

Impaired Face Processing in Autism: Fact or Artifact?

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Within the last 10 years, there has been an upsurge of interest in face processing abilities in autism which has generated a proliferation of new empirical demonstrations employing a variety of measuring techniques. Observably atypical social behaviors early in the development of children with autism have led to the contention that autism is a condition where the processing of social information, particularly faces, is impaired. While several empirical sources of evidence lend support to this hypothesis, others suggest that there are conditions under which autistic individuals do not differ from typically developing persons. The present paper reviews this bulk of empirical evidence, and concludes that the versatility and abilities of face processing in persons with autism have been underestimated.

KEY WORDS: Autism; face processing; FFA; configural; local bias.

Impaired face processing is one of the most commonly cited aspects of the social cognition deficits observed among persons with autism spectrum disorder (ASD). It is thought to arise from lack of interest in social stimuli early in life (Dawson, Webb, & McPartland, 2005; Grelotti, Gauthier, & Schultz, 2002; Schultz, 2005), and/or dysfunction of the face processing brain regions, namely the fusiform gyrus (Dawson *et al.*, 2005), the amygdala (Baron-Cohen *et al.*, 2000), or the linkage between the two structures (Schultz, 2005). Regardless of the precise source, this deficit is central to the study of

autism, as highlighted by the rapid growth of literature involving behavioral, electrophysiological, and neuroimaging research on face perception. Most of these studies are based on the premise of a deficit, but this impairment is not clearly defined across studies. In this paper, we review both the behavioral and physiological evidence of face processing in autism, and conclude that, in contradiction to the common wisdom, face processing may not be particularly impaired.

CURRENT KNOWLEDGE ON COGNITIVE AND BRAIN MECHANISMS UNDERLYING FACE PROCESSING

Faces are highly salient and biologically meaningful visual stimuli that provide a wealth of information that is crucial for social communication and for our adaptation as social animals (Ellis & Young, 1998). Faces are informative about the gender, age and identity of another person; allow for inferences about mood and intentions; and guide one's attention to objects and events. However, this information is not easily gained as faces constitute one of the most

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complex classes of stimuli encountered by the visual system. The complexity stems from the relatively little variance in underlying structure across faces (Diamond & Carey, 1986) that include a constant set of features (i.e., eyes, nose, mouth) arranged in a fairly similar manner (i.e., eyes side by side above the nose above the mouth), but dramatic differences in visual content due to changes in pose, lighting, expression, hairstyle, and other features. Despite all these difficulties, humans are remarkably expert at recognizing faces. According to recent formulations (Maurer, Le Grand, & Mondloch, 2002), there are three different types of information available in a face: first-order relations between features (i.e., two eyes above a nose above a mouth), second-order relations (i.e., the spatial relationships between the facial features) and holistic information (i.e., undecomposed whole that does not include explicit representation of facial features). It has been proposed that facial decision relies on analysis of first-order relations. This stage would logically precede the processing of the face as a whole (holistic processing) itself followed by the more subtle processing of second-order relations (configural processing) which is necessary to the recognition of individual faces.

Evidence that face recognition in humans may be qualitatively different and anatomically segregated from the recognition of objects emerged from brain lesion, behavioral, and neuroimaging studies. This evidence included studies of individuals with brain lesions who exhibited deficits in face processing (i.e. prosopagnosia) with intact visual object processing (Damasio, Tranel, & Damasio, 1990; De Renzi, 1986; Meadows, 1974), or the reverse pattern of deficit with spared face processing but impaired object processing (Moscovitch, Winocur, & Behrmann, 1997). The face recognition impairment displayed by prosopagnosic individuals was related to a loss of specific modes of face processing, such as the use of configural (Levine & Calvanio, 1989) and holistic (Farah, Wilson, Drain, & Tanaka, 1995) information, leaving intact the encoding of feature- or part-based information.

In addition, the effect of inverting stimuli from their canonical upright orientation serves as a diagnostic marker of the processing differences implicated in face and object recognition (Yin, 1969). Whereas most objects are somewhat more difficult to recognize inverted than upright, face recognition is more drastically diminished by stimulus inversion (for a review, see Valentine, 1988). Thus, face perception is thought to be mediated by special mechanisms that are more orientation-sensitive and more holistic than

those involved in object perception (Freire, Lee, & Symons, 2000; Leder & Bruce, 2000; Rhodes, Brake, & Atkinson, 1993; Searcy & Barlett, 1996). In addition to coding of local features (Rakover, 2002), upright face processing relies in some special way on the configural (second-order relations) properties of faces, the processing of which may be disrupted when faces are inverted. Inversion strikingly renders distortion in a face less perceptible, such as in the Thatcher illusion (Thompson, 1980). The impression of grotesque or bizarre-looking Thatcher faces created by inverting the eyes and mouth only is dramatically reduced when Thatcherized faces are inverted. The crucial role of configural information is also emphasized in studies on face context effect (Farah, Wilson, Drain, & Tanaka, 1998; Homa, Haver, & Schwartz, 1976; Tanaka & Farah, 1993) in which recognition of face parts is enhanced in a normal face context rather than in a disrupted context, such as an inverted or scrambled canonical arrangement of facial features.

However, the conclusion that face-specific mechanisms are distinct from object processing is challenged by the expertise hypothesis, in which face-specific effects (i.e. face inversion effect) could be observed for non-face objects among experts (Diamond & Carey, 1986; Gauthier & Tarr, 2002). Accordingly, functional differences in processing face and non-face objects stem from the level of categorization at which such stimuli are typically recognized. Unlike visual objects other than faces, face recognition is naturally achieved at a more specific level of categorization that requires precise within-category discriminatory mechanisms (Tanaka, 2001; Tarr & Cheng, 2003).

The Origin of Face Expertise

By as early as nine minutes of age, infants preferentially orient their gaze (Goren, Sarty, & Wu, 1975) and look longer at a schematic drawing of a face with face-like first-order relations than at a scrambled face or other visual patterns (see also Kleiner, 1987; Maurer & Young, 1983; Simion, Valenza, Umiltà, & Dalla Barba, 1998; Valenza, Simion, Macchi, Cassia, & Umiltà, 1996). In one theoretical framework, newborns' preferential orienting to faces is taken as evidence of an innate face-detecting device, termed CONSPEC, that selectively responds to faceness and that drives attention to faces (Morton & Johnson, 1991). CONSPEC is considered to be mediated by subcortical structures that receive

information from the retinotectal pathway. The influence of this mechanism wanes during the first two months and is eventually replaced by the CONLERN system, which supports the acquisition and learning of adequate cortical visual mechanisms to process faces. In a second framework, infants do not possess an innate representation of their conspecifics, but rather their preferential orienting to face-like stimuli is a result of the presence of some general psychophysical properties in a face pattern that best satisfy the constraints of the immature visual system at birth (Banks & Salapatek, 1981; Cassia, Turati, & Simion, 2004; Kleiner, 1987; Simion, Cassia, Turati, & Valenza, 2001).

After this early head-start, newborns learn quickly to recognize their mother's face among others based on both external and internal features (Pascalis, de Schonen, Morton, & Deruelle, 1995). At the age of six weeks they start to show some kind of configural processing, relying more on the internal configuration of their mother's face, though it remains unclear whether configural processing in young infants at this stage resembles that in adults. Besides, school-age children were found to rely more on featural, or piecemeal strategies to process faces, and at around the age of 10 years-old there is a switch to more configural and holistic strategies of processing (Carey & Diamond, 1977). However, other findings showing face inversion effects in 5 year-olds together with the evidence that configural face processing could be present in infants are not consistent with this switch in processing mode hypothesis (Brace *et al.*, 2001; Pascalis, Demont, de Haan, & Campbell, 2001).

Electrophysiological Indices of Face Processing

Face-sensitive modulations of electrical (electroencephalography, EEG) and magnetic (magnetoencephalography, MEG) field potentials recorded from the scalp are informative about the brain processes involved in face perception and recognition (Bentin & Deouell, 2000; Bötzel, Schulze, & Stodieck, 1995; Sams, Hietanen, Hari, Ilmoniemi, & Lounasmaa, 1997). The presentation of faces evokes a sequence of electromagnetic brain events whose spatio-temporal characteristics reflect different stages of face processing. Early event-related potentials (ERPs) evoked by faces entail two successive voltage fluctuations—an occipital positive peak (P1) around 100 ms that is followed by a dipolar component with a negative deflection around 170 ms at bilateral

occipito-temporal sites (the N170), and a positive peak at centro-frontal sites called the vertex positive potential, or VPP (Bötzel *et al.*, 1995; Jeffreys, 1989; George, Fiori, Davidoff, & Renault, 1996). Although the P1 is not thought to reflect *stricto sensu* activity in retinotopic visual areas, its amplitude and latency vary with respect to low-level visual characteristics (i.e. contrast, spatial frequency content, etc.) but not to high-level visual processing allowing face and object categorization (Jemel *et al.*, 2003b; Tanskanen, Nasanen, Montez, Paallysaho, & Hari, 2005¹). Instead, high-level visual processing of faces is classically associated with the N170 component (and its magnetic analogue, the M170), which is larger in response to faces than to other seemingly complex visual objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bötzel *et al.*, 1995; Halgren, Raji, Marinkovic, Jousmäki, & Hari, 2000). There are numerous pieces of evidence indicating that the N170 reflects a fairly early stage of the perceptual analysis of faces (i.e. structural, configural, holistic) rather than face recognition and identification *per se*. The amplitude and/or the latency of the M/N170 are modulated by a variety of stimulus manipulations that disturb either configural face processing (e.g. scrambling the inner features within the face context: George *et al.*, 1996; face inversion: Eimer, 2000; Rossion *et al.*, 2000; Sagiv & Bentin, 2002) or the visibility of faces (Jemel *et al.*, 2003b; Tanskanen *et al.*, 2005), but not by high-order cognitive factors, such as face familiarity (Bentin & Deouell, 2000; Eimer, 2000; but see Jemel, Pisani, Calabria, Crommelinck, & Bruyer, 2003a), attention (Cauquil Séverac, Edmonds, & Taylor, 2000; Carmel & Bentin, 2002), or repetition priming (Eimer, 2000; Schweinberger, Pickering, Burton, & Kaufmann, 2002; but see Itier & Taylor, 2002; Jemel, Pisani, Rousselle, Crommelinck, & Bruyer, 2005). Access to face memory representation and associated semantic information is associated with later ERP components, between 250 and 500 ms, taking the form of an enhanced negativity (N400) followed by an enhanced positivity beyond 500 ms post-stimulus (P600) in response to familiar faces (in comparison

¹ Other findings showed that P1 (and/or its magnetic analogue M100) is the early face-specific component, as it is sensitive to configural properties of faces (Halit, de Haan, & Johnson, 2000), face inversion (Itier & Taylor, 2002; Linkenkaer-Hansen *et al.*, 1998), early visual categorization of faces and objects (Liu, Harris, & Kanwisher, 2002), and face expression (Batty & Taylor, 2003; Pizzagalli, Regard, & Lehmann, 1999).

to the activity associated with unfamiliar faces; Bentin & Deouell, 2000; Eimer, 2000).

Developmental studies show that the electrophysiological indices of face processing undergo functional changes across ages. The ERPs of infants as young as 6 months of age show a relatively late and small N170 component in response to face images (de Haan, Pascalis, & Johnson, 2002; Nelson & de Haan, 1996) that is not affected by inversion as in older infants and adult subjects (de Haan *et al.*, 2002). They show instead later ERP differences (~400 ms after stimulus onset) between not only upright and inverted faces (de Haan *et al.*, 2002), but also between emotional expressions (e.g. happy vs. fear; Nelson & de Haan, 1996) and between their mothers' and strangers' faces (de Haan & Nelson, 1997). ERP studies with older children have shown that the N170 responses to faces do not reach full maturity until adulthood, decreasing in amplitude, and occurring at earlier latencies throughout the child and adolescent years (Taylor, Batty, & Itier, 2004; Taylor, McCarthy, Saliba, & Degiovanni, 1999).

Face Processing Brain Network

The refinement of functional brain imaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), allowed for the *in vivo* localization of the brain structures that underpin face processing. The perception of faces activates a distributed neural network in the human brain that extends posteriorly from the ventral visual cortex, including the fusiform gyrus (FG) and superior temporal sulcus (STS), to more anterior regions in the temporal pole, such as the limbic system (amygdala, insula), and the prefrontal cortex (Haxby, Hoffman, & Gobbini, 2000, 2002). These activations reflect the processing of different information that can be extracted from faces, such as gender, eye gaze, face expression, and familiarity. Certain portions of the occipito-temporal cortex, typically the mid-fusiform gyrus have been consistently found to be selectively activated by face perception as opposed to the perception of other seemingly complex visual objects (Kanwisher, McDermott, & Chun, 1997; Puce, Allison, Asgari, Gore, & McCarthy, 1996; Sergent, Ohta, & MacDonald, 1992). However, a face-sensitive region of the FG, called the fusiform face area (FFA, i.e., Kanwisher *et al.*, 1997), is not simply triggered by face perception but is recruited during processing of non-face objects for which expertise and thus

recognition at a more specific level are acquired (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Gauthier, Skudlarski, Gore, & Anderson, 2000). Consistent with this, increased hemodynamic responses to familiar relative to unfamiliar faces in the FG are reported (Henson, Shallice, & Dolan, 2000; Katanoda, Yoshikawa, & Sugishita, 2000; Sergent *et al.*, 1992), suggesting that the FFA is likely to be the neural system that underlies recognition at an individual level. In addition to the FFA, more anterior regions, such as the anterior middle temporal gyrus and the orbitofrontal cortex, show increased activity to famous and personally familiar people (Gorno-Tempini *et al.*, 1998; Gorno-Tempini & Price, 2001; Nakamura *et al.*, 2000; Sergent *et al.*, 1992). Other specific functions with regard to face processing activate the amygdala during the processing of emotionally relevant stimuli (LeDoux, 2000), especially negative emotions such as fear, anger, and disgust (Adolphs, Tranel, Damasio, & Damasio, 1994; Breiter *et al.*, 1996; Morris *et al.*, 1996; Vuilleumier, Armony, Driver, & Dolan, 2001), and the STS during eye-gaze processing (Puce, Allison, Bentin, Gore, & McCarthy, 1998; Wicker, Michel, Henaff, & Decety, 1998).

FACE PROCESSING IN AUTISM

Behavioral Evidence for Atypical Perceptual Processing of Faces in Autism

Clinical surveys based on parents' reports and retrospective reviews of family home movies abound with signs of atypical social behaviors in children later diagnosed with autism. These include poor eye contact, delayed onset or complete lack of gaze following, decreased orienting to faces, absence of use of social smile, lack of facial expression, lack of responsiveness to parents' voices or attempts to play and interact, and lack of spontaneous imitation (cf. Volkmar, Chawarska, & Klin, 2005; for an overview). In order to better characterize the social cognition deficits in autism, experimental studies focused primarily on face processing abilities in children and adults with ASD, as the consistency of the above-cited early signs of social deficits suggests a relationship between lack of social interest in autism and abnormalities of face processing (Schultz, 2005).

Different aspects of face processing have been investigated, and the consensus reached from several of these studies is that children and adults with ASD display specific deficits in processing information

conveyed by faces (for an example of this position, see Gepner, de Gelder, & de Schonen, 1996). Poor performances have been reported in autistics with below normal measured intelligence: recognition of previously familiar faces (Boucher, Lewis, & Collins, 1998), immediate recognition of unfamiliar faces (Boucher & Lewis, 1992; Gepner *et al.*, 1996; Hauck, Fein, Maltby, Waterhouse, & Feinstein, 1998), matching of facial expressions (Celani, Battacchi, & Arcidiacono, 1999; Gepner *et al.*, 1996; Hobson, 1986a, b; Tantam, Monaghan, Nicholson, & Stirling, 1989), etc. Other lines of evidence suggest that individuals with ASD do not have a profound and absolute deficit in face processing but rather some peculiar way of processing not only faces but also non-social information (Barton *et al.*, 2004; Behrmann *et al.*, 2006; Lahaie *et al.*, 2006; Lopez, Donnelly, & Hadwin, 2004; Rouse, Donnelly, Hadwin, & Brown, 2004).

Langdell's landmark 1978 study is often invoked as a foundation for the claim that autistics are impaired in face processing, but in fact found atypical face processing strategies without an actual deficit. Autistic children and adolescents (mean IQ of 60.3 and 63 respectively) and their mental-age and chronological-age matched controls were asked to identify faces of their peers that were partially masked with different facial areas revealed. While the younger autistics performed less accurately and the older autistics equally accurately compared to their respective control groups when upper areas were revealed, both groups of autistics were more accurate than their controls when the lower areas were revealed. That is, the younger autistics achieved an overall accuracy similar to their controls but with a different distribution of correct responses across conditions, and the older autistics were either equal to or better than their controls across all conditions, resulting in an overall superior accuracy. Thus no overall impairment in familiar face recognition can be concluded, and while older autistic children performed better than younger autistic children, typical children did not show this kind of improvement with age. However, this improvement in autistics was also accompanied by the development of superior performance compared to controls in identifying inverted faces. This study has been interpreted as showing a specific deficit in configural face processing, with autistics having to rely to an abnormal degree on part-based encoding. Subsequent studies pursued the investigation of the nature of the perceptual processing of faces in autism and to

what extent configural face processing may be impaired in these individuals.

The possibility that face processing in autism is preferentially oriented toward local aspects can be inferred from Langdell's study, and from subsequent findings showing that children and adults with ASD tend to manage face identities and expressions in a piecemeal fashion. Regarding atypical face scanning patterns, results are conflicting. Whereas Joseph and Tanaka (2003) and Klin, Jones, Schultz, Volkmar, and Cohen (2002) concluded that autistic individuals attend significantly more to the lower part of faces than do non-autistics, results from Pelphey *et al.* (2002), van der Geest, Kemner, Camfferman, Verbaten, and van Engeland (2002), Dalton *et al.* (2005), Lahaie *et al.* (2006), and Bar Heim *et al.* (this issue) fail to support this conclusion. However, the local bias hypothesis in autism has been more directly assessed in a recent study (Lahaie *et al.*, 2006) using a priming paradigm in which recognition of newly learned faces was either primed by one, two, three or four face parts, being either natural (i.e. eyes, mouth, contour, nose) or arbitrary parts (i.e., face parts containing partial information on two or more facial features, and thus containing some configural information). The results showed similar priming effects with the two types of face segmentation in both autistic and control groups with a greater accelerating priming function when increasing the number of natural than arbitrary parts in the primes. Interestingly, in the natural part priming condition, autistic participants displayed a consistent priming effect for single face parts while participants without ASD did not. The superior effect of a single natural facial part on recognition speed observed among participants with ASD suggests an enhanced processing for individual face parts. Furthermore, an advantage of the mouth region for priming the whole face was not found in this study. The single feature priming effect obtained in the autistic group was mostly driven by the eyes and to a lesser extent by the mouth. This finding of a local bias in face recognition among individuals with ASD parallels other findings showing an over-functioning of low-level perceptual processing for non-social information in autism, such as those evidenced in the embedded figure task, the Navon task, etc. (for a review, see Mottron *et al.*, this issue).

The finding that individuals with ASD tend to process faces in terms of their component parts should not necessarily imply that configural/holistic processing strategies are impaired. This hypothesis

has been addressed either directly or indirectly through the face inversion paradigm. Some studies concluded that individuals with ASD are less disturbed by face inversion compared to typically developing individuals. However, the actual results appear to be less conclusive. For example, Hobson *et al.* (1988) found that adolescents with ASD were superior to controls in both expression and identity sorting tasks when photographs were presented upside down, though the difference between the two groups of subjects did not reach significance. In addition, it was found that the performance scores of both the autistic and non-autistic groups was lower in the upside-down condition than in the upright condition, which clearly indicates that face inversion affected autistic individuals' performances. In Tantam *et al.* (1989), the absence of face inversion effect in children with ASD is obscured by an overall floor effect. In fact, while the control group's performance at labeling the face expressions was affected by turning the photos upside-down, the autistic group's performance in the inverted condition was as limited as in the upright condition. More recent studies did find a typical decline of performance due to face inversion in individuals with ASD (Joseph & Tanaka, 2003; Lahaie *et al.*, 2006; Teunisse & de Gelder, 2003) as well as a Thatcher illusion effect (Rouse *et al.*, 2004). Although the superior processing of local aspects of faces was previously thought to derive from a deficit in the perception of global and configural information, these latter findings suggest an enhanced low-level perceptual processing with absence of global perceptual impairments. Indeed, similar to typically developing subjects, participants with ASD were better at recognizing facial features, especially the mouth (cf. Joseph & Tanaka, 2003) when they had been previously encoded in a face context than in isolation. In addition, the advantage of encoding features presented in a whole-face context is accrued when configural processing is cued (Lopez *et al.*, 2004), which suggests that individuals with ASD are capable of deriving a holistic representation of faces.

While a greater than typical absolute preference for lower parts of the face has not necessarily been supported by studies using direct measures of gaze scanning, these studies do support the use of atypical strategies by persons with ASD when processing faces (Dalton *et al.*, 2005; Klin *et al.*, 2002; Pelphrey *et al.*, 2002; but see van der Geest *et al.*, 2002). During the observation of videotapes of socially interacting actors, Klin *et al.* (2002) showed that while typical

controls concentrated their fixations on the eyes of the protagonists, participants with ASD spent significantly less time fixating the eye than the mouth region, while fixating equally on eyes and bodies, and least on surrounding objects. In contrast to a group of chronological-age matched control participants who showed a rather stereotyped and systematic way of scanning facial expressions, it was shown that the scanpaths of the participants with ASD were in general less controlled and less strategic (Pelphrey *et al.*, 2002). They spent more time examining "unimportant" features of the face (e.g., an ear, the chin, or region of the hair line) than the internal facial features (i.e., eyes, mouth, nose), but when fixating the internal features, they spent relatively more time fixating the eyes than the mouth and nose regions. This pattern of result did not differ as a function of the instructions given to the participants (i.e., free viewing of face expressions or emotion identification). Dalton *et al.* (2005) found also that fixation time devoted to the eye region was reduced in autistic participants relative to typically developing individuals in two different tasks (face expression, face familiarity judgment). However, there was no difference between groups in time spent fixating on the mouth region.

The hypothesis that a failure to perceive social cues in the faces of others and a difficulty in understanding others' emotions constitute the primary social deficit in autism (Gross, 2004; Hobson, 1986a) has generated numerous studies assessing the ability of individuals with ASD to recognize and identify face expression. Consistent with this hypothesis, some studies have reported impaired recognition, identification and understanding of facial expression in autism (Celani *et al.*, 1999; Gross, 2004; Hobson, 1986a, b, 1987; Tantam *et al.*, 1989). In matching task paradigms, it was found that low-functioning autistic children had difficulty matching photographs and videos of facial expressions of emotion with appropriate drawings/pictures of facial expressions (Celani *et al.*, 1999; Deruelle, Rondan, Gepner, & Tardif, 2004; Hobson, 1986a, b). They were found to be significantly worse than non-autistic children at finding the odd facial expression out, at labeling facial emotions (Tantam *et al.*, 1989), at classifying (Gepner *et al.*, 1996), and identifying emotional facial expressions (Gross, 2004). They tended to match face pictures according to irrelevant dimensions, such as accessories and paraphernalia, rather than according to their facial expressions as

controls tended to do (Davies, Bishop, Manstead, & Tantum, 1994; Weeks & Hobson, 1987). In Pelphrey *et al.* (2002), these deficits in processing facial emotions were specifically evident for fearful faces; and Adolphs, Sears, and Piven (2001) found limitations in judging the “trustworthiness” and “approachability” of face images in autistic adults. In addition, unlike their control subjects, low functioning children with ASD performed no better when viewing the full face than when viewing the lower or the higher part of faces (Gross, 2004). These impairments were thought to be specific to processing facial emotions in autism as the performance of individuals with ASD on facial identity, lip reading, and gaze direction were not as impaired (Gepner *et al.*, 1996; Hobson *et al.*, 1988).

These results were however challenged by several other findings that either showed intact face expression processing in individuals with ASD (Braverman, Fein, Lucci, & Waterhouse, 1989; Castelli, 2005; Grossman, Klin, Carter, & Volkmar, 2000; Ozonoff, Pennington, & Rogers, 1990; Pelphrey *et al.*, 2002; Prior, Dahlstrom, & Squires, 1990), or a general face processing deficit that was not specific to emotions (Davies *et al.*, 1994; Gepner, Deruelle, & Grynfeldt, 2001; Teunisse & De Gelder, 1994). Given that facial expression tasks often rely on verbal mediation, some authors found that deficits in emotion perception disappeared when autistic subjects were matched with controls on verbal mental age (Braverman *et al.*, 1989; Ozonoff *et al.*, 1990). Ozonoff *et al.* (1990) found that the ability to sort and match emotional expressions in autistic children did not differ from that of control subjects matched on verbal mental age. In addition, several studies have failed to find impaired recognition of basic emotions (e.g., Adolphs *et al.*, 2001; Baron-Cohen, Spitz, & Cross, 1993; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Grossman *et al.*, 2000; Volkmar, Sparrow, Rende, & Cohen, 1989), or of videotaped sequences of emotional expressions (Gepner *et al.*, 2001) in autistic participants. Interestingly, in Grossman *et al.* (2000)’s study, participants with Asperger syndrome showed a bias towards verbal information when presented with facial expressions paired with a mismatching word (e.g. a happy face paired with angry verbal labeling), which led the authors to suggest that the understanding of facial expression in these high functioning autistic subjects is analytic and verbally mediated rather than holistic and intuitive as it is assumed to be in individuals without Asperger syndrome. However, Davies *et al.* (1994) found that

high functioning autistic subjects performed worse than did low functioning autistics in face expression tasks. These findings were consistent across two testing conditions: a sorting task (experiment 1) and a matching task (experiment 2). It is interesting to note that there are some commonalities between the two latter studies (Davies *et al.*, 1994; Grossman *et al.*, 2000), although their general conclusions may seem conflicting. In fact, the differences observed between high functioning autistics and their matched control subjects might have arisen due to the experimental tasks used which, as noted by the authors themselves, might have involved an important executive function component: namely inhibiting a response to the verbal label while focusing on the facial expression as in a Stroop-like effect (Grossman *et al.*, 2000), and shifting flexibly between sets or classification concepts as in the Wisconsin Card Sorting Task (Davies *et al.*, 1994, experiment 1).

In sum, these findings lend support for an overall amodal and non-domain-specific difference in perceptual processing (cf. Behrmann *et al.*, 2006, and Mottron *et al.*, this issue), characterized among other peculiarities by a locally oriented perception of faces, but without a deficit in perception of global features, and even in face identity and emotion recognition *per se*.

ERP and MEG Studies of Face Processing in Autism

Although electrical and magnetic brain evoked signals are useful in identifying the temporal dynamics of face processing mechanisms, there are only a few published articles in autism using these techniques (Bailey, Braeutigam, Jousmaki, & Swithenby, 2005; Dawson *et al.*, 2002; Dawson, Webb, Carver, Panagiotides, & McPartland, 2004; Grice *et al.*, 2001, 2005; McPartland, Dawson, Webb, Panagiotides, & Carver, 2004; O’Connor, Hamm, & Kirk, 2005; Senju, Tojo, Yaguchi, & Hasegawa, 2005). These studies involved participants with ASD of different ages: very young children from 30 to 61 months (Dawson *et al.*, 2002, 2004; Grice *et al.*, 2005), children having a mean age of 11.6 years (O’Connors *et al.*, 2005; Senju *et al.*, 2005) and/or adolescents and adults between 15 and 52 years (Bailey *et al.*, 2005; Grice *et al.*, 2001; McPartland *et al.*, 2004; O’Connor *et al.*, 2005). Electrical brain activity related to face perception was assessed using pictures of upright and inverted faces (Grice *et al.*, 2001) and objects (Bailey *et al.*, 2005; McPartland

et al., 2004); same-different judgments of sequentially presented pairs of faces, objects (i.e. mugs) and dot patterns (Bailey *et al.*, 2005); passive viewing of familiar and unfamiliar faces and objects (Dawson *et al.*, 2002), and of facial emotions (Dawson *et al.*, 2004); an explicit facial emotion recognition task (O'Connor *et al.*, 2005), and images of faces depicting deviant vs. direct eye gaze (Grice *et al.*, 2005; Senju *et al.*, 2005). The reported differences between subjects with ASD and typically developing subjects are: delayed latency (McPartland *et al.*, 2004; O'Connor *et al.*, 2005) and smaller amplitude (Bailey *et al.*, 2005; O'Connor *et al.*, 2005) of electrical (and magnetic) brain evoked responses to face stimuli; atypical scalp distributions of the face-sensitive ERP responses (Bailey *et al.*, 2005) with no right-hemisphere lateralization (Dawson *et al.*, 2004; McPartland *et al.*, 2004; Senju *et al.*, 2005); and lack of differential responses to face orientation (Grice *et al.*, 2001; McPartland *et al.*, 2004), familiarity (Dawson *et al.*, 2002) and expression (Dawson *et al.*, 2004).

The delayed peak latency of the face-sensitive N170 component in adolescents and adults with ASD (McPartland *et al.*, 2004; O'Connor *et al.*, 2005) has been taken as evidence for a slower speed of early structural encoding of faces (Dawson *et al.*, 2005), reflecting the difficulty that autistic individuals experience when processing faces. O'Connor *et al.* (2005) investigated different ERP components (P1, N170, occipital P2) elicited by five emotional face stimuli (happy, sad, angry, scared, and neutral) in young and adult subjects with ASD and their sex- and age-matched control subjects. Their results show longer latencies of P1 and N170 components along with smaller N170 amplitudes to all categories of facial emotions in the adult group with autism than in their matched control group. No such between-groups differences were found when comparing ERPs in the younger subjects with and without autism. The authors concluded that individuals with ASD display impairments in configural face processing, and that they process faces like objects, though no direct experimental manipulation in this study allows such strong conclusions. Moreover, the assumption that faces may be processed in a similar fashion as objects in autism is inconsistent with face-specificity in the amplitude of the N170 component (or its evoked magnetic field analogue) reported by Bailey *et al.* (2005), McPartland *et al.* (2004) and Grice *et al.* (2005). Similar to their matched controls, individuals

with ASD show typical, and even larger, face-object N170 differences (see Fig. 3 in McPartland *et al.*, 2004).

It is important to note that findings reporting differences in amplitude and latency of evoked ERP brain responses between autistic and non-autistic populations without any interaction with one or more experimental variables should be cautiously interpreted (Picton *et al.*, 2000). Accordingly, within- and between-subject variations are a rule in ERP studies, especially in atypical populations. In addition, several biophysical factors inherent to EEG recordings affect the strength of the recorded signals over the scalp. The EEG signal is dependent on the volume conduction in the outer tissue layers of the head (skull, bone, cerebrospinal fluid, gray matter), their thickness, and their homogeneity (Akhtari *et al.*, 2002; Chauveau *et al.*, 2004; Haueisen *et al.*, 2002). For instance, bone thickness can vary in the same skull between frontal and temporal regions (Rush & Driscoll, 1968), and between subjects. Thus, in the absence of normative data concerning the conductive properties of these tissues in the autistic population, one should exercise caution when interpreting ERP results.

Atypical scalp distribution of face-related ERPs noted in two- to four-year old infants (Dawson *et al.*, 2004) and in adolescents and adults with ASD (Bailey *et al.*, 2005; McPartland *et al.*, 2004; Senju *et al.*, 2005) have been taken as evidence for abnormal cortical specialization for faces in autism (Dawson *et al.*, 2005). The most replicated finding is an absence of right hemisphere lateralization of the ERP components associated with perceptual face processing (McPartland *et al.*, 2004), and processing of face expression (Dawson *et al.*, 2004). However, these findings are not supported by a recent MEG study that revealed stronger right-sided activation to faces than to other categories of objects (Bailey *et al.*, 2005) in individuals with ASD, although the location of the MEG sources for faces overlapped that of the objects' sources. Such a spatial overlap between face and object sources was accounted for by the higher level of inter-individual variations among subjects with ASD in the orientation and strength of the dipoles of faces as well as of objects (Bailey *et al.*, 2005).

Two studies have demonstrated an absence of face inversion related-modulations on N170 latency (McPartland *et al.*, 2004) and on gamma (γ) power

responses² (Grice *et al.*, 2001) in adolescents and adults with ASD. Although McPartland *et al.*'s conclusions emphasized the absence of face inversion effect based on the latency of the face-sensitive N170 component their autistic group did show the typical N170 amplitude enhancement for inverted relative to upright faces (McPartland *et al.*, 2004). This latter result suggests that perceptual face processing was somehow affected by inversion. An absence of face inversion effect on γ responses in adults with ASD was observed by Grice *et al.* (2001), who reported that the spectral power of the gamma responses was not reduced by face inversion as in the control group. However, normal binding-related γ -oscillations for the upright face condition, probably reflecting normal visual binding of facial features into a coherent face gestalt, was displayed by the autistic group (but see comment on this result, Dawson *et al.*, 2005). Similar visual binding mechanisms might therefore be at work to process upright and inverted faces in the autistic group. However, given that the task instructions (e.g., passive viewing or face/no-face decisions as in Rodriguez *et al.*'s 1999 study) are not specified in the study report, it is difficult to establish how inverted and upright faces were actually processed and subjectively perceived by the subjects. Indeed, previous studies have consistently demonstrated that gamma responses are known to be highly dependent on the subjects' state of perception (Cosmelli *et al.*, 2004; Tallon-Baudry *et al.*, 1997; Rodriguez *et al.*, 1999).

Lastly, there is some evidence that infants with ASD, unlike their mental age-matched peers, do not show differential electrical brain activity when presented with their mother's face vs. a stranger's face,

² Gamma (γ) responses correspond to oscillations in the EEG within a 30–70 Hz frequency band. A strong correlation between γ -band responses and stimulus coherency has been greatly highlighted by multiunit recording studies in animals (Gray, König, Engel, & Singer, 1989) and by studies at coarser level of spatial resolution (scalp and intracortical EEG) in humans (Gruber, Müller, & Keil, 2002; Lachaux *et al.*, 2000; Rodriguez *et al.*, 1999; Tallon-Baudry, Bertrand, Delpuech, & Pernier, 1997). In contrast to the evoked- γ response (\sim 100 ms), the induced- γ activity (\sim 200–300 ms) which is neither phase nor time-locked to stimulus onset is the neural signature of perceptual grouping and integration (visual binding), and seems to be modulated by past experience, attention, etc., and other cognitive factors. Gamma-range spectral power is calculated via time-frequency wavelet decomposition of the EEG signal, a method that provides a time-varying magnitude within a specific frequency band, leading to time by frequency (TF) representation of the signal. TF energy is averaged across single trials, allowing detection of non-phase-locked γ -responses to target stimuli.

but do show an enhancement of ERP amplitude to an unfamiliar object as compared to a favorite toy, at the level of the P400 component (over posterior lateral sites) and to a lesser extent at the frontal Nc component (Dawson *et al.*, 2002). In another study, it was found that the N300 component (considered as the precursor to the adult N170 component) and a later negative slow wave (NSW) did not respond differently to a face depicting a fear expression relative to a face depicting a neutral expression in young infants with ASD (Dawson *et al.*, 2004).

In summary, it is premature to conclude on impairment in a particular stage of face processing in autism based on current ERP findings. The available studies indicate rather that individuals with autism display the typical ERP responses associated with face perception. However, a differential responsiveness to different attributes of face stimuli is not consistently observed, which may be indicative of a different processing mode in the form of diminished specialization, and not of a deficit.

Discrepancies in the FFA Findings

Over the past five years, we have witnessed an increasing number of neuroimaging studies using blood-oxygenation-level-dependent (BOLD) fMRI signals and PET-regional cerebral blood flow (rCBF) investigating brain activity responses to faces in persons with autism. These studies focused on two Regions of Interest (ROIs), the fusiform gyrus and the amygdala, known to be part of the social cognition network (Haxby *et al.*, 2000, 2002). Given the hypothesis that deficits in social cognition and impairment in face processing in autism could stem from a limited experience with faces, it was predicted that the modulation of FFA activation could mirror this lack of face expertise in autistic subjects. Schultz *et al.* (2000) were the first to provide direct neuro-functional evidence for atypical face processing in autism. One group of individuals with high-functioning autism and Asperger syndrome and two IQ and age matched control groups were scanned during a face and object (cars, boats, birds, planes, bottles, or chairs) within-category discrimination task (same-different judgments of stimulus pairs). The functional brain maps activated during the face and object tasks were subtracted from those activated during a pattern discrimination task. Overall, the pattern of brain activation in the face task differed between the autistic and control groups, while object-related brain activities in the infero-temporal gyrus (ITG) were

comparable in the two groups of subjects. More precisely, the autism group showed lower FFA and higher ITG activation than the control group in the face perception task. The authors concluded that the finding that face perception in autistics recruited object-related areas (ITG) was possibly indicative of their heavier reliance on object-like perceptual strategies (i.e., part-based processes) when processing faces (Schultz *et al.*, 2000). These authors took a step further by suggesting that a limited experience with faces among individuals with ASD might have led to an underdevelopment of the FG and thus to a hypo-responsiveness of this brain structure to faces. However, this hypothesis has been later discarded by Schultz and colleagues following two major findings from the same research team (Grelotti *et al.*, 2005; Schultz *et al.*, 2005). First, an activation of the FFA similar to that observed in typical individuals when viewing faces was found in a young boy with ASD when he was presented with cartoon characters ("Digimon") for which he had a special interest, but FFA hypoactivation was found in the same subject when he was presented with pictures of faces (Grelotti *et al.*, 2005). Second, a recent structural brain imaging study using a voxel-based morphometric whole brain analysis in a large sample of persons with autism ($n = 111$) and of controls ($n = 102$) has revealed an overall brain size increase in the autism group relative to the controls, but the FG enlargement was evident only when comparing older subjects in both groups (Schultz *et al.*, 2005; see also Waiter *et al.*, 2004). Taken together, these findings suggest functional abnormalities of the FFA and its lack of tuning toward face processing could not credibly be accounted for by structural abnormalities of the FG (Grelotti *et al.*, 2002).

Until recently (Hadjikhani *et al.*, 2004; Pierce, Haist, Sedaghat, & Courchesne, 2004), similar FFA hypoactivation in individuals with ASD was found in other studies using gender discrimination (Hubl *et al.*, 2003; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001) and facial expression judgment tasks (Critchley *et al.*, 2000; Hall, Szechtman, & Nahmias, 2003; Hubl *et al.*, 2003; Piggot *et al.*, 2004, condition A; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004, condition A). Although the diminished activation of the FFA was stressed, some of these studies reported widely scattered activation in response to face images in autistic subjects when individual-specific sites were examined (Pierce *et al.*, 2001). In addition, it was found that face processing in autistic individuals recruits similar cortical networks as those involved

during a pattern-processing task, implicating larger portions of the visual areas than that observed in the control group (Hubl *et al.*, 2003). Together with behavioral evidence of different hierarchical strategies when processing faces, these atypical neural activations suggest that individuals with ASD use different brain areas to perform face tasks, which may reflect a temporary rededication of neural resources, but also atypical autistic strategies interacting with specific aspects of study design and task demand. Lastly, Dalton *et al.* (2005) combined a high-resolution 3T fMRI study with eye-fixation measurements in individuals with ASD in emotion detection and face familiarity tasks. Both tasks showed FG hypoactivation to face images in autistics, but FG activation was correlated to the amount of time spent fixating on the eyes in this group. The typical controls' absence of a similar correlation was attributed to a ceiling effect, as the controls differed from the autistic participants in having most of their fixation time concentrated on the eyes.

Other recent findings have further clouded the situation by showing a normal activation of the FFA in response to faces in autistic subjects under different task conditions: a passive viewing of face images (Hadjikhani *et al.*, 2004), gender discrimination of familiar and unfamiliar face images (Pierce *et al.*, 2004), and in a facial emotion labeling task (Piggot *et al.*, 2004; condition B; Wang *et al.*, 2004, condition B). Hadjikhani *et al.* (2004) found typical activation of the face processing brain network in a group of individuals with ASD ($n = 11$) during a passive viewing of faces. This activation included the FG (i.e. the FFA), the inferior occipital gyrus, and the superior temporal sulcus (STS), brain regions that are known to be involved during face processing in typically developing individuals. Pierce *et al.* (2004) advanced the hypothesis that familiarity of face stimuli should modulate the level of FFA activation, bringing it to a normal level, in autistic subjects. These authors predicted that more affectively engaging faces, such as those of close relatives, would elicit FFA activation in ASD and control subjects. In contrast, an absence of FFA activation in response to unfamiliar faces was expected in ASD subjects only. Pierce *et al.* observed no difference in FFA activation between ASD and comparison participants, which was similarly affected by familiarity. This result also contrasts with Dalton *et al.* (2005, experiment 2) in which a task involving discrimination of familiar from non-familiar face images resulted in FG hypoactivation in autistics compared to typical

controls, with greater FG activation to familiar versus unfamiliar faces found in typical but not in autistic individuals.

Several reasons may account for the discrepancies between studies showing FFA hypoactivation and those showing typical FFA activation in ASD subjects, though none can survive the existing counterexamples. The degree of severity of social impairments in the autistic group as reflected in ADI-R scores could contribute to the absence or presence of FFA activation. Among peer-reviewed studies showing FFA hypoactivation in autism, only four (Grelotti *et al.*, 2005; Hubl *et al.*, 2003; Pierce *et al.*, 2001; Schultz *et al.*, 2000) out of nine provided a detailed description of the ADI-R scores of the autistic participants. All reported scores well above the cut-off threshold in all domains relevant for diagnosis. For these four studies, the mean scores were 21.45 (SD = 3.4) for qualitative impairments in social interaction, 16.73 (SD = 3.1) in communication, and 6.65 (SD = 2.3) in stereotyped, repetitive behavior. Only two (Hadjikhani *et al.*, 2004; Pierce *et al.*, 2004) out of four studies with experiments showing normal FFA activation in autism reported the ADI scores of their participants with ASD. As noted by Schultz (2005), the autistic sample in Hadjikhani *et al.*'s (2004) study seems to be less socially impaired than the autistic samples in prior studies. In average, they ($n = 9$) scored 16.3 (SD = 4.1), 9.8 (SD = 3.2), and 4.1 (SD = 2.4) in the ADI-R for social, communication, and repetitive behavior symptoms, which is still well above diagnostic threshold. However, participants in Pierce *et al.*'s (2004) study displayed a normal FFA activation despite having comparable ADI-R scores (social: 25 ± 3 ; communication: 15.1 ± 3 ; restricted interests and stereotyped behaviors: 7.9 ± 2.2) to those in studies displaying absence of FFA activation (Grelotti *et al.*, 2005; Hubl *et al.*, 2003; Pierce *et al.*, 2001; Schultz *et al.*, 2000). Thus, although one cannot preclude the possibility that the degree of severity of observable autistic symptoms could be related to the level of activation of the FFA to faces, variation in ADI-R score is not a convincing explanation for the conflicting FFA activation pattern reported in the available fMRI face studies.

Other possible explanations for this pattern of findings are differences in magnet strength (1.5 T vs. 3 T) between studies (Dalton *et al.*, 2005; Hadjikhani *et al.*, 2004), and additive and/or interactive effects of variability in the location and level of brain activations across subjects. However, neither of these hypotheses holds. First, although higher magnetic

fields increase the signal associated with BOLD contrast, Pierce *et al.* (2004) did find FFA activation in ASD subjects scanned with a 1.5 T magnet. Second, a similar variability of the location and level of brain activations to faces was found in the autistic and in the comparison group (Hadjikhani *et al.*, 2004; Schultz *et al.*, 2000). A third hypothesis invoking variations in study design and task demands is plausible in that autistics adopt atypical strategies in responding to task demands involving a wide range of stimuli (Mottron *et al.*, this issue), and truly identical tasks involving face images have produced virtually identical findings of autistic compared to non-autistic FFA activation when replicated across studies (Wang *et al.*, 2004; Piggot *et al.*, 2004). However, typical FFA activation in ASD subjects has been found in studies using tasks targeting different aspects of face processing (passive viewing to neutral faces, gender judgment of familiar mixed with unfamiliar faces, and emotion labeling). The ability of autistics to perform well in face image tasks of varying difficulty while showing FG hypoactivation (e.g., Pierce *et al.*, 2001; Schultz *et al.*, 2000), and findings of both FFA hypoactivation (Pierce *et al.*, 2001) and typical activation (Pierce *et al.*, 2004) in tasks differing in some aspects but not conceivably in difficulty, are evidence that there is no direct relationship between task difficulty and FFA activation in autistics. Accordingly, while differences in task demands and study design, which plausibly would interact with atypical autistic perception and attention strategies, can be invoked as an important factor in fMRI studies of face processing in autism, task difficulty as judged from a typical viewpoint cannot be invoked to negate findings of typical FFA activation in autistics, as by Schultz (2005). To summarize, it is difficult to maintain in light of such conflicting findings that absence of FFA activity during face processing represents a reliable neurofunctional marker of autism, and additional studies are needed to delineate the conditions modulating FFA activation in ASD subjects.

Similar to the variety of results in FFA activation in autism, fMRI studies reporting amygdala activation to face images present a wide range of results, from hypoactivation in autistics compared to typical controls (Baron-Cohen *et al.*, 1999, in a study using images of the eye region only; Critchley *et al.*, 2000; Pierce *et al.*, 2001); to typical activation in autistics (Piggot *et al.*, 2004; Pierce *et al.*, 2004) to hyperactivation in autistics compared to controls (Dalton *et al.*, 2005, both experiments); to typical

activation but marginally significant atypical modulation between tasks in autistics (Wang *et al.*, 2004). This impressive range of findings has been selectively recruited in support of various proposed deficits related to processing of facial identities and emotions in autistics (e.g., Schultz, 2005). However, taken as a whole these findings cannot be considered as supporting abnormal or impaired amygdala structure or function as centrally or consistently associated with atypical social behaviors in autistics, including atypical face processing. For example, Dalton *et al.*'s (2005) proposal that autistics avoid fixating on the eye area due to negatively valenced overarousal as reflected in amygdala hyperactivation correlated with eye fixation, including to neutral face images, along with their similar proposal that FG activation is also correlated with eye fixation in autistics, is contradicted by Pierce *et al.* (2004). Here typical FFA activation accompanies typical amygdala activation in autistics as compared to their controls, a combination of findings which would be precluded were the amygdala-based hypothesis proposed by Dalton *et al.* valid.

GENERAL CONCLUSIONS

The overview of behavioral, ERP and functional imaging data on face processing in autism leads to the conclusion that a deficit in overall face recognition, and more specifically of the global aspect of faces, is not grounded by strong empirical bases. However, there is now converging evidence from behavioral cognitive studies that the “default processing” of faces is more oriented toward their local aspects, but that this spontaneous orientation can be overcome by specific task demands. Typical category- and dimension-specific modulations of ERP activity seems diminished or absent in autism, but the interpretation of this series of differences as a by-product of locally-oriented hierarchical strategies, and/ or of hardwired differences in the visual cortex remains to be established. Lastly, conflicting results from fMRI studies of brain activity during face image inspection indicate that typical FFA and amygdala activation is not mandatory in autism, but is possible. Taken together, this series of findings indicates that the versatility and abilities of face processing in persons with autism have been underestimated.

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