# Attentional Effects of Gaze Shifts Are Influenced by Emotion and Spatial Frequency, but Not in Autism

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**ABSTRACT**

**Objective:** Impaired gaze following is an important hallmark of autism spectrum disorders (ASDs) in clinical settings. Yet, ASD subjects perform normally on laboratory tasks involving gaze shifts. We investigated this contradiction, hypothesizing that impaired gaze following in ASDs is not related to basic impairments in attention orienting but to impaired emotion perception and abnormal processing of spatial frequencies (i.e., local and global information). **Method:** We tested 30 high-functioning, school-age children with ASDs and 30 age- and IQ-matched controls on a task involving gaze shifts that cue the location of targets. The cueing faces differed in emotionality and were filtered for different spatial frequencies. We recorded behavioral responses (reaction times) and brain responses (event-related potentials). **Results:** ASD subjects performed normally when neutral faces were used. However, emotional faces elicited modified face and gaze cue processing in control subjects, but not in the ASD subjects. Furthermore, the control group was biased toward the use of low spatial frequencies (global information) to process gaze cues, whereas the ASD group was biased toward the use of high spatial frequencies (local information). **Conclusions:** We conclude that impaired gaze following in ASDs is related to impaired emotion processing. Moreover, ASD subjects show an abnormal reliance on local information to process gaze cues. *J. Am. Acad. Child Adolesc. Psychiatry,* 2008;47(4):443–454. **Key Words:** autism, gaze, emotion, spatial frequency, event-related potentials.

An intriguing contradiction exists between clinical reports of impaired gaze following in autism spectrum disorders (ASDs), on the one hand, and studies failing to reproduce this effect in the laboratory on the other. Gaze following is a social skill by which individuals direct their attention to the same location by observing each other's gaze direction. In clinical settings, impaired gaze following is recognized as an important hallmark of ASDs, both in young children and adolescents.[1,2] In fact, it is one of the earliest detectable symptoms of these disorders and is probably directly related to problems in social interactions typical for ASDs.[3,4] Nonetheless, several recent studies showed irreproducibility of this attribute of ASD in the laboratory.[5–10] The present study aimed to investigate this conundrum, hypothesizing that the negative results obtained in laboratory settings are an effect of the low ecological validity of the experimental stimuli used.[11] To date, face motion and emotion have not been included in experimental setups. Instead, all previous studies relied on static neutral faces. Therefore, we designed an experimental task involving dynamic emotional faces.

Laboratory tasks used to study gaze following typically comprise a centrally presented, nonemotional face that cues the location of a peripheral target through a gaze shift. The rest of the face remains static. The gaze cue leads to faster detection times for correctly cued targets.[12,13] To display naturally looking emotional expressions that accompany the gaze shift, we designed a gaze cue task with dynamic faces. We hypothesized that

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attention orienting in typically developing children is affected by emotion because emotional expressions are known to influence spatial attention. Fearful expressions in particular have the capacity to modify attention orienting in a fast and involuntary manner.[14,15] For children with ASDs, we assumed that emotion would not affect attention orienting because these children have abnormalities in the processing of emotion.[16–20]

Our hypothesis is supported by a deficit in the processing of facial information in ASD,[16] such as impaired recognition of emotional expressions.[17] In addition, brain regions involved in the perception of facial emotions are hypoactive in individuals with ASD.[18–20] These brain regions include the fusiform gyrus, often referred to as the fusiform face area, the amygdala, known for its role in the appraisal of emotional stimuli, and the superior temporal sulcus, a region mediating biological motion perception in, for example, expression changes and gaze shifts.[18–20] It therefore is likely that not impairments in gaze cue processing per se but rather abnormalities in emotion processing lead to the impaired gaze following seen in ASDs in clinical settings and daily life.

Some authors have proposed that the deficits in emotion processing in ASD are the result of a decreased social motivation that corrupts the development of face-processing skills.[16] However, there is increasing evidence that the cause of the abnormal emotion processing in ASDs is not social in nature but is related to perceptual abnormalities.[21,22] Various previous studies indicate that ASD subjects focus on local rather than global aspects of stimuli,[22,23] both for social[17,24] and nonsocial[25,26] information. In other words, local aspects (i.e., individual face features, such as expression-related wrinkles) are processed more thoroughly in ASD than global aspects (coarse information about the configuration of features).

The processing of local and global information may be linked to the processing of high and low spatial frequencies (SFs), respectively.[27–30] Global information conveyed by low SFs (Fig. 1) activates rapid threat/saliency detection systems in the brain.[30,31] In this way, low SFs are believed to mediate fast and unconscious social adjustments of behavior,[30,32] whereas the detailed information conveyed by high SFs (Fig. 1) mediates conscious perception and memory of emotional faces, at the expense of processing speed.[29,32] An interesting finding is that emotional faces containing solely low SFs activate the amygdala and the fusiform face area, whereas emotional faces containing solely high SFs do not.[31,33,34] As mentioned above, the amygdala and fusiform face area are both important for emotion perception and are hypoactive in ASDs.[18–20]

This suggests that the focus on local information in ASDs is related to hypoprocessing of low SFs or a relative overuse of high SFs. In line with this idea, Deruelle et al.[35] found that children with ASDs had more difficulty than controls in identifying faces when only low SFs are shown. In contrast, the controls had more difficulty than the ASD children when only high SFs were shown. Atypical processing of high SFs in ASDs has also been found using simple grating stimuli.[36] It therefore seems that, for social as well as nonsocial information, there is a bias toward the use of local information and high SFs in ASDs. This bias probably affects emotion processing, given the above-described differential involvement of high and low SFs in emotion processing.

We included high-pass filtered (fine grained) and low-pass filtered (blurry) faces in our experimental setup

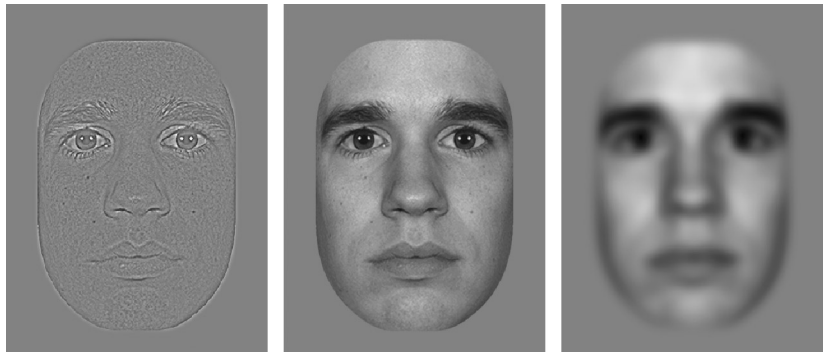

**Fig. 1** Example of an unfiltered face stimulus (middle) and its high-pass (left) and low-pass (right) filtered versions.

to investigate whether a bias toward the processing of local information and high SFs indeed influences emotion processing and, possibly, gaze cue processing in ASDs. For the control group, we hypothesized that low SFs are of particular importance in the processing of emotional gaze cues because the present task does not emphasize conscious emotion processing. Also, the effect of gaze cues is believed to depend on the contrast between the iris and sclera,[37] which is a low SF feature in normal viewing conditions as well as in our experimental setup. In contrast, we expected the ASD group to show a relative overreliance on high SF information.

While subjects performed the task, we recorded reaction times (RTs) and brain activity (event related potentials [ERPs]) related to face processing (N170 peak) and attention orienting (P100 and N200 peaks). It is well documented that the N170 peak in response to faces reflects face-specific brain activity originating most likely from the fusiform gyrus or superior temporal sulcus.[38,39] Previous studies indicated that emotion and SF filtering affect the N170[40,41] (see also a study done by Holmes et al.[42]). The occipitotemporal P100 and N200 peaks in response to the peripheral targets are typically earlier and larger for correctly cued targets, which probably reflects increased neural activity in the extrastriatal visual cortex to facilitate the processing of attended stimuli.[43] Kemner et al.[5] found the N170, P100, and N200 to be normal in ASD patients during a gaze cue task with neutral expressions. In our emotional gaze cue task, we expect abnormal brain activity in the ASD group because of the effects of emotion and SF filtering. A group of school-age children with a diagnosis of either autistic disorder or Asperger syndrome and an evenly numbered group of age- and IQ-matched typically developing controls participated in this study.

## METHOD

### Subjects

The ASD and control groups both consisted of 30 high-functioning (IQ >80) children, matched for sex, age (school age, 7–13 years old), and IQ (Table 1). IQ was obtained using the revised Dutch edition of the WISC. All of the subjects had normal or corrected to normal vision and no neurological history. Control children were screened for psychopathology by means of the Child Behavior Checklist[44] and excluded if scores were within the clinical range. Sixty-seven percent of subjects were also screened by means of the Teacher's Report Form.[45] The ASD subjects were diagnosed with either autistic disorder or Asperger syndrome by a child and adolescent psychiatrist using *DSM-IV* criteria.[4] In addition, the Autism Diagnostic Interview Revised[46] was administered to the parents by a trained rater (Table 1). Of all of the patients, 24 met full Autism Diagnostic Interview Revised criteria for autistic disorder (cutoffs shown in Table 1) and six met criteria for an ASD (defined as scoring 1 point below cutoff on only one of the three Autism Diagnostic Interview Revised domains, which was the stereotypy domain in five of the six cases). None of the patients had a comorbid psychiatric or neurological disorder. Seven patients used psychoactive medication (three methylphenidate, one typical neuroleptic, two atypical neuroleptics, and one selective serotonin reuptake inhibitor), and subjects on methylphenidate were instructed not to take this medication on the day of testing. The study was approved of by the Medical Ethics Committee of the University Medical Center, and all of the parents gave written informed consent before participation.

**TABLE 1**
Subject Characteristics (Mean ± Standard Error)

| | ASD | Control |
|---|---|---|
| No. of subjects | 30 (24 M, 6 F) | 30 (24 M, 6 F) |
| Age, y | 10.7 ± 1.8 | 10.6 ± 1.6 |
| Total IQ | 108.4 ± 2.6 | 111.5 ± 2.2 |
| Verbal IQ | 113.3 ± 2.7 | 116.3 ± 2.5 |
| Performance IQ | 101.4 ± 3.1 | 100.6 ± 2.5 |
| ADI-R social domain[a] | 20 ± 1.1 | |
| ADI-R communication domain[b] | 16 ± 0.8 | |
| ADI-R stereotype domain[c] | 6 ± 0.5 | |

*Note:* ASD = autism spectrum disorders; M = male; F = female; ADI-R = Autism Diagnostic Interview Revised.
[a] Cutoff for autism: 10.
[b] Cutoff for autism: 8.
[c] Cutoff for autism: 3.

### Stimuli

Pictures of 10 different actors displaying fearful and neutral expressions were taken from the MacBrain Face Stimulus Set. (Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at *tott0006@tc.umn.edu* for more information concerning the stimulus set.) Using Adobe Photoshop 7.0.1 software, straight and averted eyes were created, and the faces were matched for size (6.46 cm horizontally, which corresponds to 3.7° because the viewing distance was 1 meter), shape, luminance (18 cd/m$^2$), and contrast. To generate dynamic stimuli, fearful and neutral pictures of the same actor were "morphed" using Meesoft Smartmorph 1.55 software (resulting in 13-frame movie clips). High- and low-pass filtering was done using a two-dimensional Fourier transformation with cutoff values of >22.2 cycles/image (equivalent to more than six cycles per degree) and <7.4 cycles/image (equivalent to fewer than two cycles per degree), respectively (Fig. 1).

### Design

Two different emotional conditions were compared. In the neutral-to-fearful (N-to-F) condition, a neutral face changed to

fearful while making a gaze shift from straight to averted. In the fearful-to-neutral (F-to-N) condition, a fearful face changed to neutral while changing gaze direction. For the N-to-F condition, we expected enhanced cueing effects because the averted fearful gaze was expected to enhance the shift of attention to the periphery. For the F-to-N condition, we expected decreased cueing effects because the straight fearful gaze was expected to attract attention to its location.[15] SF filtering of these conditions yielded six conditions (2x unfiltered, 2x high SF, 2x low SF). To be able to replicate previous findings of studies testing ASD subjects on gaze cue tasks, we included a seventh condition (neutral-to-neutral) involving static neutral faces (unfiltered).

## Procedure

Each subject completed 700 trials (100 trials per condition), presented over four blocks. Additional trials (175 maximally) were presented in the same session to three ASD subjects and two control subjects to compensate for excessive movement artifacts in the ERP signal. The chronological sequence of events in a trial was as follows: fixation dot (1,000 milliseconds), initial face with straight gaze (373 milliseconds), movie clip showing gradual change of facial expression and gaze direction (11 frames, 40 milliseconds per frame), final face gazing randomly to the left or right (373 milliseconds), target cross (subtending 0.7°) placed randomly on the left or right (5.7° off center, 1,000 milliseconds), pseudo-random delay (1,100–1,700 milliseconds; Fig. 2). During target presentation, the final face remained visible on the screen to avoid offset effects. Stimuli were presented on a gray background matching the average luminance of the face stimuli. Subjects were made aware of the fact that gaze direction did not predict target location. Subjects were instructed to fixate on the central face throughout the experiment and to respond to appearance of the target by pressing a corresponding left or right button as quickly and accurately as possible.

## Data Recording

Subjects were seated in an electronically and acoustically shielded room. EEG was recorded with 34 silver/silver chloride (Ag/AgCl) flat type active electrodes (Active Two System, Biosemi) positioned at standard locations on an elastic cap (Quickcap, Neuromedical Supplies of Neurosoft Inc.). EEG was sampled at 2,048 Hz and stored as a continuous signal. Two electrodes in the electrode cap provided an active ground. In addition, horizontal and vertical electro-oculograms were measured. Data were resampled offline at 500 Hz and analyzed using Brain Vision Analyser software (Brainproducts GmbH). A 2-Hz high-pass filter, a 20-Hz low-pass filter, and a 50-Hz Notch filter were applied. All of the electrodes were referenced to the right mastoid. Eye movement artifacts (detected using the algorithm by Gratton et al.,[47] which is implemented in the Brain Vision Analyser) and EEG artifacts (defined as amplitudes >±100 μV, amplitude differences within epoch >137 μV, amplitude differences within 200 milliseconds <3 μV, voltage steps per sample point >15 μV) were removed.

## Data Analysis

Epochs were extracted offline from the continuous data. The face-specific N170 peak was defined as a negative deflection 165–235 milliseconds after onset of the initial face (at electrodes P3, P4, CP5,

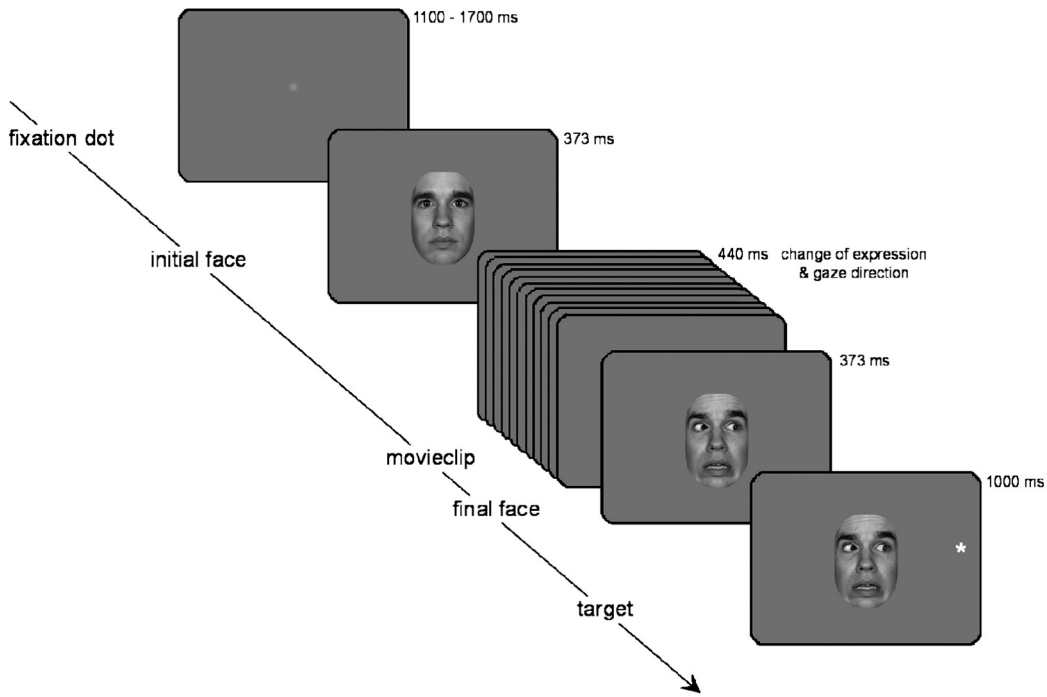


**Fig. 2** Sequence of events in one trial. Shown here is the neutral-to-fearful condition, which was compared with the fearful-to-neutral condition to reveal the effects of emotion. A neutral-to-neutral condition, involving a gaze change without an expression change, was also included. Targets were correctly cued by gaze direction in 50% of the trials. Event-related potentials were measured in response to the initial face and in response to the target.

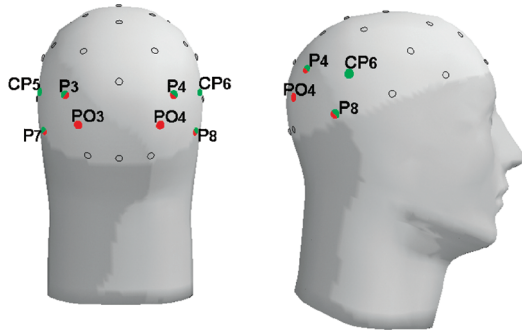


**Fig. 3** Positions of the analyzed electrodes. Red: Used for the face-specific N170; green: used for the P100 and N200 in response to target appearance.

CP6, P7, and P8). The N170 therefore reflects processing of the initial emotion (of the first face) and is not influenced by the emotion of the final face. To study attention orienting, we analyzed the P100 (positive deflection 110–160 milliseconds after target onset) and N200 (negative deflection 165–215 milliseconds after target onset) at electrodes PO3, PO4, P3, P4, P7, and P8 (Fig. 3). Electrode sites to be analyzed were chosen based on previous studies and data inspection.[5,38,43] For the N170, a broader window was chosen to enable scoring within one window of the high SF and low SF conditions, which differ slightly in their N170 latency. Baseline correction was done on a 100-millisecond prestimulus interval for the N170 and a longer (200 milliseconds) prestimulus interval for the P100 and N200, the latter because there was no rest period before target appearance. Measured variables were baseline to peak amplitudes and stimulus onset to peak latencies. Trials with correct responses and without EEG artifacts were included in the analyses (analyzed trials per subject: 85% and 86% on average in ASDs and control groups, respectively). RTs ranging from 100 to 1,500 milliseconds were included in the analyses, after exclusion of the 5% slowest reaction times per subject.

### Statistical Analysis

We performed a repeated-measures analysis of variance with group as the between factor and emotion, laterality (electrodes in left or right hemisphere), and position (of the bilateral electrodes) as within factors. Cue validity and filter type (high pass or low pass) were added as within factors for the analysis of the P100 and N200 and the analysis of the filtered conditions, respectively. We restricted the analyses to effects relevant to our hypotheses. For the N170, we tested for effects of (and interactions with) emotion (using the unfiltered faces) and effects of filter type (using the filtered faces). Regarding RTs and the P100 and N200, we tested for effects of cue validity in the static neutral condition, interactions between cue validity and emotion in the dynamic emotional conditions, and interactions between cue validity and filter type in the filtered conditions. A two-tailed α value of .05 was adopted, and the Greenhouse-Geisser correction was applied. The filtered and unfiltered conditions were analyzed in independent analyses to avoid interference of the effect of filtering per se, which is the effect of omitting an important (middle) part of the frequency spectrum in both filtered conditions.[28] The static neutral condition was analyzed independently because of the absence of face motion in this condition. Partial effects were only tested when the overall effect was significant, except for a post hoc test that was done per group on the cue validity–emotion interaction on RTs (based on visual inspection of the data; Fig. 7).

## RESULTS

In none of the conditions was there a significant difference between the control group and the ASD

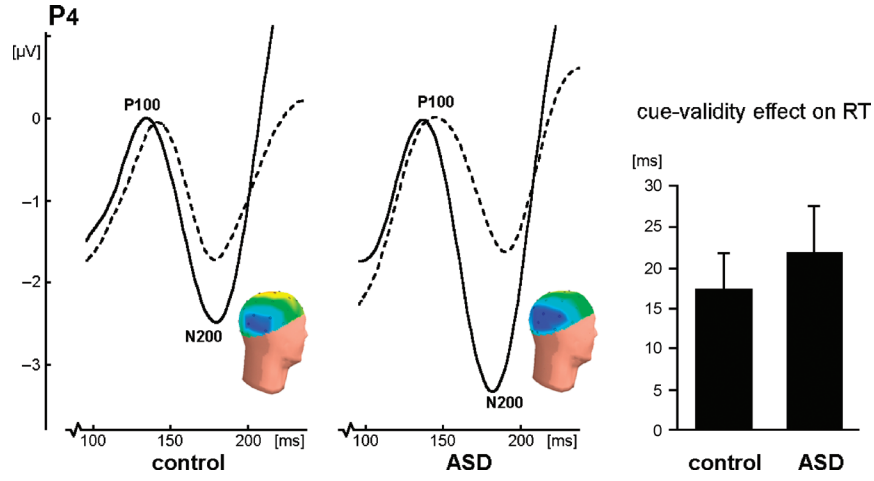


**Fig. 4** Results of the neutral-to-neutral condition, showing no impairments in autism spectrum disorders (ASD). Left: P100 and N200 peaks in response to correctly cued (solid lines) and incorrectly cued (dashed lines) targets at electrode P4 (right hemisphere). The peaks are earlier and larger for correctly cued targets, although the P100 amplitude effect is only evident in the left hemisphere (Table 3), which is not shown here. Inset: Heads show the distribution of N200 activity to correctly cued targets (negativity in blue, positivity in yellow). Right: The cue-validity effect (± SE) on reaction times (RTs), given as the RT to incorrectly cued targets minus the RT to correctly cued targets. This effect did not differ between the subject groups.

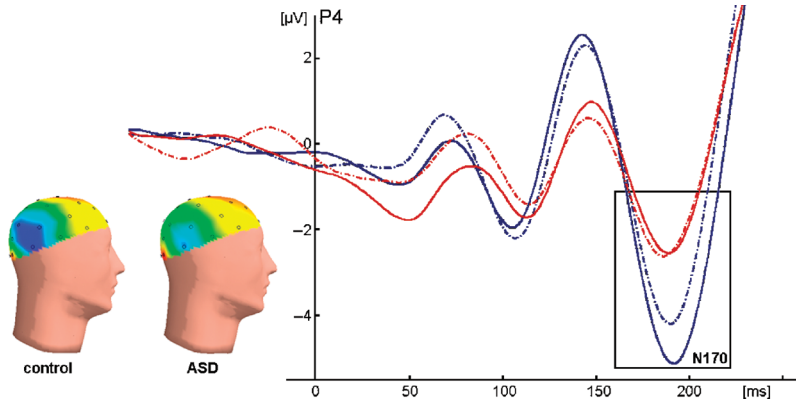


**Fig. 5** Effects of emotion on face processing. The N170 peak in response to unfiltered fearful (solid lines) and neutral (dashed lines) faces for both groups (control group in blue, autism spectrum disorders [ASD] group in red) at electrode P4. Inset: Heads show the distribution of N170 activity to fearful faces (negativity in blue, positivity in red). Note that control subjects have an enlarged N170 to fearful faces, whereas ASD subjects do not.

group in absolute RTs or number of correct responses. In the static neutral condition, the cue-validity effects on RTs, P100, and N200 latency did not differ between the subject groups. On N200 amplitude, the ASD group showed a larger cue-validity effect (Fig. 4). In both groups, correctly cued targets elicited earlier and larger P100 and N200 peaks and faster RTs than incorrectly cued targets (significant effects and statistical values are shown in Table 3).

### Effects of Emotion on Face Processing (N170 Peak)

The effects of emotion on face processing concern the emotion of the initial (not yet dynamic) face. The amplitude of the N170 was affected by emotion in the

**TABLE 2**
Overview of the Processing Results

| Effects of Interest | Overall Effects Found | Group Effects Found | Results |
|---|---|---|---|
| **EMOTION** | | | |
| **N170 latency** | **lat*emo** $F(1,58) = 4.2$, $p < 0.05$<br>↳ P4-P8-CP6: **emo** $F(1,58) = 7.1$, $p < 0.01$ | | both groups:<br>neutral »» fearful |
| **N170 amplitude** | **emo** $F(1,58) = 7.0$, $p < 0.05$ | **emo*group** $F(1,58) = 4.3$, $p < 0.05$<br>↳ control: **emo** $F(1,29) = 11.7$, $p < 0.005$<br>ASD: **emo** $F(1,29) = 0.2$, $p = 0.7$<br>↳ neutral: **group** $F(1,58) = 1.4$, $p = 0.2$<br>fearful: **group** $F(1,58) = 4.5$, $p < 0.05$ | control group only:<br>fearful > neutral<br>fearful faces only:<br>control > ASD |
| **FILTERING** | | | |
| **N170 latency** | **fil** $F(1,58) = 45.3$, $p < 0.001$<br>**pos*fil** $F(2,57) = 15.0$, $p < 0.001$<br>↳ P3-P4: **fil** $F(1,58) = 23.0$, $p < 0.001$<br>P7-P8: **fil** $F(1,58) = 155.1$, $p < 0.001$ | **pos*lat*fil*group** $F(2,57) = 3.8$, $p < 0.05$<br>↳ P7: **fil*group** $F(1,58) = 5.0$, $p < 0.05$<br>↳ **control: fil** $F(1,29) = 128.9$, $p < 0.001$<br>**ASD: fil** $F(1,29) = 12.2$, $p < 0.005$ | mainly in<br>control group:<br>low-pass»»high-pass |
| **N170 amplitude** | **fil** $F(1,58) = 11.2$, $p < 0.005$<br>**pos*fil** $F(2,57) = 29.0$, $p < 0.001$<br>**pos*lat*fil** $F(2,57) = 6.2$, $p < 0.005$<br>↳ CP5, CP6, P3, P4:<br>**fil** all $F(1,58) > 13.3$, all $p < 0.005$ | | both groups:<br>high-pass > low-pass |
| **EMOTION*FILTERING** | | | |
| **N170 amplitude** | | **pos*lat*emo*fil*group**<br>$F(2,57) = 5.2$, $p < 0.005$** | |

*Note:* All significant results (in bold) and partial effects (indicated by a ↳ sign) are presented. Effects without significant partial effects per electrode (indicated by **) are not reported in the text. emo = emotion; fil = filter type; pos = position of bilateral electrodes; lat = laterality; »» = earlier than; > = larger than.

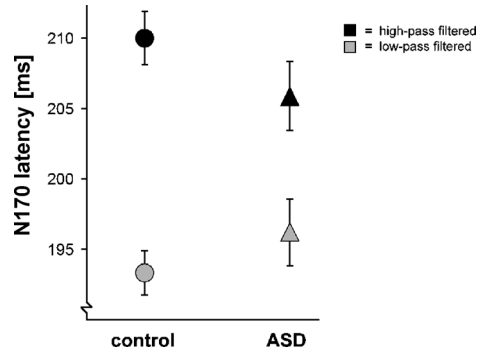


**Fig. 6** Effects of filter type on face processing. N170 latencies (± SE) for high-pass (black) and low-pass (gray) filtered faces at electrode P7. The autism spectrum disorder (ASD) group showed a smaller effect of filter type.

control group only (Fig. 5): the control group showed an enlarged N170 for fearful faces (compared with neutral faces), whereas the ASD group did not. The N170 elicited by fearful faces was significantly larger in the control group than in the ASD group, whereas the N170 elicited by neutral faces did not significantly differ between the groups (Table 2). Both groups showed a delayed N170 in response to fearful as compared with neutral faces. We found no interactions between effects of emotion and effects of SF filtering; however, the groups did differ in the main effect of filter type. Although both groups showed an earlier and smaller N170 for low SF filtered faces compared with high SF filtered faces, this effect was significantly smaller in the ASD group than the control group on N170 latency (Fig. 6, significant effects and statistical values in Table 2).

### Effects of Emotion on Gaze Cueing (P100 and N200 Peaks)

The RTs, P100 peak, and N200 peak reflect the effects of the dynamic change in emotion (from neutral to fearful or vice versa) on attention orienting. The control group showed a significant cue-validity effect only in the N-to-F condition and not in the F-to-N condition. The ASD group showed no influence of emotion, with the cue-validity effects in both emotional conditions being intermediate to the cue-validity effects in the control group (Fig. 7). This pattern of results was found for brain activity (N200 latency) as well as RT (the latter in a post hoc test) and did not interact with effects of SF filtering. Furthermore, we found that, for control subjects, the cue-validity effect was significantly larger in the low SF condition than in the high SF condition, whereas this was reversed for ASD subjects, with a trend toward a greater cue-validity effect in the high SF condition than in the low SF condition (Fig. 8). This difference between the groups was most significant in the high SF condition (significant effects and statistical values are shown in Table 3).

## DISCUSSION

The aim of the present study was to investigate the apparent discrepancy between clinical findings of impaired gaze following in ASD and laboratory findings of normal attention orienting in response to (neutral) gaze cues in these patients. Because previous laboratory studies relied on static neutral faces, we hypothesized that this discrepancy could be the result of low ecological validity of the experimental stimuli used thus far. For this reason, we tested high-functioning children with ASDs and age- and IQ-matched controls using dynamic emotional gaze cues. We demonstrated that attention orienting in response to gaze shifts was influenced by emotion in the control group, but not in the ASD group. In addition, the ASD subjects showed a relative overuse of high SFs when processing gaze cues, in line with previous reports.[35,36] This supports the abnormal dependence on local information found previously in ASDs.[23–25]

### Effects of Emotion on Face Processing

The processing of static faces was studied by analyzing brain activity (i.e., the N170 peak) in response to the initial (not yet dynamic) face presented during the task. In the control group, the amplitude of the N170 increased in response to fearful faces in comparison with neutral faces (Fig. 5), which probably reflects the recruitment of additional neural populations for the processing of emotion (in line with a study by Batty and Taylor[40]). In contrast, the ASD group did not show an increased amplitude for fearful faces. This could suggest that in ASD subjects, the perception of fear taps the same neural processes as the perception of neutral expressions. Perhaps this reflects an inability of ASD subjects to engage additional resources as the control subjects do when processing emotion. Studies have shown that an enlarged N170 for fearful expressions gradually emerges during typical development and is most evident in adults.[48] Therefore, the present results suggest that there is a developmental lag in the specialized processing of emotion in ASD.

Rapid processing of emotion is believed to rely on low SFs, which carry global and configurational stimulus information; however, patients with ASDs show an

**TABLE 3**
Overview of the Results on the Effect of the Gaze Cue

| Effects of Interest | Overall Effects Found | Group Effects Found | Results |
|---|---|---|---|
| **CUE-VALIDITY** | | | |
| **RT** | **val** $F(1,58) = 29.0$, $p < 0.001$ | | both groups: correctly cued»»incorrectly cued |
| **P100 latency** | **lat*val** $F(2,57) = 10.5$, $p < 0.005$<br>↳ P4-PO4-P8: **val** $F(1,58) = 5.1$, $p < 0.05$ | | both groups: correctly cued»»incorrectly cued |
| **P100 amplitude** | **lat*val** $F(1,58) = 9.8$, $p < 0.005$<br>↳ P3-PO3-P7: **val** $F(1,58) = 4.7$, $p < 0.05$ | | both groups: correctly cued > incorrectly cued |
| **N200 latency** | **lat*val** $F(1,58) = 13.2$, $p < 0.001$<br>↳ P4-PO4-P8: **val** $F(1,58) = 11.5$, $p < 0.005$ | | both groups: correctly cued»»incorrectly cued |
| **N200 amplitude** | **val** $F(1,58) = 13.5$, $p < 0.001$<br>**pos*lat*val** $F(2,57) = 3.3$, $p < 0.05$<br>↳ P3-P4-PO3-PO4-P8:<br>**val** all $F(1,58) > 5.7$, all $p < 0.05$ | **val*group** $F(1,58) = 10.0$, $p < 0.005$<br>**pos*lat*val*group** $F(2,57) = 3.4$, $p < 0.05$<br>↳ P3-PO3-PO4-P7:<br>**val*group** all $F(1,58) > 4.2$, all $p < 0.05$<br>↳ ASD: **val** $F(1,29) = 22.8$, $p < 0.001$<br>control: **val** $F(1,29) = 0.1$, $p = 0.7$ | mainly in ASD group: correctly cued > incorrectly cued |
| **CUE-VALIDITY*EMOTION** | | | |
| **RT** | | post hoc test per group:<br>ASD: **val*emo** $F(1,29) = 0.4$, $p = 0.5$<br>control: **val*emo** $F(1,29) = 3.5$, $p = 0.07$<br>↳ control, N-to-F: **val** $F(1,29) = 5.9$, $p < 0.05$<br>control, F-to-N: **val** $F(1,29) = 0.2$, $p = 0.7$ | (post hoc test)<br>trend only in control group:<br>val effect for N-to-F only |
| **N200 latency** | | **val*emo*gr** $F(1,58) = 4.2$, $p < 0.05$<br>↳ ASD: **val*emo** $F(1,29) = 0.0$, $p = 0.9$<br>control: **val*emo** $F(1,29) = 8.1$, $p < 0.01$<br>↳ control, N-to-F: **val** $F(1,29) = 7.6$, $p < 0.05$<br>control, F-to-N: **val** $F(1,29) = 0.2$, $p = 0.7$ | control group only:<br>val effect for N-to-F only |
| **CUE-VALIDITY*FILTERING** | | | |
| **P100 latency** | | **pos*lat*val*fil*group** $F(2,57) = 3.9$, $p < 0.05$ | |
| **N200 amplitude** | | **pos*lat*val*fil*group** $F(2,57) = 5.2$, $p < 0.01$<br>↳ P3: **val*fil*group** $F(1,58) = 5.0$, $p < 0.05$<br>↳ ASD: **val*fil** $F(1,29) = 3.9$, $p = 0.06$<br>control: **val*fil** $F(1,29) = 7.0$, $p < 0.05$<br>↳ high-pass: **val*group** $F(1,29) = 20.6$, $p < 0.001$<br>low-pass: **val*group** $F(1,29) = 3.7$, $p = 0.06$<br>↳ ASD high-pass: **val** $F(1,29) = 28.8$, $p < 0.001$<br>ASD low-pass: **val** $F(1,29) = 4.6$, $p < 0.05$<br>control high-pass: **val** $F(1,29) = 2.9$, $p = 0.1$<br>control low-pass: **val** $F(1,29) = 28.4$, $p < 0.001$ | control group only:<br>val effect: low-pass > high-pass<br><br>high-pass only:<br>val effect: ASD > control |
| **CUE-VALIDITY*EMOTION*FILTERING** | | | |
| **P100 latency** | **lat*val*fil*emo** $F(1,58) = 4.3$, $p < 0.05$ | | |
| **P100 amplitude** | **pos*val*fil*emo** $F(2,57) = 4.6$, $p < 0.05$ | | |

*Note:* Overview of the results on the effect of cue validity, i.e., the effect of the gaze shift. RT = reaction time; val = cue validity. See Table 2 footnotes for further explanations.

overuse of local information, mediated by high SFs.[22,23] We hypothesized that this hinders emotion processing in ASDs. Although the present results do not provide direct support for this hypothesis, there were indications that the ASD group has a diminished specialization in the differential processing of high and low SFs (Fig. 6). Supporting a diminished specialization in the processing high and low SFs via different neural pathways, Boeschoten et al. [36] found that the amplitude of the P1 peak in response to grating stimuli differed for different SFs in control subjects, but not in ASD subjects. In addition, when processing faces, control subjects were found to activate different sources in the brain for high-pass and low-pass filtered faces, whereas ASD subjects did not.[49] The relative overreliance on high SF information seen in ASDs may be a consequence of a disrupted specialization process during visual development. This could well be a basic neural mechanism of ASD worthy of clinical and scientific interest.

### Effects of Emotion on Gaze Cueing

To study attention orienting in response to gaze shifts, we analyzed RTs as well as brain activity (the P100 and N200 peaks) in response to the appearance of targets. We replicated previous findings of normal attention orienting in response to static neutral gaze cues

in ASDs (Fig. 4), confirming that the processing of unemotional gaze cues is not impaired in patients with ASDs. We even found an increased, rather than decreased, effect of the gaze cue on the N200 amplitude in the ASD group, which could reflect an increased effect of (expected) target onset or a superior attention to the task in ASD subjects.[50] A similar result was observed in a study by Kemner et al.,[5] although it was not statistically significant in this study, perhaps due to the smaller number of subjects.

Although subjects with ASDs performed normally when neutral gaze cues are used, we expected abnormalities to arise when dynamic emotional expressions co-occur with the gaze shifts. We compared two dynamic emotional gaze cues and found that the cue-validity effect, which reflects attention orienting in response to the gaze shift, was influenced by emotion in the control group only. In the ASD group, effects of emotion were absent. This pattern of results was found for brain activity (ERPs) as well as RTs (Fig. 7), although the latter did not reach significance in the overall analysis, perhaps due to the large variability. These findings reveal that subjects with ASD are specifically impaired in a naturalistic setup, in which dynamic emotional gaze cues require the integration of emotional information and gaze information.

Attention orienting in response to gaze shifts is an involuntary behavior that persists even when the gaze cue is counterpredictive (e.g., when subjects know that 75% of the targets are incorrectly cued).[13] Our results, showing that facial expression influences gaze cueing in healthy control subjects, therefore emphasize the intimate link between emotion perception and subconscious behavioral adjustments. To our knowledge, this finding has not been reported before (see Holmes et al. [14] for a study of high-state anxious participants). A previous study, using static instead of dynamic emotional gaze cues, did not find emotion to modulate gaze cueing.[51] However, static displays are less ecologically valid and miss the change in expression that was found to influence gaze cueing in the present study (i.e., static faces associate the emotion with both straight and averted gaze instead of either of the two). In our setup, face motion mediated a naturally looking emotional change that modified attention orienting in healthy controls (Fig. 7), but left face and gaze cue processing in ASDs largely unaffected.

Some authors have proposed that abnormal emotion processing in ASDs is the result of a decreased social motivation that corrupts the development of face processing skills.[16] However, the perception of social cues depends on fast brain systems that involve magnocellular pathways in subcortical structures and regions of the dorsal visual stream. These systems are sensitive to low SFs and global information[28–32] and may be disrupted in ASDs, which is reflected in a relative overuse of high SFs, in other words, local information.[29,32,35,36] The present results support this. In the control group, the cue-validity effect was larger in the low SF condition, whereas in the ASD group, it was more evident in the high SF condition (Fig. 8). Although this effect was found for brain activity (ERPs) only in this study, it may also affect behavior in more delicate social situations. An abnormal reliance on high SFs could be a characteristic of ASDs that is directly related to the neural mechanisms underlying these disorders. In the light of early intervention, it may

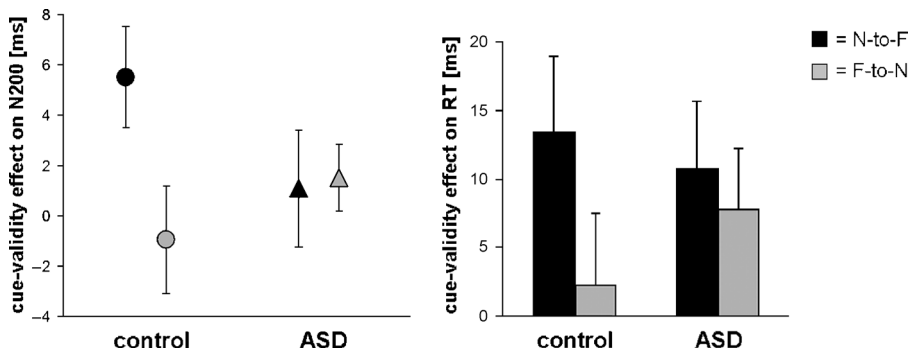


**Fig. 7** Effects of emotion on gaze cueing. The cue-validity effect on N200 latency (left) and reaction times (right) in the unfiltered neutral-to-fearful (N-to-F) and fearful-to-neutral (F-to-N) conditions (± SE). For the control group the cue-validity effect was enhanced for N-to-F and decreased for F-to-N, whereas the autism spectrum disorder (ASD) group showed intermediate cue-validity effects for both emotional conditions.

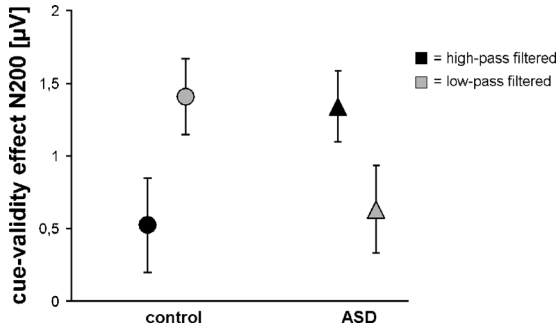


**Fig. 8** Effects of filter type on gaze cueing. The cue-validity effect (± SE) on N200 amplitude at electrodes P3 and P7 in the high-pass (black) and low-pass (gray) filtered conditions. The cue-validity effect was largest in the low-pass filtered condition for the control group and largest in the high-pass filtered condition for the autism spectrum disorder (ASD) group.

serve as a useful marker for identifying young children at risk of ASD.

Analogous to the processing of gaze cues, we expected control subjects to rely on low SFs for the processing of emotion, but the present results do not provide evidence of this. It is possible that subtle interactions between effects of emotion and effects of SF filter type were disrupted by filtering out the middle part of the frequency spectrum in both filtered conditions. This part of the frequency spectrum is known to be important for face perception.[28] Another factor that may be the relatively long cue duration that we used.[12,13] The difference in processing speed for high and low SFs may no longer have been present within the time frame of the trials. For further studies, we suggest the use of variable cue durations.

Our findings provide interesting insight into the link between emotion processing and gaze cueing in typically developing children and children with ASDs. However, our experimental setup, although more ecologically valid than previous setups, is still simplified compared with everyday life. In daily social interactions, not only impairments in emotion processing but also other factors may contribute to impairments in gaze-following behavior, for example, an increased tendency to be distracted by socially irrelevant stimuli. In addition, we cannot rule out the possibility that some effects reflect a type I error. To tackle the problem of multiple testing, we restricted the number of analyses to only those that specifically addressed the hypotheses and, therefore, were clinically relevant. Nevertheless, future studies are needed to test the robustness of the present results. These studies should involve analysis of behavioral as well as brain activity measures because in developmental disorders such as ASDs, neural abnormalities may be compensated by adaptational strategies, resulting in masking of the abnormalities at the behavioral level. Indeed, with regard to gaze cueing, most differences between the subject groups were found for the N200 brain activity peak.

Based on several previous studies that indicate that subjects with ASDs spend less time looking at the eye region when viewing faces,[52] it could be suggested that abnormal gaze fixation patterns have influenced our findings. However, several other studies have found normal scanning patterns in ASD subjects in response to both neutral and emotional faces.[53–55] Also, the fact that there was no overall group difference in the magnitude of the effect of the gaze cue contradicts a possible lack of gaze at the eye region in the ASD group. Eye-tracking equipment may be useful in future studies to support these arguments. In addition, the diagnostic procedure could be refined by using the Autism Diagnostic Observation Schedule[56] as well as the Autism Diagnostic Interview Revised.[46]

To conclude, we showed for the first time that ASD patients process gaze cues normally when static neutral faces are presented, but deviate from normal when dynamic emotional faces are presented. More specifically, the effect of the gaze cue was modified by emotion in the control group but not in the ASD group. We suggest that the impaired gaze following evident in ASDs in clinical situations is not the result of a basic deficit in attention orienting but is caused by impaired processing of social information, in other words, emotional expressions. We also found that subjects with ASDs rely on high SF information when processing gaze cues, whereas the control subjects rely on low SF information. The present data thus directly relate atypical low-level visual processing to abnormalities in the processing of social information in subjects with ASD.

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**Barriers to the Identification and Management of Psychosocial Issues in Children and Maternal Depression** S.M. Horwitz, Kelleher KJ, Stein RE, et al.

*Context:* Child psychosocial issues and maternal depression are underidentified and undertreated, but we know surprisingly little about the barriers to identification and treatment of these problems by primary care pediatricians. *Objectives:* The purpose of this work was to determine whether (1) perceived barriers to care for children's psychosocial issues and maternal depression aggregate into patient, physician, and organizational domains, (2) barrier domains are distinct for mothers and children, and (3) physician, patient, and practice/organizational characteristics are associated with different barrier domains for children and mothers. *Methods:* We conducted a cross-sectional survey of the 50,818 US nonretired members of the American Academy of Pediatrics. Of a random sample of 1600 members, 832 (745 nontrainee members) responded. This was a mailed 8-page survey with no patients and no intervention. We measured physician assessment of barriers to providing psychosocial care for children's psychosocial problems and maternal depression. *Results:* Pediatricians frequently endorse the lack of time to treat mental health problems (77.0%) and long waiting periods to see mental health providers (74.0%) as the most important barriers to the identification and treatment of children's psychosocial problems. For maternal depression, pediatricians most often endorsed lack of training in treatment (74.5%) and lack of time to treat (64.3%) as important barriers. Pediatricians' reports of barriers clustered into physician and organizational domains. Physician domains were distinct for children and mothers, but organizational domains were not. Several physician and practice characteristics are significantly associated with the 4 barrier scales, and different characteristics (eg, sociodemographic, attitudinal, and practice features) were related to each barrier area. *Conclusions:* Pediatricians endorse a wide range of barriers with respect to the diagnosis and treatment of children's mental health problems and maternal depression. The specificity of factors relating to various barrier areas suggests that overcoming barriers to the identification and treatment of child mental health problems and maternal depression in primary care pediatrics is likely to require a multifaceted approach that spans organizational, physician, and patient issues. In addition, comprehensive interventions will likely require social marketing approaches designed to engage diverse audiences of clinicians and their patients to participate. Reproduced with permission from **Pediatrics** 2007;119(1): e208–218, copyright 2007 by the AAP.