

Link Between Facial Identity and Expression Abilities Suggestive of Origins of Face Impairments in Autism: Support for the Social-Motivation Hypothesis

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Abstract

Individuals with autism spectrum disorder (ASD) often have difficulties with processing identity and expression in faces. This is at odds with influential models of face processing that propose separate neural pathways for the identity and expression domains. The social-motivation hypothesis of ASD posits a lack of visual experience with faces as the root cause of face impairments in autism. A direct prediction is that identity and expression abilities should be related in ASD, reflecting the common origin of face impairment in this population. We tested adults with and without ASD ($n_s = 34$) in identity and expression tasks. Our results showed that performance in the two domains was significantly correlated in the ASD group but not in the comparison group. These results suggest that the most likely origin for face impairments in ASD stems from the input stage impacting development of identity and expression domains alike, consistent with the social-motivation hypothesis.

Keywords

autism spectrum disorder, social-motivation hypothesis, face perception, identity, expression

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Individuals with autism spectrum disorder (ASD) often have difficulties with processing identity and expression in faces (Harms, Martin, & Wallace, 2010; Pellicano, Jeffery, Burr, & Rhodes, 2007; Weigelt, Koldewyn, & Kanwisher, 2012). On the surface, this is at odds with influential models of face processing, which propose separate functional and neurological pathways for the identity and expression domains (Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2000). It seems unlikely that brain alterations in ASD would simultaneously impact neural circuits of both identity and expression processing. Indeed, in acquired prosopagnosia, in which individuals are severely impaired in recognition of identity because of a localized brain lesion, recognition of expression is often spared (e.g., Fox, Hanif, Iaria, Duchaine, & Barton, 2011). A reconciliation of this apparent contradiction is offered by the social-motivation hypothesis of ASD, which posits a lack of visual experience with faces as the root cause of face

impairments in autism (Dawson, Webb, & McPartland, 2005; Schultz, 2005). In the absence of appropriate visual input, typical development of a range of face skills would be disrupted altogether (e.g., Fine et al., 2003; Huber et al., 2015). A direct prediction of this hypothesis is that identity and expression abilities should be related in ASD, reflecting the common origin of face impairment in this population.

We tested adults with and without ASD in facial identity and expression tasks. We found that performance in the two domains was significantly correlated in the ASD group but not in the comparison group. We also assessed social motivation in both groups and

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found it to be significantly reduced in the ASD group. Importantly, social motivation was significantly correlated with face ability only for ASD individuals with low social motivation. Social motivation was not predictive of face abilities in the comparison group. These results provide strong support for the social-motivation hypothesis of autism, suggesting that the most likely origin for face impairments in ASD stems from the input stage impacting development of both identity and expression domains alike.

Method

We tested 34 adults with ASD and 34 adults without ASD in tasks assessing performance in facial identity and expression domains as well as social motivation. This sample size was chosen because it is comparable with, or in many cases substantially larger than, those employed in similar correlation analyses of behavioral data in the context of assessing visual performance in ASD. Our measure of identity performance was based on face-identification contrast thresholds (Oruc & Barton, 2010a, 2010b). To assess face-selective identification, we used a closely matched nonface stimulus category, houses, as a control (Shafai & Oruc, 2018). Face-selective identification was then assessed via the ratio of face- to house-identification thresholds. Our measure of expression performance was based on discrimination thresholds between pairs of happy, sad, and angry facial expressions.

We adopted a classical orientation-discrimination paradigm in the context of facial expressions (Regan & Beverley, 1985). In each expression set, psychophysical thresholds were estimated to discriminate a pair of expressions, such as happy and sad. At each trial, participants were shown both expressions in two randomly ordered temporal intervals and instructed to indicate the interval that featured more of one of the two expressions (e.g., “Which one is happier?”). Three independent thresholds were obtained for discriminating happy–sad, happy–angry, and sad–angry pairs. Our social-motivation measure was based on the Multidimensional Social Competence Scale, a 77-item self-assessment tool that provides a social-motivation score (Yager & Iarocci, 2013) alongside scores for six other subdomains. Verbal and nonverbal intelligence was assessed for all participants using the second edition of the Wechsler Abbreviated Scale of Intelligence (WASI-II; Wechsler & Chou, 2011).

Participants

Thirty-four adult participants with ASD (13 women; age: $M = 23.9$ years, $SD = 7.8$) and 34 without ASD (11 women; age: $M = 26.5$ years, $SD = 6.8$) took part in this experiment. WASI-II Full Scale IQ scores ranged from 76 to 134 ($M = 100.3$, $SD = 15.7$) for the group with

ASD, whereas scores for the comparison group ranged from 77 to 138 ($M = 116.4$, $SD = 12.0$). The two groups were not matched on IQ ($p < .001$). Age and gender did not differ significantly between the two groups, $t(66) = -1.48$, $p = .15$; $\chi^2(1, N = 68) = 0.26$, $p = .61$. All participants completed Experiments 1 and 2. Social-motivation scores were obtained for all participants, with the exception of 3 participants in the ASD group.

All participants received a visual exam by an optometrist to confirm normal or corrected-to-normal visual acuity. The eye exam consisted of autorefractometry and manual refraction, if necessary, followed by visual acuity at an intermediate distance (67 cm). Inclusion in the study was based on 20/30 or better acuity at the intermediate distance of 67 cm. Any prescription glasses were measured with a lensometer to confirm that the appropriate corrective lenses were being worn. If a participant did not have the correct refraction prescription, trial lenses were loaned for the duration of the experiment.

Any participants with a WASI-II Full Scale IQ score less than 75 were excluded from the study to prevent confounds due to intellectual disabilities. Autism-spectrum quotient (AQ) scores (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) were also obtained for all but 3 ASD participants and all comparison participants. AQ scores ranged from 10 to 46 ($M = 28.56$, $SD = 10.64$) for the ASD group, whereas scores for the comparison group ranged from 4 to 20 ($M = 13.41$, $SD = 4.40$). An AQ score above 20 was used as an exclusion criterion for the comparison group. Participants in the comparison group were recruited from the community through online advertisements.

All participants with ASD ($n = 34$) were previously diagnosed by a clinician using the criteria from the text revision of the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2000). Diagnostic reports were obtained to verify the diagnoses. In addition, the Autism Diagnostic Observation Schedule was administered by trained researchers in the Autism and Developmental Disorders Lab for the majority of participants in the ASD group ($n = 25$). For a full listing of WASI-II, AQ, and Autism Diagnostic Observation Schedule scores, see Table S1 in the Supplemental Material available online.

The protocol was approved by the ethics review boards of the University of British Columbia, Simon Fraser University, and Vancouver General Hospital. In accordance with the Declaration of Helsinki, informed consent was obtained from each participant.

Experimental setup

A computer equipped with a Cambridge Research Systems (CRS) VSG 2/3 graphics card and SONY Trinitron 17-in. monitor (model Multiscan17seII) was used for

the experiments. A CRS OptiCAL photometer (Model OP200-E) and software provided by CRS were used to carry out gamma correction. Mean luminance of the display was 17.4 cd/m². MATLAB (The MathWorks, Natick, MA) and tools from the CRS VSG Toolbox for MATLAB and the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) were used to program the experiment. All participants were seated 70 cm from the screen. Experiments 1 and 2 used the same experimental setup.

Experiment 1: identity

Contrast-threshold estimates for identifying faces were measured in a five-alternative forced-choice paradigm (Oruc & Barton, 2010a, 2010b). This same task was repeated with house stimuli as the nonface control (for further details of this protocol, see Shafai & Oruc, 2018). The identification contrast-threshold estimates for each class of stimuli were used to derive a *face-selective identification score* defined as $\log c_f/c_b$, where c_f and c_b denote the contrast-threshold estimates for face and house identification, respectively.

Stimuli

Face stimuli. The face stimuli consisted of five female faces with neutral expressions chosen from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Each face was converted to gray scale, and an oval aperture was used to cover the external features. The faces were aligned horizontally by centering the tip of the nose and vertically by aligning the height of the pupils through all faces. The faces were presented at 6.75 degrees of face width when viewed at the fixed distance of 70 cm (for further details, see Oruc & Barton, 2010a, 2010b).

House stimuli. To create the control stimuli, we took photographs of a portico, a covered porch leading into the front entrance of a home. The five porticos chosen had similar complex elements (e.g., style of front doors, stairs, house siding) while also containing the featural information in the center of the photograph, similar to the face stimuli. Any identifying features, such as addresses, plants, or decorations, were removed using Adobe Photoshop and Illustrator. As with the face stimuli, each house was converted to gray scale, and an oval aperture was used to cover the external information, allowing the portico to be the focal point of the stimuli (for further details, see Shafai & Oruc, 2018). House stimuli were viewed from the same distance and subtended the same visual size as the face stimuli.

For both the face and house stimuli, the root-mean-square contrast was defined as the standard deviation

of luminance divided by mean luminance. For each image, the mean luminance was set to half maximum, whereas the root-mean-square contrast was set to 1 inside the oval aperture. This ensured standard contrast across the stimuli images prior to manipulation during the experimental protocols. Generation of the oval mask, alignment of the stimuli vertically and horizontally, and adjustment of the luminance and contrast were implemented in MATLAB.

Procedure. Each trial began with a 150-ms fixation cross, a 150-ms blank interval, a 150-ms stimulus, and a 150-ms blank interval, followed by a screen displaying all five available choices. This choice screen remained visible until the participant responded via pressing a key. Each response was entered using the keys on the number pad of a computer keyboard that spatially corresponded to the position of each face or house on the choice screen. Feedback for each response was given via auditory clicks. A single click indicated a correct response, and two clicks indicated an incorrect response. Two randomly interleaved 40-trial staircases controlled the contrast of the stimuli. Thus, each 80-trial block produced two independent threshold estimates at 82% accuracy, which were then averaged to yield a single threshold in the given condition. Each participant was randomly assigned to begin with either the face or house stimuli blocks, followed by the alternate task.

Experiment 2: expression

Facial-expression-discrimination thresholds were measured for pairs of three expressions (angry, happy, and sad) in three blocks. A single expression threshold was produced for the correlation analysis by averaging the three independent threshold estimates. Each block featured a single identity associated with one expression pair that was also constant throughout each block.

Stimuli. Three male faces from the Karolinska Directed Emotional Faces database (Lundqvist et al., 1998) were selected. Each individual had one neutral and two expression images selected from the database. We chose angry and sad for identity A, happy and sad for identity B, and happy and angry for identity C. For each identity, we created two morph series—one that gradually morphed from neutral to Expression 1, and another that morphed from neutral to Expression 2. For example, for identity A, one series morphed from neutral to angry, and the other series morphed from neutral to sad. Middle points in each morph series represented weaker signal strengths for the expressions. For example, a 5% sad morph consisted of 95% neutral and 5% sad images of a given identity.

Procedure. Each trial presented both expression morphs in a random order in a two-interval two-alternative forced-choice paradigm. The participant's task was to indicate which interval contained more of the target expression (e.g., happier). At each block, each participant was randomly assigned to one of the two possible target expressions, which remained constant throughout that block. Each trial began with a 150-ms fixation cross, a 1-s test screen containing one of the two expression morphs (e.g., sadder), a second 150-ms fixation cross, another 1-s test screen containing the other expression (e.g., angrier), and a blank screen. The blank screen remained until the participant indicated whether the first or second test screen contained the target expression. Correct responses resulted in a single auditory click, whereas incorrect responses resulted in two clicks.

Assessment of social motivation. We administered the Multidimensional Social Competence Scale to all but three of the ASD participants ($n = 31$) and to all comparison participants ($n = 34$). This 77-item questionnaire assesses seven distinct domains of social competence: social motivation, social inferencing, demonstrating empathic concern, social knowledge, verbal conversation skills, nonverbal sending skills, and emotion regulation (Yager & Iarocci, 2013). Guided by the specific hypothesis we were testing in this study, we extracted only the score for the social-motivation domain of the Multidimensional Social Competence Scale—the subscale that is relevant to the current study, which measures how much interest and enjoyment one has when interacting with other people. Thus, social motivation is the only domain for which scores were analyzed and are reported.

Results

Group averages showed that ASD performance was diminished in both identity and expression tasks in relation to the comparison group (see Figs. 1a and 1b). For the identity task, a repeated measures analysis of variance showed no main effect of group, $F(1, 66) = 0.56, p = .46, \eta_p^2 = .008$, or stimulus category, $F(1, 66) = 0.52, p = .48, \eta_p^2 = .008$, but revealed a significant interaction between the two, $F(1, 66) = 7.71, p = .007, \eta_p^2 = .11$. Post hoc pairwise comparisons showed that face-identification thresholds were significantly higher for the ASD group ($M = .08$) than for the comparison group ($M = .04$; Tukey-Kramer multiple comparison test, $p < .05, d = 0.39$). House-identification thresholds did not significantly differ between the ASD group ($M = .05$) and comparison group ($M = .06; p > .05, d = -0.19$). House-identification thresholds did not differ from face-identification thresholds for either group ($p > .05$; see Fig. S1 in the Supplemental Material). To quantify face-selective identification, we

calculated the log-threshold ratio of face to house tasks for the two groups (see Fig. 1a), which differed from each other significantly ($p = .009$, two-tailed t test, $d = 0.65$).

For the expression task, discrimination thresholds were lower in the comparison group for all pairs of expressions compared with the ASD group (all $ps < .05$; see Fig. 1b). To obtain a single measure of expression performance, we averaged the three independent measurements of expression-discrimination threshold. We calculated correlation coefficients between face-selective identification scores (identity measure) and log-mean expression-discrimination thresholds (expression measure) for the ASD and the comparison groups (see Fig. 1c).

We found a significant correlation between identity and expression performance in the ASD group ($r = .49, p = .003$), which remained after accounting for Full Scale IQ ($r = .47, p = .006$), Verbal IQ ($r = .47, p = .006$), and Nonverbal IQ ($r = .48, p = .005$). No correlation was found between identity and expression performance in the comparison group ($r = .04, p = .85$). A pairwise comparison based on nonparametric bootstrapping (100,000 repetitions) showed that the correlation coefficient in the ASD group was significantly higher than that in the comparison group ($p = .03$).

The social-motivation score for the ASD group ($M = 31.84$) was significantly lower than that for the comparison group ($M = 41.15$), as confirmed by a two-sample two-tailed t test, $t(63) = -4.96, p < .001, d = 1.23$ (see Fig. 1d). A compound face-ability score was calculated for each participant by averaging the z scores of his or her respective performances in the identity and expression tasks. No correlation was found between social motivation and compound face-ability scores for the ASD group ($r = .17, p = .82$) or the comparison group ($r = -.19, p = .14$) on the basis of one-tailed tests. To determine whether gross social-motivation level mediated this relationship, we used the average social-motivation score for the ASD group ($M = 31.84$) and the comparison group ($M = 41.15$) as criterion levels to partition the social-motivation scale into low-, medium-, and high-social-motivation ranges (see Fig. 1e). The same analysis carried out for each social-motivation range revealed a significant correlation in the ASD group between social motivation and compound face ability for only the low-social-motivation subgroup ($r = -.53, p = .03$) and not the medium-social-motivation subgroup ($r = -.10, p = .37$). Only three individuals with ASD were in the high-social-motivation range; thus, a correlation for this subgroup was not calculated. No correlation between social motivation and compound face ability was found for the medium- ($r = .02, p = .54$) or high- ($r = -.05, p = .43$) social-motivation subgroups of the comparison group. Only 2 individuals in the

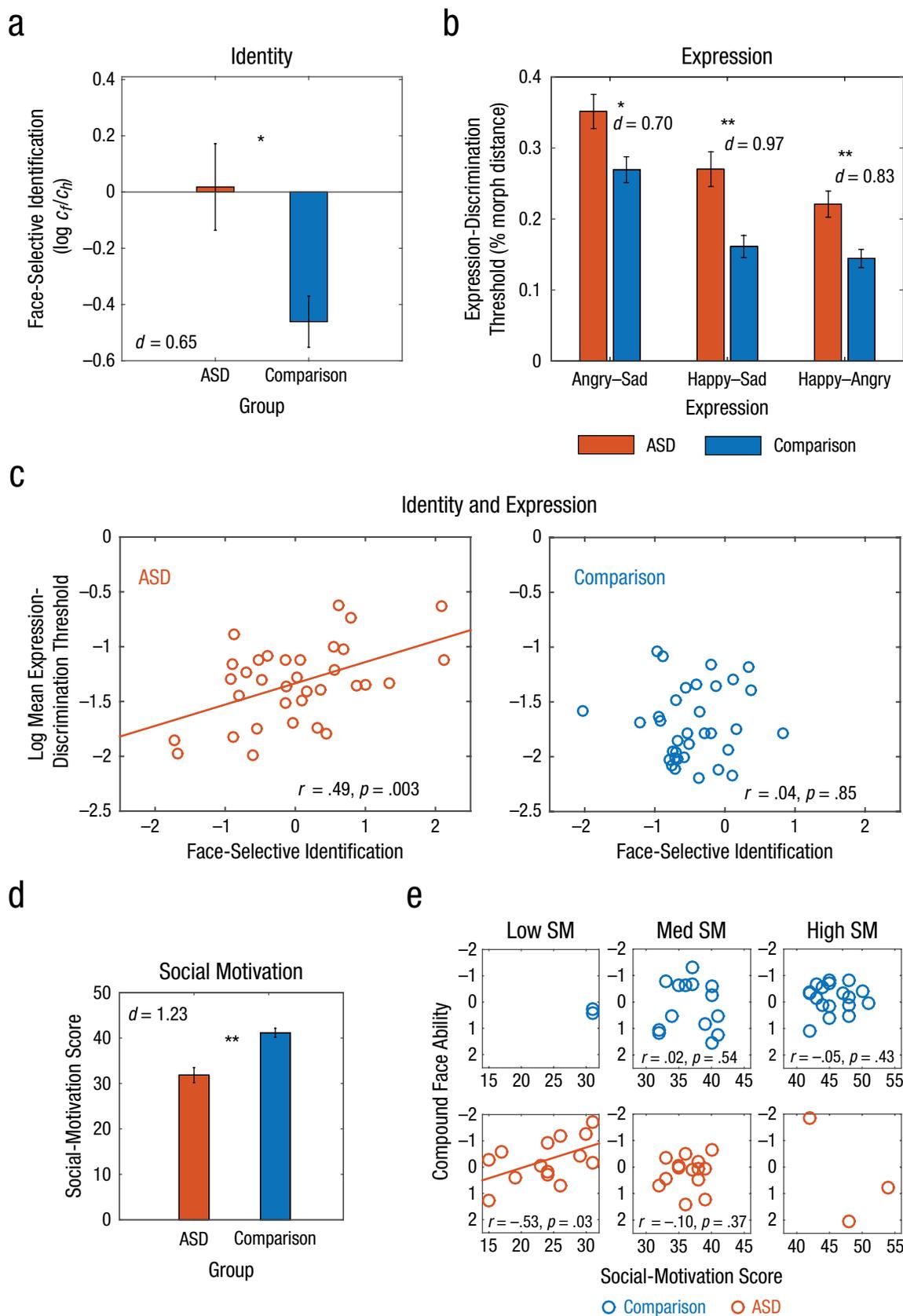


Fig. 1. Results. Mean face-selective identification score (a), defined as the log ratio of face- to house-identification thresholds, is plotted for the autism spectrum disorder (ASD) group and the comparison group. Expression-discrimination

Fig. 1. (continued on next page)

Fig. 1. (continued)

thresholds (b) are plotted for three independent experimental blocks assessing discrimination of angry–sad, happy–sad, and happy–angry expressions for the two groups. A single expression-discrimination score was calculated by averaging the three independent threshold estimates. Correlations between the identity and expression scores (c) are plotted separately for the ASD group and the comparison group. A best-fitting regression line is shown for the ASD group. Mean social-motivation (SM) score (d) is plotted for the ASD group and comparison group. Correlations between SM score and a compound face-ability score (e) are plotted for the low-SM, medium-SM, and high-SM subgroups, separately for the ASD and comparison groups. Note that the *y*-axis, representing the compound face scores, is reversed to reflect the fact that this threshold-based measure indicates better performance with lower scores. Thus, a correlation in the expected direction linking higher SM to better face ability has a negative value. In panels (a), (b), and (d), error bars represent standard errors of the mean, and asterisks indicate significant differences between groups (* $p < .01$, ** $p < .001$).

comparison group were in the low-social-motivation range; thus, a correlation for this subgroup was not calculated (see Fig. 1e).

Discussion

There is a rich literature on facial identity and expression processing in ASD (Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Boucher & Lewis, 1992; O’Hearn, Schroer, Minshew, & Luna, 2010; Wallace, Coleman, & Bailey, 2008; for reviews and a meta-analysis, see Harms et al., 2010; Tang et al., 2015; Uljarevic & Hamilton, 2013; Weigelt et al., 2012). Deficits in both domains have been reported, although overall, impairments may be moderate and marked by substantial individual variation. To pick up the more subtle deficits in this population, researchers have found that fine-grained and targeted approaches, such as the use of face stimuli with high ecological validity, have been more effective (e.g., Chevallier et al., 2015). Few studies have compared identity and expression ability in the same group of participants with ASD. Krebs et al. (2011) measured reaction times in a face-categorization task involving identity (or expression) while ignoring the task-irrelevant information regarding expression (or identity). They found that children with ASD processed identity and expression independently, unlike the asymmetric pattern in typical processing, in which task-irrelevant identity information interferes with the expression task, but task-irrelevant expression information does not interfere with the identity task. Although Krebs et al. (2011) revealed atypical processing of expression in ASD, they did not examine the association between competence in identity and expression tasks at the individual participant level.

In the present study, we hypothesized that limited exposure to faces, possibly due to lower social motivation, is an important contributing factor in the face impairments often associated with ASD. On the basis of this front-end constraint, we predicted performance variation in facial identity and expression tasks to be related in our ASD group. Consistent with our hypothesis, a significant correlation between performance in

the identity and expression tasks was evident for the ASD group but not the comparison group. This pattern of results is not without precedent. Wilson, Brock, and Palermo (2010) recorded eye movements of children with ASD and typically developing children while performing a face-matching task. They found a significant correlation between a measure of social attention (proportion of trials in which people were fixated before objects) and face-matching scores for children with ASD but not for the typically developing children. The lack of association in the comparison participants in the context of significant correlations in the ASD group is consistent with the social-motivation hypothesis of autism. There are substantial individual differences regarding face abilities in the general population. This variation stems from a range of distinct sources, including inherent robustness of underlying neural substrates and varying degrees of exposure to appropriate visual input during development. Lack of social motivation curtails visual experience with faces in ASD and consequently impacts development of a range of face processes altogether. Thus, variation in face abilities in the ASD population is largely determined by the degree of (or lack of) visual experience with faces. Yet for those individuals with plenty of exposure to faces, experience is not a limiting factor and is therefore no longer a source of significant variation. Instead, other factors drive attainment of superior performance.

In the present study, an empirical measure of our participants’ face exposure during development was not available. Instead, we assessed social motivation as a predictor of face exposure. As expected, the average social-motivation score for the ASD group was lower than that of the comparison group (see Fig. 1d). However, contrary to our expectation, social motivation did not explain individual variation in face ability in either group. On the other hand, on the basis of our hypothesis, the impact of exposure on face ability would be most apparent in the context of scarce exposure. And despite group-level difference in social motivation, there was also overlap between the ASD group and the comparison group (i.e., individuals with similar social-motivation scores from either group). To examine

individuals with different levels of social motivation separately, we partitioned the social-motivation scale into low, medium, and high ranges, and we split both groups into these ranges accordingly. This analysis revealed a significant correlation between social motivation and face ability for the low-social-motivation ASD group only (see Fig. 1e). These results are consistent with the idea that the extent of face exposure is related to face ability when face exposure may be limited but not when more frequent. The boundary for the low-social-motivation range was arbitrarily chosen (on the basis of average social-motivation score in the ASD group) and thus does not hold any special meaning regarding how much exposure is scarce versus sufficient. Nevertheless, any effects of insufficient face exposure would be expected to be most apparent in the low-social-motivation range. The pattern of results in our study, as well as findings from Wilson et al. (2010), provides compelling evidence in support of the social-motivation hypothesis of autism.

Deficits in face processing in ASD are mirrored in reduced functional MRI activation of the face-selective regions in the ventral visual cortex, such as the fusiform face area (e.g., Humphreys, Hasson, Avidan, Minshew, & Behrmann, 2008). This is believed to be an indirect effect of abnormal modulation of face-selective cortex by the amygdala, a brain structure that is often implicated in ASD (Baron-Cohen et al., 2000), resulting in a reduction of automatic stimulus-driven orientation to faces (Schultz, 2005). However, a recent study reported intact involuntary exogenous orienting to facelike stimuli in adults with ASD (Shah, Gaule, Bird, & Cook, 2013), which is contrary to the predictions of the social-motivation hypothesis. On the other hand, it remains unclear which aspects of social motivation are primarily involved in the emergence of social impairments in ASD (Chevallier, Kohls, Troiani, Brodtkin, & Schultz, 2012). The role of the amygdala is not confined to involuntary exogenous orienting; rather, it is thought to be broadly involved in prioritization of and orienting to socially relevant stimuli, including directing overt attention to faces (Adolphs, 2008; Adolphs & Spezio, 2006). Thus, reduced visual exposure to face stimuli in ASD need not stem from an innate lack of involuntary attention to faces but can be a consequence of deliberate voluntary looking behaviors giving rise to limited social engagement and exposure to faces throughout development.

Another finding interpreted as evidence against the social-motivation hypothesis (Johnson, 2014) comes from a study that showed that 2-month-old infants, who were later diagnosed with ASD, fixated the eye region of faces just as long as typical infants (Jones & Klin, 2013). However, this same study also showed that for infants with ASD, unlike for typical infants, eye fixation

declines consistently from 2 to 24 months of age. Furthermore, normative levels of eye looking in the first months of life do not readily relate to face-processing deficits in ASD because face-processing abilities are refined through a protracted developmental period (Carey, Diamond, & Woods, 1980; de Heering, Rossion, & Maurer, 2012) and peak after 30 years of age (Germine, Duchaine, & Nakayama, 2011). We suspect, given our results in the context of other results in the literature, that face deficits in ASD most likely stem from a bottleneck in the quality and quantity of visual exposure to faces, possibly because of voluntary avoidance of face looking over prolonged periods. More research is needed to confirm this hypothesis.

Action Editor

Alice J. O'Toole served as action editor for this article.

Author Contributions

All the authors contributed to the study design and writing of the manuscript. Testing and data collection were performed by F. Shafai. I. Oruc analyzed the data in consultation with the other authors. All the authors approved the final manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Supplemental Material

Additional supporting information can be found at <http://journals.sagepub.com/doi/suppl/10.1177/0956797618795471>

Open Practices

Data and materials for this study have not been made publicly available, and the design and analysis plans were not preregistered.

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