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Impaired recognition of facial emotions from low-spatial frequencies in Asperger syndrome

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Abstract

The theory of 'weak central coherence' [Happe, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *36*(1), 5–25] implies that persons with autism spectrum disorders (ASDs) have a perceptual bias for local but not for global stimulus features. The recognition of emotional facial expressions representing various different levels of detail has not been studied previously in ASDs. We analyzed the recognition of four basic emotional facial expressions (anger, disgust, fear and happiness) from low-spatial frequencies (overall global shapes without local features) in adults with an ASD. A group of 20 participants with Asperger syndrome (AS) was compared to a group of non-autistic age- and sex-matched controls. Emotion recognition was tested from static and dynamic facial expressions whose spatial frequency contents had been manipulated by low-pass filtering at two levels. The two groups recognized emotions similarly from non-filtered faces and from dynamic vs. static facial expressions. In contrast, the participants with AS were less accurate than controls in recognizing facial emotions from very low-spatial frequencies. The results suggest intact recognition of basic facial emotions and dynamic facial information, but impaired visual processing of global features in ASDs.

Keywords: Autism spectrum disorders; Weak central coherence; Visual perception; Face processing; Basic emotions

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1. Introduction

Autistic spectrum disorders (ASDs) are characterized by impairments in social reciprocal interaction, verbal or non-verbal communication, and rigid and repetitive pattern of behavior, all present from early childhood (American Psychiatric Association, 1994; World Health Organization, 1993). Autistic disorders also appear to involve a peculiar pattern of perceptual-cognitive information processing referred to as "weak central coherence" (Frith & Happe, 1994; Happe & Frith, 2006; Hill & Frith, 2003). "Central coherence" refers to a tendency for typically developing children and adults to process information in a global context, often at the expense of local details. Individuals with autism show an opposite bias in processing local details with a possible failure to process global and contextual information. Such a bias may be reflected in rigid routines and preoccupation with object details characteristic to all ASDs, as well as outstanding skills of some low-functioning autists on certain restricted areas such as calendar calculation or musical competence (Hill & Frith, 2003).

In line with the hypothesis of weak central coherence, several studies have reported superior processing of local level details in ASDs (for a recent review, see Happe & Frith, 2006). individuals with autism show faster recognition of embedded figures (Jolliffe & Baron-Cohen, 1997), are less prone to visual illusions (Happe, 1996) and perform better in the block design task of Wechsler intelligence scale (Shah & Frith, 1993) than non-autistic control participants. The block design task involves segmenting whole designs into their constituent blocks. It is typically experienced as being difficult because of the strong gestalt qualities of the design. Therefore superior processing of local level details could be expected to improve the performance in this particular test. Whether this local bias entails global processing deficits has been debated (Happe & Frith, 2006). Contrary

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to non-autistic individuals, individuals with ASDs recognize local features faster and more accurately than global ones from hierarchical letters (large letters consisting of smaller ones), suggesting a high interference from local to global level (Behrmann et al., 2006; Plaisted, Swettenham, & Rees, 1999). Individuals with autism do exhibit a typical global precedence effect when explicitly instructed to attend to global letters (Plaisted et al., 1999). Although such a result suggests that the local bias can be overcome by attention, several other findings are difficult to explain without invoking a global processing deficit: individuals with autism utilize gestalt grouping principles less often than controls (Brosnan, Scott, Fox, & Pye, 2004), fail to show a typical global priming effect in matching hierarchical geometric figures (Behrmann et al., 2006) and are impaired in recognizing coherent global motion (Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005) and biological movement from moving dots (Blake, Turner, Smoski, Pozdol, & Stone, 2003).

It is generally agreed that face recognition depends both on perceiving individual facial features (such as eyes, nose and mouth) and their configurations (Maurer, Le Grand, & Mondloch, 2002). A facial configuration is typically used to refer to at least two kinds of concepts: "second-order" facial relations, i.e., metric relations between individual facial features, and the perception of face as a whole. Second-order relations are thought to underlie facial identity recognition. Holistic perception is apparent, for example, in composite face effect (slower recognition of top half of a face when aligned with bottom half of another) and whole-part advantage effect (improved recognition of isolated facial features when embedded in a whole face). The role of global vs. local level facial details in configural processing has been considered in recent spatial frequency studies (Goffaux, Hault, Michel, Vuong, & Rossion, 2005; Goffaux & Rossion, 2006). Any image can be decomposed into spatial frequency components representing different levels of details: higher spatial frequencies (HSFs) depict more local and lower spatial frequencies (LSFs) more global level features. It has been shown that the composite face and whole-part advantage effects are larger for LSF than for HSF components of faces (Goffaux & Rossion, 2006). Similarly, it has been shown that configural differences between faces (e.g., differing interocular distances) are recognized better from LSFs rather than HSFs, whereas the contrary is true for recognizing featural differences (Goffaux et al., 2005). Such studies clearly indicate that both holistic and second-order configural processing are dependent mainly on global facial features.

Because face recognition apparently requires global processing, it is natural to assume that weak central coherence is related to the high prevalence of prosopagnosia (impaired recognition of identity from faces) evident both in children (de Gelder, Vroomen, & van der Heide, 1991; Klin et al., 1999; Tantam, Monaghan, Nicholson, & Stirling, 1989) and adults (Barton et al., 2004; Nieminen-von Wendt et al., 2005) with autistic disorders. ASDs involve superior processing of facial features: individuals with autism exhibit a local matching preference with face-like or geometrical stimuli involving configural features (Rondan & Deruelle, 2007), and are impaired less than controls by procedures that disrupt the configural processing of faces such as face inversion (Hobson, Ouston, & Lee, 1988) or misalignment of face parts (Teunisse & de Gelder, 2003). A global processing deficit has been demonstrated for example in that children with autism fail to show a typical whole-part advantage in processing faces (Joseph & Tanaka, 2003). Furthermore, the degraded performance of autistic participants in matching face stimuli has been shown to be related to degraded global processing of hierarchical objects (Behrmann et al., 2006). Spatial frequency studies have provided further evidence on enhanced local and degraded global processing of facial information in autism. In a study by Deruelle, Rondan, Gepner and Tardif (2004), children with autism recognized facial identity better from HSFs (above 36 cycles/face width (c/fw)) than from LSFs (below 12 c/fw),[1] whereas the opposite was true with typically developing children. Apparently, children with autism recognized identity significantly better from HSFs and significantly worse from LSFs than typically developing children. Consistently, a case study by Curby, Schyns, Gosselin and Gauthier (2003) reported results from a young adult male with autism who relied on drastically higher spatial frequencies (45–90 c/fw) in recognizing faces than non-autistic participants (11–22 c/fw), and showed both enhanced recognition performance in this spatial frequency range and progressively degrading performance in lower ranges.

The recognition of emotional facial expressions from different spatial frequency ranges has not been studied earlier. Based on the weak central coherence hypothesis, it can be hypothesized that individuals with autism recognize facial emotions worse from low-spatial frequencies (i.e., global facial features) than non-autistic individuals. In the present study, we evaluated the recognition of four static and dynamic basic facial emotions (anger, disgust, fear and happiness) (Ekman, Friesen, & Ellsworth, 1982) from different extents of low-spatial frequencies in adult individuals with Asperger syndrome (AS) and their matched controls. Our main hypothesis was that participants with AS would recognize facial emotions worse from low-spatial frequency conditions than their controls. We made no prior hypotheses on whether the participants with AS would show emotion recognition difficulties from original facial expressions, as the results from previous studies have been contradictory. Some studies have demonstrated that adults with ASDs have difficulties recognizing basic facial emotions (Adolphs, Sears, & Piven, 2001; Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Boraston, Blakemore, Chilvers, & Skuse, 2007; Dziobek, Fleck, Rogers, Wolf, & Convit, 2006; Humphreys, Minshew, Leonard, & Behrmann, 2007), whereas others have shown difficulties only in making more complex social or emotional judgments from faces (Adolphs et al., 2001; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Golan, Baron-Cohen, & Hill, 2006).

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[1] For clarity, we describe all cutoff frequencies on an object scale (c/fw) rather than on a retinal-centered scale (cycles per degree of visual angle (c/d)). In the case of this study, the latter was converted into the former trivially by multiplying the original spatial frequency values (2 and 6 c/d) by the width of the visual angle (6°).

In the present study, we concentrated on AS in order to avoid heterogeneous results by including several clinically divergent subtypes of ASDs. AS is a condition in the autistic spectrum with social deficits characteristic of all ASDs but without severe verbal or cognitive deficits typical for more severe conditions (Happe & Frith, 1996). Dynamic facial expressions were included in order to study whether dynamic information would compensate for the hypothesized ASD-related deficit in processing low-spatial frequencies. The fact that ASDs involve global movement processing difficulties (Bertone, Mottron, Jelenic, & Faubert, 2003; Blake et al., 2003; Pellicano et al., 2005) suggests that participants with AS would be less efficient in utilizing movement. On the contrary, a recent study has demonstrated equal recognition of static and dynamic facial animations in participants with autism (Back, Ropar, & Mitchell, 2007).

2. Methods

2.1. Participants

Twenty adult individuals with AS (13 males and 7 females, mean age 32) were recruited from the Hospital for Children and Adolescents at the Department of Child Neurology in Helsinki University Central Hospital, and Helsinki Asperger Center in Medical Center Dextra. The Department of Child Neurology serves primarily the catchments area of the Helsinki University Central Hospital (population 1.5 million) and as a tertiary referral unit the whole Finland (population 5.3 million). Helsinki Asperger Center is a private clinic serving the whole Finland. The inclusion criteria were an age of 18–65 years and the diagnosis of AS based on standard ICD-10 (World Health Organization, 1993) and DSM-IV (American Psychiatric Association, 1994) taxonomies. Additional methods used in the diagnostic procedure were ASSQ (Ehlers, Gillberg, & Wing, 1999; Gillberg & Gillberg, 1989), ADI-R (Lord, Rutter, & Couteur, 1994) and ADO-S (Lord et al., 1989). The exclusion criteria were schizophrenia, obsessive-compulsory disorders, severe depression and learning difficulties (as reported in existing medical records).

Twenty age- and sex-matched healthy control subjects were recruited from the authors' social surrounding and by advertisements in the Open University of the University of Helsinki and the Finnish Labour Force Bureau. The exclusion criteria were schizophrenia, obsessive-compulsory disorders, severe depression, learning disabilities and prosopagnosia (tested with self-report questionnaires; see more below), and autistic symptoms (tested with ASSQ screening questionnaire; Ehlers et al., 1999; Gillberg & Gillberg, 1989). Two of the original control subjects were excluded and replaced by new participants because of the used criteria. All participants were native speakers of Finnish and had either normal or corrected vision. The costs of participants were covered. A written consent was obtained from all participants. The study was approved by Ethics Committee for Pediatrics, Adolescent Medicine and Psychiatry; located in Helsinki University Central Hospital.

To diagnose prosopagnosia, all participants were interviewed for prosopagnosic symptoms and those reporting any subjective face recognition difficulties were administered the face recognition task of NEPSY (developmental neuropsychological assessment) test battery (Korkman, Kirk, & Kemp, 1997). Participants with AS were interviewed in a clinical setting, and control participants were asked to fill a self-report questionnaire containing prosopagnosia-related questions.[2] Because NEPSY has been developed for testing children, the used prosopagnosia standards were adopted from those of 12-year-old children.[3] Subjective face recognition difficulties were reported by ten of the participants with AS, of whom nine were diagnosed prosopagnosic according to the used NEPSY standards. None of the control participants reported difficulties recognizing faces.

Table 1
Demographic variables and psychological test results for AS and control subjects

	AS	Control	*p*
Gender (male/female)	13/7	13/7	–
Age	32 (10)	31 (8)	0.80
Full-scale IQ	112 (13)	116 (11)	0.35
Verbal IQ	110 (11)	116 (8)	0.05
Performance IQ	113 (16)	113 (14)	0.97
TAS-20	55 (12)	36 (6)	<0.001
TAS-20 factor-1	21 (5)	11 (3)	<0.001
TAS-20 factor-2	16 (6)	9 (2)	<0.001
TAS-20 factor-3	18 (5)	15 (5)	0.06

p values refer to level of significance from *t*-tests for independent samples. Other values, except gender, are given as mean (S.D.).

All participants were administered the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981) and the 20-item Toronto alexithymia scale (TAS-20) (Finnish translation) (Bagby, Parker, & Taylor, 1994) tests. TAS-20 evaluates alexithymia, which has been characterized as "emotional blindness" involving three distinct factors (Parker, Bagby, Taylor, Endler, & Schmitz, 1993): (1) difficulties in understanding and (2) describing emotions, and (3) externally oriented thinking on emotional events. Alexithymia is also known to involve difficulties naming emotional facial expressions (Parker, Taylor, & Bagby, 1993). Demographic background factors and intelligence measures of the AS and the control group did not differ significantly (Table 1). The AS group had significantly higher overall TAS-20 scores, as also of the first and second factors. Seven of the AS subjects, but none of the control subjects, had a TAS-20 score high enough (>60 points) to indicate alexithymia. These results were expected because alexithymia is a known comorbid disorder for AS (Fitzgerald & Molyneux, 2004; Nieminen-von Wendt, 2004). No significant differences existed between prosopagnosic and non-prosopagnosic AS subjects on any measured parameters.

2.2. Design

The experiment had a 2 × 2 × 4 × 3 mixed-design with a between-subjects factor group (AS, control) and within-subjects factors dynamics (static, dynamic), emotion (anger, disgust, fear and happiness) and filtering (none, "slight" and "strong").

2.3. Stimuli

Facial expression stimuli were selected from "TKK video sequence collection" (Kätsyri, 2006) containing facial expressions of six basic emotions recorded from six Finnish actors. A previous study (Kätsyri, 2006) has shown that facial expressions in the TKK collection are recognized as well as those in a standardized facial expression collection (Ekman & Friesen, 1978). For the experiment facial expressions were selected from two male and two female actors who showed the highest mean recognition of the selected facial emotions (anger, disgust, fear and happiness). All selected items were converted to a

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[2] "Do you recognize people readily from their faces?", "Do you recognize people better from their style of walking, clothing or voice rather than from their faces?" and "Would you be able to recognize a familiar person in a novel context if he had changed his clothing or hair style?".

[3] It has been suggested that the face recognition ability typically reaches maturity at the age of 12 years (Temple, 1997); however, also contradictory evidence exists (e.g., Pozzulo & Lindsay, 1998). Therefore, it is possible that the used standards failed to indicate slight prosopagnosia (i.e., face recognition ability close to 12-year olds' standards but below typical adult levels). However, the discrimination between severe prosopagnosia and close-to-optimal face recognition ability was considered to be sufficient for the purposes of this study.

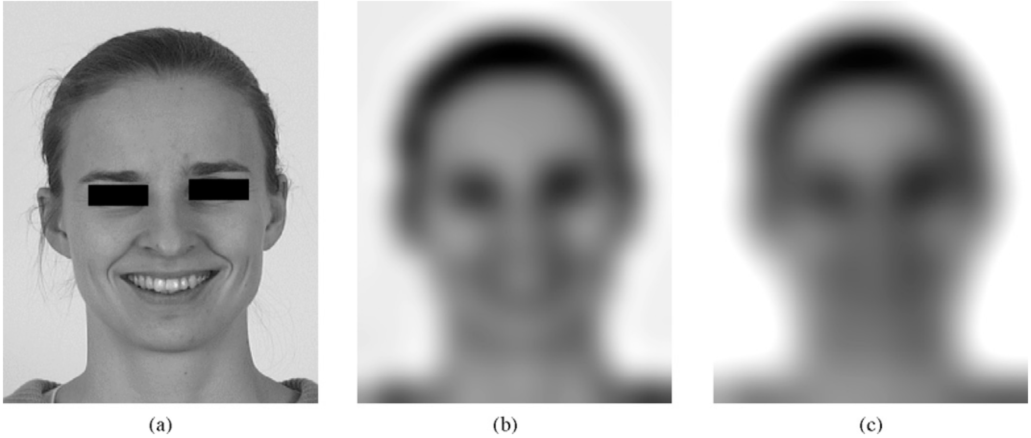

Fig. 1. An example set of the stimuli showing (a) no filtering (original image), (b) slight low-pass filtering (spatial frequencies <3.7 c/fw), and (c) strong low-pass filtering (<1.8 c/fw).

256-color grayscale and resized to show a constant face width of approximately 61 mm (4.4° visual angle). The original 16 facial expressions were duplicated in static (pictures) and dynamic (video sequences) conditions and in conditions with none, “slight” and “strong” filtering (see below), producing a total of 96 stimuli.

Dynamic video sequences showed transition from neutral face to an emotional expression (mean duration 1.3 s; range 0.8–1.7 s), whereas the static pictures showed only the last frames of these sequences. All stimuli were displayed for 2 s; with dynamic stimuli, this was obtained by prolonged presentation of the last frame. Low-pass filtering was employed to remove all HSFs above a certain cutoff threshold from original facial expression stimuli so that their identification would show either slight or strong degradation. Low-pass filtering was conducted by convolution method with a circularly symmetric ideal low-pass filter (Gonzales & Woods, 1993), followed by luminance value normalization to span the used grayscale fully. Low-pass filtering cutoff frequencies were selected on the basis of an earlier study with healthy subjects (Kätsyri, 2006): for angry and disgusted expressions, the selected values were 7.3 and 3.7 c/fw and for fearful and happy expressions, 3.7 and 1.8 c/fw. Lower cutoff values were required for the latter expressions as they are identified generally better from low-spatial frequencies than the former ones (Kätsyri, 2006). Fig. 1 shows an example set of the stimuli.

2.4. Procedure

The participants’ task was to evaluate how well each of the six basic emotions (anger, disgust, fear, happiness, sadness, and surprise) applied to each presented stimulus on a seven-step Likert scale ranging from total disagreement (1) via uncertainty (4) to total agreement (7). The evaluation of each stimulus begun with the presentation of a fixation mark (gray square). The evaluated stimulus was repeated once before the presentation of an emotional question, until all questions had been evaluated (Fig. 2), i.e., each stimulus was repeated six times in a row. The order of questions was varied randomly with each presented stimulus. Subjects were instructed to answer based on their first impression; however, no response time limits were used. Analysis of response times showed no significant differences between participant

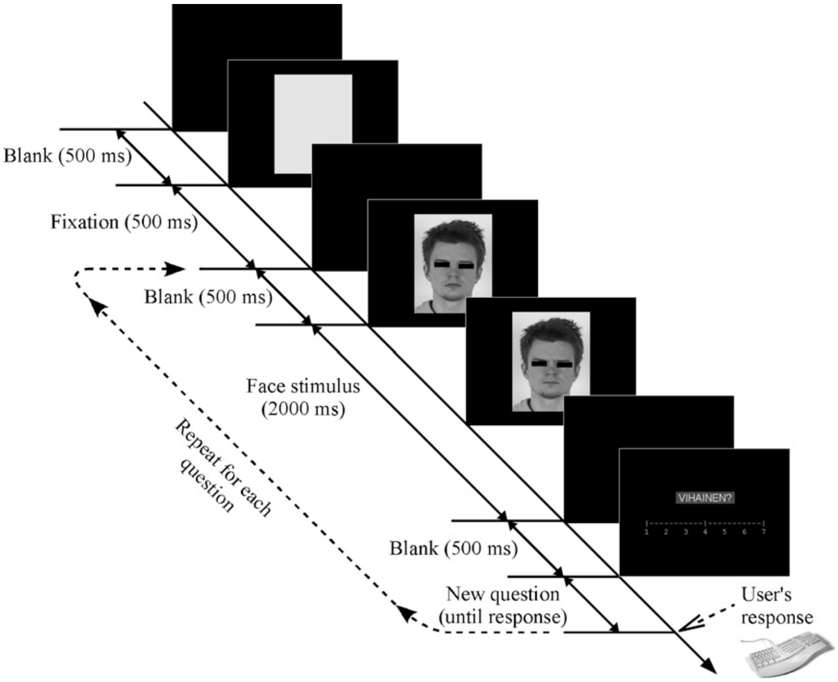

Fig. 2. Diagram illustrating the evaluation of one stimulus.

groups or significant interactions between groups and within-subjects factors. Displaying question texts at constant location could have altered the eye gaze patterns typical to individuals with an ASD while observing faces (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002). To avoid such possibility, the fixation mark was shaped as a square instead of a cross, and the location of question texts was varied randomly within a window of 35 mm × 35 mm.

Stimuli were evaluated in three blocks with short breaks (a minimum of 3 min) between them, with each block representing a certain filtering condition. To minimize learning effects, the order of the blocks was always from strong to slight to no filtering. Stimuli within each block were presented in random order with the constraint that static and dynamic versions of the same facial expression were never presented consecutively. The experiment was performed with Presentation software (Version 9.51, http://www.neuro-bs.com). The stimuli were presented on a 19 in. CRT monitor with a viewing distance of 80 cm. Responses were made via a standard keyboard with clearly marked response buttons.

2.5. Analysis

2.5.1. Error correction

Several participants reported making at least one erroneous response during the experiment, typically an opposite answer to the one intended (e.g., a key response 1 instead of 7 or vice versa). A conservative error correction procedure was carried out, separately for AS and control groups, in which a given rating was replaced by the median of other ratings if it was at least five points lower/higher than the reference group's lowest 10th/90th percentile. As a result, a total of three and four error corrections were made for AS and control groups. No more than two corrections were made for any subject in either group.

2.5.2. Data reduction

In order to analyze the recognition accuracies with one dependent variable, we converted the six original emotion ratings to single recognition scores ranging from −1 to 1. The scoring method was based on measuring how distinctly the presented basic expressions were evaluated as depicting their intended basic emotions. When the intended basic emotion was rated higher than all other emotions, the score was 1. Each confusion, i.e., an unintended basic emotion receiving at least as high rating as the intended emotion, reduced the score by a constant of 0.4 so that when the intended emotion was rated no higher than any other emotion, the score was −1. Random ratings would produce an average of 2.5 confusions per evaluation and, respectively, a mean identification score of 0.

2.5.3. Statistical comparisons

Results were averaged over the four actors and analyzed with a mixed-design ANOVA. Post-hoc analyses were conducted with Newman–Keuls tests and contrast tests. Significance level was set to $\alpha = 0.05$. Bonferroni correction was applied in non-planned contrast tests involving multiple comparisons.

3. Results

3.1. All participants

The main effect of filtering was significant ($F(2, 76) = 185.22$, $p < 0.001$), so that non-filtered faces were recognized better than slightly filtered, and slightly filtered better than strongly filtered faces. Both the main effect of dynamics ($F(1, 38) = 56.28$, $p < 0.001$) and its interaction with filtering ($F(2, 76) = 21.35$, $p < 0.001$) were significant. Dynamic facial expressions were recognized significantly better than static ones in slightly ($F(1, 38) = 8.26$, $p = 0.007$) and strongly filtered ($F(1, 38) = 47.49$, $p < 0.001$) conditions. A significant linear trend ($F(1, 38) = 32.76$, $p < 0.001$) demonstrated an increasing recognition difference between dynamic and static stimuli over filtering levels (see Fig. 3).

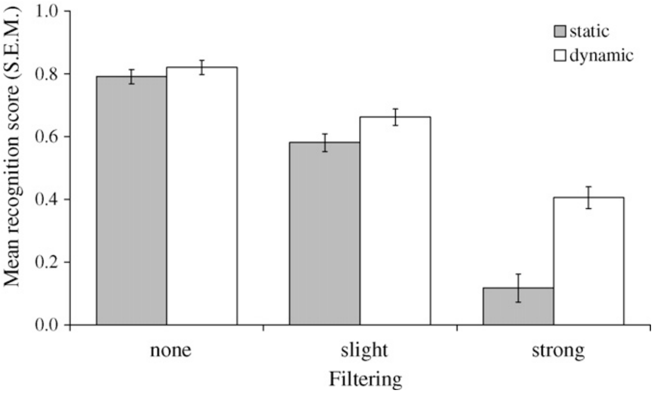

Fig. 3. General results (pooled over AS and control groups): emotion recognition accuracies of static and dynamic facial expressions at different filtering conditions.

The main effect of emotion ($F(3, 114) = 111.29$, $p < 0.001$) and its interactions with filtering ($F(6, 228) = 17.82$, $p < 0.001$) and dynamics ($F(2, 76) = 21.35$, $p < 0.001$) reached significance. Happy faces (mean score ± S.E.M.: 0.90 ± 0.02) were recognized better than disgusted faces (0.61 ± 0.03), which were recognized better than angry (0.37 ± 0.03) and fearful faces (0.38 ± 0.03). Filtering degraded and dynamics facilitated the recognition of all emotions; however, happiness was affected less by both filtering ($F(1, 38) = 103.74$, $p < 0.001$) and dynamics ($F(1, 38) = 14.96$, $p < 0.001$) than other emotions. The three-way interaction between dynamics, filtering and emotion was not significant.

3.2. Participants with Asperger syndrome

The main recognition score difference between participants with AS and their controls was not significant. The only significant interaction involving group was that between group and filtering ($F(2, 76) = 3.45$, $p = 0.04$). Notably, the interaction group × dynamics and all of its further interactions were nonsignificant, indicating no AS-related difficulties in evaluating dynamic facial expressions.

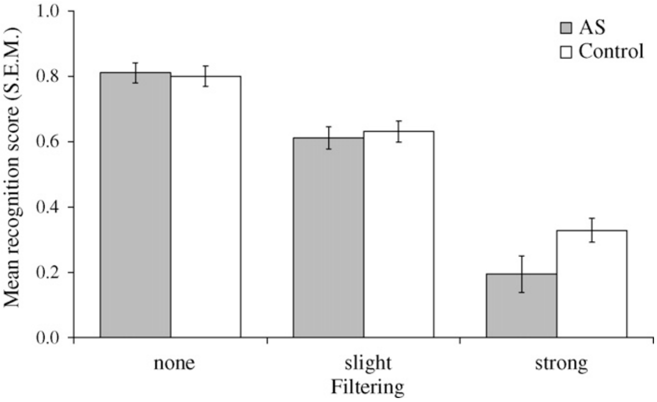

Fig. 4. The effect of AS on evaluating filtered facial expressions: emotion recognition accuracies in different filtering conditions in AS and control groups. Please note that the results have been pooled over static and dynamic stimuli.

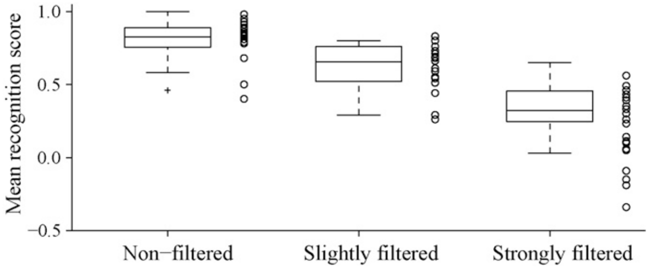

Fig. 5. Individual AS participants' results at non-filtered and strongly filtered levels (pooled over static and dynamic stimuli). Each data point (a circle) illustrates result from one participant with AS. Control participants' results are illustrated by standard box-and-whisker plots.

The mean recognition scores for AS and control groups at different filtering levels are illustrated in Fig. 4. Because the a priori hypothesis was that participants with AS would recognize facial emotions worse than controls from the low-pass filtered conditions, the group differences in slightly and strongly filtered conditions were tested with one-way planned comparisons. A significant result ($F(1, 38) = 3.99$, $p = 0.03$ (one-tailed)) was observed in the strongly filtered condition. A two-tailed test for the non-filtered condition provided a non-significant result. The results for individual participants are shown in Fig. 5. As illustrated by the figure, performance below the level of control participants is apparent with some but not all participants with AS at the strong filtering level: 10 out of 20 participants with AS received scores below the first quartile of the control subjects, and four of them received scores below those of all control subjects. At the non-filtered and slightly filtered conditions, respective figures were three and four participants (below first quartile) and one participant (below all controls).

To test whether prosopagnosia had any significant effect on the performance of participants with AS, a new mixed-design ANOVA was conducted with a between-subjects factor group (AS with and without prosopagnosia)[4] and within-subjects factors dynamics, emotion and filtering. The results showed that the main effect of group and all of its interactions with other factors were non-significant, indicating no prosopagnosia-related effects.

3.3. Psychometric factors

The significance of relationships between age and psychometric test results (intelligence and alexithymia measures) on one hand and the degradation caused by filtering on the other were tested with Spearman rank tests (Table 2). To measure the extent of degradation caused by filtering for each individual participant, mean recognition score differences were calculated over presented facial expressions between their non-filtered and strongly filtered displays (larger positive values denote more severe degradation). The results showed that degradation correlated statistically significantly only with alexithymia measures. When the AS group was considered separately, there was no significant correlation for any of the alexithymia measures. In the control group, the overall alexithymia score and the third alexithymia factor (externally oriented thinking) reached significance. To evaluate whether the gender of the participant had any significant effects on the results, a new mixed-design ANOVA with factors sex (male, female) and group (AS, control) was conducted with the degradation measure as a dependent variable. As a result, both sex and sex × group were non-significant.

Table 2
Correlations between psychometric variables and the degradation caused by filtering (i.e., the difference between non-filtered and strongly filtered faces) in recognizing emotional facial expressions

	Degradation effect		
	AS ($n = 20$)	Control ($n = 20$)	Both ($n = 40$)
Age	0.24	0.41	0.28
Full-scale IQ	0.36	0.09	0.21
Verbal IQ	0.36	0.06	0.15
Performance IQ	0.33	0.12	0.25
TAS-20	0.21	0.58**	0.40*
TAS-20 factor-1	0.15	0.04	0.31*
TAS-20 factor-2	0.20	0.24	0.34*
TAS-20 factor-3	0.12	0.58**	0.32*

* $p < 0.05$.
** $p < 0.01$.

4. Discussion

Recognition of emotional facial expressions from different spatial frequency contents in autistic spectrum disorders has not been studied earlier. In the present study, we compared the recognition of four basic emotional facial expressions in adults with AS and in non-autistic adults. Low-pass filtering was used to produce "slightly" and "strongly" filtered displays of facial expressions in addition to original non-filtered ones. The main finding was a deficit in recognizing facial expressions from their strongly filtered displays in subjects with AS. Although this effect was evident at the group level, it was not evident with all individual participants with AS. The AS group did not differ from control group in recognizing the emotional expressions from their non-filtered or slightly filtered displays. The AS group also showed no atypical results in utilizing dynamic information related to emotional facial expressions. The prosopagnosia classification used in the present study (subjective face recognition difficulties confirmed with a further face recognition task) indicated no prosopagnosia-related effects on the recognition of emotional facial expressions in ASDs. The observation that facial identity and facial emotion recognition difficulties are not related with each other in ASDs is congruent with a previous conclusive evaluation (Hefter, Manoach, & Barton, 2005). In the control subjects, a significant relationship was observed between alexithymia level and the extent of degradation caused by filtering.

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[4] In practice, also control group results were included in this analysis to increase the degrees of freedom for the error term and respectively the statistical power of ANOVA. Main and interaction effects of prosopagnosia factor were tested with contrast analyses ignoring control group results.

In the present study, virtually all (19 out of 20) participants with AS performed similarly as control subjects in recognizing facial expressions from low-spatial frequency information present in the *slightly* filtered condition (i.e., frequencies below 3.7 or 7.3 c/fw, depending on expression). This result is in contrast with the results of Curby et al. (2003) who showed degraded facial identity recognition performance on low-spatial frequencies (below 45 c/fw) in a young male with AS. Our result suggests intact processing of some low-spatial frequency facial expression information in individuals with an ASD. However, our participants with AS also showed clear degradation in recognizing facial expressions from *strongly* filtered faces (frequencies below 1.8 or 3.7 c/fw). Obviously, the demands for global processing were higher in the strong rather than slight filtering condition. The fact that participants with AS performed worse than controls in evaluating strongly filtered faces clearly indicates a global processing deficit in processing very low-spatial frequencies (below 1.8 or 3.7 c/fw). This result is in concordance with the weak central coherence hypothesis (Frith & Happe, 1994; Happe & Frith, 2006; Hill & Frith, 2003) positing a perceptual bias to local visual stimulus features with a consequent deficit in processing global features. Although recent postulations of the weak central coherence theory have de-emphasized the global processing deficit (Happe & Frith, 2006), several studies with non-social stimuli have implied global level visual perception difficulties in ASDs (Behrmann et al., 2006; Blake et al., 2003; Brosnan et al., 2004; Pellicano et al., 2005).

Earlier studies have suggested that autism spectrum disorders may involve perceptual difficulties in processing global-level movement (Bertone et al., 2003; Blake et al., 2003; Pellicano et al., 2005). On the other hand, a recent facial animation study (Back et al., 2007) has suggested intact use of movement information in recognizing emotional facial expressions. Similarly, the present study showed that individuals with AS are able to utilize movement information as efficiently as control subjects in recognizing emotional facial expressions from low-pass filtered faces. A possible concern is that because the duration of video sequences was equalized by prolonged presentation of the emotional apex, the dynamic condition contained an additional 300–1200 ms period of static presentation. However, because the dynamics effect was found after severe degradation of static information, it is unlikely that the period of static presentation was of significance to the results.

The fact that no statistically significant differences were observed between participants with and without an ASD in recognizing basic facial expressions from non-filtered displays is congruent with some earlier studies (Baron-Cohen, Jolliffe et al., 1997; Baron-Cohen, Wheelwright et al., 1997; Spezio, Adolphs, Hurley, & Piven, 2007) but incongruent with others (Adolphs et al., 2001; Ashwin et al., 2006; Boraston et al., 2007; Dziobek et al., 2006; Humphreys et al., 2007). In the former studies, the differences might have failed to reach significance because of a small subject sample (nine autistic participants in Spezio et al., 2007) or an easy task (forced-choice task with only two response choices in Baron-Cohen, Jolliffe et al., 1997; Baron-Cohen, Wheelwright et al., 1997). The results of present study could have been affected by learning effects, as the non-filtered faces were always evaluated after filtered ones. This evaluation sequence was necessary because our study concentrated specifically on the evaluation of filtered faces. The picture is complicated further by methodologically valid studies suggesting typical recognition of basic facial expressions in autistic individuals already during childhood (Capps, Yirmiya, & Sigman, 1992; Castelli, 2005). Obviously, future studies on the recognition of basic facial expressions in autistic disorders are needed to solve this issue.

Some possible caveats of the present study should be noted. First, the study concentrated only on low-spatial frequencies. Because the strongly filtered faces were generally the most difficult ones to evaluate, the poorer performance of participants with AS as compared to controls could be related to task difficulty. If this were the case, a similar effect should be evident also in the evaluation of high-pass filtered faces. This possibility is, however, unlikely because both our participants with AS and control participants showed equal (and above norm) cognitive functionality. Furthermore, previous facial identity studies (Curby et al., 2003; Deruelle et al., 2004) would suggest that participants with ASDs are superior in processing high-spatial frequency facial information. Secondly, our results showed large variation between individual subjects. Some of this variation could be due to the use of odd instead of even number of response choices (a seven-point Likert scale) that allowed for expressing uncertain responses. This may have allowed for different response strategies due to different uncertainty thresholds. However, even if this was the case, the results would still indicate higher uncertainty thresholds in the AS group specifically in evaluating strongly filtered faces. Thirdly, the results may be specific for Asperger syndrome. For example, it has been shown that whereas children with AS recognize basic facial expressions as well as typically developing children, children with high-functioning autism (HFA) perform significantly worse (Mazefsky & Oswald, 2007; Nieminen-von Wendt, 2004, pp. 23–25). The present results could be similarly dependent on the exact ASD diagnosis. On the other hand, it has to be noted that the diagnostic separation between HFA and AS is rather ambiguous: no explicit diagnostic guidelines exist for diagnosing HFA, and the symptoms of AS and HFA show considerable overlap (Nieminen-von Wendt).

As discussed earlier, the worse performance in individuals with an ASD in evaluating emotional faces after the removal of HSFs (local facial features) is in accordance with the weak central coherence hypothesis positing a bias on details rather than wholes. Because the present results appear to be related to visual perception in general rather than to emotional facial expressions in particular, it is tempting to consider possible neurological explanations for the results. In particular, the worse processing of low-spatial frequencies in autistic disorders could be related to abnormal dorsal visual pathway functioning (for a similar interpretation, see Deruelle et al., 2004). Although this interpretation is coherent with our results (see below), it should be taken with caution because no neurological hypotheses were explicitly tested in our study.

Most early visual information processing occurs on a pathway from retina via lateral geniculate nucleus to primary visual cortex. This retinal-geniculate-cortical pathway can be divided into magnocellular and parvocellular streams of which the former is more sensitive to low-spatial frequencies and the latter to high-spatial frequencies (Merigan & Maunsell, 1993). Although the processing of magno- and parvocellular signals is intermixed in extrastriatal areas, the magnocellular channel projects primarily into dorsal stream leading to parietal areas and parvocellular channel into ventral stream leading to temporal areas (Livingstone & Hubel, 1988; Merigan & Maunsell, 1993). Vuilleumier, Armony, Driver and Dolan (2003) have studied the neural activations occurring while observing high- and low-spatial frequency components of facial emotions. Their results show that certain temporal areas (e.g., fusiform face area) are activated preferentially by high-spatial frequencies and certain parietal areas (e.g., parieto-occipital cortex) by low-spatial frequencies. Even if the magno-dorsal and parvo-ventral pathways are interconnected with each other and show overlapping functions (Livingstone & Hubel, 1988; Merigan & Maunsell, 1993), the results by Vuilleumier et al. clearly indicate that the former is more sensitive to low and the latter to high-spatial frequencies.

Considering the role of dorsal pathway in processing low-spatial frequency information, its functional abnormality could underlie the global processing deficit in ASDs. Impaired performance in motion perception tasks depending on dorsal pathway functioning have been demonstrated in individuals with ASDs (Bertone et al., 2003; Pellicano et al., 2005; Spencer et al., 2000). For example, Pellicano et al. (2005) showed that individuals with ASDs are impaired in a global motion recognition but not in a flicker sensitivity task. Most of the motion processing occurs along the magno-dorsal pathway (Merigan & Maunsell, 1993). Because flicker perception depends on early magnocellular processing and global motion perception on late dorsal processing, the results were taken to imply dorsal pathway impairment with intact magnocellular pathway functionality. Importantly, Pellicano et al. also showed a relationship between impaired processing of global movement and enhanced processing of local level details (recognition of embedded figures). This relationship suggests that both the local bias and global processing deficit are related to abnormal dorsal pathway functioning.

Abnormal dorsal pathway functioning in ASDs might be related to an early developmental deficit in amygdala (cf. Johnson, 2005). Evidence exists on impaired amygdala functioning in autistic disorders. For example, individuals with ASDs show decreased amygdala activity while making mental inferences from eyes and faces (Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, 2007; Baron-Cohen et al., 2000) and make similar atypical social evaluations from faces as amygdala lesion patients (Adolphs et al., 2001). Kluver-Bucy syndrome in animals resembles human autism and is caused by amygdala lesions (Baron-Cohen et al., 2000). Some visual information is passed from retina via superior colliculus and pulvinar to amygdala. This subcortical route matures early in development, is faster than the reticular-geniculate-cortical route, modulates neural activity in cortical areas and, importantly, operates preferably on low-spatial frequencies. Respectively, an early developmental deficit in amygdala might lead to reduced association between low- and high-spatial frequencies in cortical areas and a permanent neurological bias on the latter at the cost of the former (Johnson, 2005).

We observed a relationship between alexithymia scores and the recognition decrements caused by filtering. Interestingly, such relationship suggests that the effects of filtering indeed were affected by emotional processes in addition to purely perceptual ones. The results suggest that alexithymic personality trait involves difficulties in recognizing facial emotions from low-spatial frequencies. Whether the worse performance of participants with AS is solely due to their high-alexithymia levels can not be answered on the basis of this study, because high-alexithymia scores were observed only in the AS group.

In conclusion, our results supported a global processing deficit in autistic disorders in evaluating naturalistic stimuli (emotional facial expressions). The results are congruent with the weak central coherence account of autism positing a general information processing bias on details instead of wholes. Our study gave no support for impaired recognition of basic facial expressions or impaired processing of dynamic facial information in autistic disorders.

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