. Neuroreport 11 (10), 2319 .

Farran, E.K., Branson, A., King, B.J., 2011. Visual search for basic emotional expressions in autism; impaired processing of anger, fear and sadness, but a typical happy face advantage. Res. Autism Spectr. Disord. 5 (1), 455–462.

Gauthier, I., Tarr, M.J., 1997. Becoming a "Greeble" expert: exploring mechanisms for face recognition. Vision. Res. 37 (12), 1673–1682.

Gofaux, V., Gauthier, I., Rossion, B., 2003. Spatial scale contribution to early visual differences between facial and object processing. Cogn. Brain Res. 15, 416–424.

Hadjikhani, N., de Gelder, B., 2003. Seeing fearful body expressions activates the fusiform cortex and amygdala. Curr. Biol. 13, 2201–2205.

Harms, M.B., Martin, A., Wallace, G.L., 2010. Facial emotion recognition in autism spectrum disorders: a review of behavioral and neuroimaging studies. Neuropsychol. Rev. 20 (3), 290–322.

Hobson, R.P., Ouston, J., Lee, A., 1988. What's in a face? The case of autism. Br. J. Psychol. 79 (4), 441–453.

Kuusikko, S., Haapsamo, H., Jansson-Verkasalo, E., Hurtig, T., Mattila, M.L., Ebeling, H., Jussila, K., Bölte, S., Moilanen, I., 2009. Emotion recognition in children and adolescents with autism spectrum disorders. J. Autism Dev. Disord. 39 (6), 938–945.

Malaia, E., 2017. Current and future methodologies for quantitative analysis of information transfer in sign language and gesture data. Behav. Brain Sci. 40.

Malaia, E., Bates, E., Seitzman, B., Coppess, K., 2016. Altered brain network dynamics in youths with autism spectrum disorder. Exp. Brain Res. 234 (12), 3425–3431.

Malaia, E., Borneman, J.D., Wilbur, R.B., 2016. Assessment of information content in visual signal: analysis of optical flow fractal complexity. Vis. Cognit. 24 (3), 246–251.

Malaia, E., Newman, S., 2015. Neural bases of syntax-semantics interface processing. Cognit. Neurodyn. 9 (3), 317–329.

Malaia, E., Ranaweera, R., Wilbur, R.B., Talavage, T.M., 2012. Neural representation of event structure in American Sign Language: fMRI comparison of cortical activations in deaf signers and hearing non-signers. Neuroimage 59, 4094–4101.

Malaia, E., Tommerdahl, J., Mckee, F.W., 2015. Deductive and heuristic reasoning processing markers in EEG. J. Psycholinguist. Res. 44 (5), 533–544.

Marsh, A.A., Ambady, N., Kleck, R.E., 2005. The effects of fear and anger facial expressions on approach-and avoidance-related behaviors. Emotion 5 (1), 119.

Marsh, P.J., Luckett, G., Russell, T., Coltheart, M., Green, M.J., 2012. Effects of facial emotion recognition remediation on visual scanning of novel face stimuli. Schizophr. Res., ID# 22959743 Advance Online Publication. Retrieved from. ⟨http://www.ncbi.nlm.nih.gov/pubmed⟩.

Macdonald, H., Rutter, M., Howlin, P., Rios, P., Conteur, A.L., Evered, C., Folstein, S., 1989. Recognition and expression of emotional cues by autistic and normal adults. J. Child Psychol. Psychiatry 30 (6), 865–877.

Meeren, H.K.M., Van Heijnsbergen, C.C.R.J., de Gelder, B., 2005. Rapid perceptual integration of facial expression and emotional body language. Proc. Natl. Acad. Sci. USA 102 (45), 16518.

Mehrabian, A., 1972. Nonverbal Communication. Aldine, Chicago.

Mehrabian, A., Ferris, S.R., 1967. Inference of attitudes from nonverbal communication in two channels. J. Consult. Psychol. 31 (3), 248.

Newcomer, P., Hammill, D., 2009. Pragmatic Language Observation Scale. Hammill Institute on Disabilities, Austin, TX.

Phelps-Terasaki, D., Phelps-Gunn, T., 2007. Test of Pragmatic Language, 2nd ed. Pro-Ed Publishers, Austin, TX.

Pichon, S., de Gelder, B., Grezes, J., 2009. Two different faces of threat. Comparing the neural systems for recognizing fear and anger in dynamic body expressions. Neuroimage 47 (4), 1873–1883.

Rossion, B., Jacques, C., 2008. Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170. NeuroImage 39 (4), 1959–1979.

Stekelenburg, J.J., Gelder, B., 2004. The neural correlates of perceiving human bodies: an ERP study on the body-inversion effect. Neuroreport 15 (5), 777.

Thierry, G., Martin, C.D., Downing, P., Pegna, A.J., 2007. Controlling for interstimulus perceptual variance abolishes N170 face selectivity. Nat. Neurosci. 10, 505–511.

Tottenham, N., Tanaka, J.W., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A., Nelson, C., 2009. The NimStim set of facial expressions: judgments from untrained research participants. Psychiatry Res. 168 (3), 242–249.

Uljarevic, M., Hamilton, A., 2013. Recognition of emotions in autism: a formal meta-analysis. J. Autism Dev. Disord. 43 (7), 1517–1526.

Van der Geest, J.N., Kemner, C., Verbaten, M.N., Van Engeland, H., 2002. Gaze behavior of children with pervasive developmental disorder toward human faces: a fixation time study. J. Child Psychol. Psychiatry 43 (5), 669–678.

Wallbott, H.G., 1998. Bodily expression of emotion. Eur. J. Social. Psychol. 28 (6), 879–896.