SHORT REPORT

The Development of Perceptual Expertise for Faces and Objects in Autism Spectrum Conditions

Cara Damiano, Owen Churches, Howard Ring, and Simon Baron-Cohen

Previous research indicates that individuals with autism spectrum conditions (ASC) do not develop face expertise to the same extent as typical individuals. Yet it remains unclear whether this atypicality is specific to faces or related to more pervasive perceptual or cognitive deficits involved in the actual process of gaining expertise. To address this question, we examined the extent to which adults with ASC were capable of developing expertise with non-face objects. To become experts, all participants completed a 2-week training program with novel objects, known as *Greebles*. Level of expertise was assessed throughout training by measuring the ability to identify Greebles on an individual level. The perceptual strategies acquired as a result of expertise were measured through an inversion effect task completed before and after training, in which performance with upright Greebles and faces was compared to performance with inverted Greebles and faces. After expertise training, it was found that individuals in both the ASC and the typical group successfully achieved expertise and showed an enhanced Greeble inversion effect as a result of training. The development of an inversion effect with Greebles suggests that individuals with ASC may employ the same processing strategies as the typical group. Although exploratory, these findings have implications for understanding the nature of the face processing deficit in ASC as well as offering potential insights into face processing interventions for individuals with ASC. ***Autism Res*** *2011,4:297–301*. © 2011 International Society for Autism Research, Wiley Periodicals, Inc.

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Most human adults have developed a finely tuned expertise for perceiving and processing faces. However, the development of face expertise in individuals with autism spectrum conditions (ASC) follows an atypical course [Grelotti, Gauthier, & Schultz, 2002]. Expertise is typically associated with a ''configural processing'' strategy [i.e. higher-order perception of the spatial relations among parts; Maurer, Le Grand, & Mondloch, 2002], yet complex objects may also be perceived through ''local processing'' (i.e. the examination of individual parts).

One approach for examining processing strategy is to compare performance on *upright* vs. *inverted* stimuli (the ''inversion effect''), as inversion disproportionately disrupts configural information [Freire, Lee, & Symons, 2000]. Although many children and low-functioning individuals with ASC lack a face inversion effect (FIE) [Hobson, Ouston, & Lee, 1988; Langdell, 1978] and tend to employ local rather than configural processing [Jolliffe & Baron-Cohen, 1997; Plaisted, O'Riordan, & Baron-Cohen, 1998], there is some evidence that high-functioning adults with ASC eventually develop a FIE and some degree of configural processing [Lahaie et al., 2006; Teunisse & de Gelder, 2003]. These findings, along with evidence from successful face training interventions [Golan & Baron-Cohen, 2006], suggest that expertise and perceptual strategy are experience-dependent in ASC.

The goal of the current study is to investigate the malleability of expertise processing in ASC. We hypothesized that typical individuals and individuals with ASC would develop expertise with novel, laboratory-created objects in the same time period and that both would rely on configural processing strategies as experts, which would be evident in the development of an enhanced Greeble inversion effect (GIE) after training. We further hypothesized that expertise training would enhance the FIE in both groups, as expertise processing may rely on the same neural substrates as face processing [Gauthier, Skudlarski, Gore, & Anderson, 2000].

From the Autism Research Centre, Department of Psychiatry, University of Cambridge, Cambridge, United Kingdom (C.D., O.C., H.R., S.B.-C.); Department of Psychology, University of North Carolina, Chapel Hill, North Carolina (C.D.); Cambridge Intellectual and Developmental Disability Research Group, University of Cambridge, Cambridge, United Kingdom (H.R.); University of South Australia, Adelaide, Australia (O.C.)
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Address for correspondence and reprints: Cara Damiano, Department of Psychology, University of North Carolina, 247 Davie Hall, Chapel Hill, NC 27599-3270. E-mail: cdamiano@email.unc.edu and Simon Baron-Cohen, Autism Research Centre, Psychiatry Department, University of Cambridge, Douglas House, 18b Trumpington Road, Cambridge CB2 8AH, UK. E-mail: sb205@cam.ac.uk
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Methods

Participants

Eighteen adults with ASC and 20 age- and IQ-matched typical individuals were recruited from the Cambridge Autism Research Centre website (www.autismresearchcentre.com) and advertisements. Exclusion criteria included psychosis, epilepsy, or traumatic brain injury. Participants with ASC received a clinical diagnosis of either autism or Asperger syndrome (AS) from a clinical psychologist or psychiatrist based upon DSM-IV criteria [APA, 1994].

Stimuli

Greebles are a set of novel, non-face objects obtained from Michael J. Tarr at Brown University (http://www.tarrlab.org/) (Fig. 1) [Gauthier & Tarr, 1997]. The faces were obtained from the Max-Planck Institute for Biological Cybernetics in Tuebingen, Germany [Troje & Bülthoff, 1996]. Twenty Greebles and 20 faces were presented in the pre-training session and then the same 20 Greebles were used in training. A new set of 20 Greebles and faces were presented in the post-training session.

Procedure

The procedure of this experiment, which was adapted from that of Gauthier et al. [1998], was comprised of three parts: a pre-training inversion effect task, 10 sessions of training, and a post-training inversion effect task.

Pre-training session. Participants performed a computerized inversion effect task with interleaved presentation of Greebles and faces. Greebles subtended $7.2° \times 3.9°$ and faces subtended $7.5° \times 3.9°$. After 20 practice trials, participants completed 12 blocks of 40 trials each. Figure 2 illustrates the sequence of each trial. The sequence timing was designed to match a related study in typical individuals [Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002]. Between stimuli, a scrambled Greeble or face was presented to prevent retinal persistence in matching stimuli. A blank screen followed the second stimulus for 1,800 msec, during which time participants indicated whether stimuli were the same or different.

Greeble training program. An internet-based program was developed to accommodate participants who did not live near our laboratory. This program consisted of ten 1-hr sessions completed over 2 weeks (no

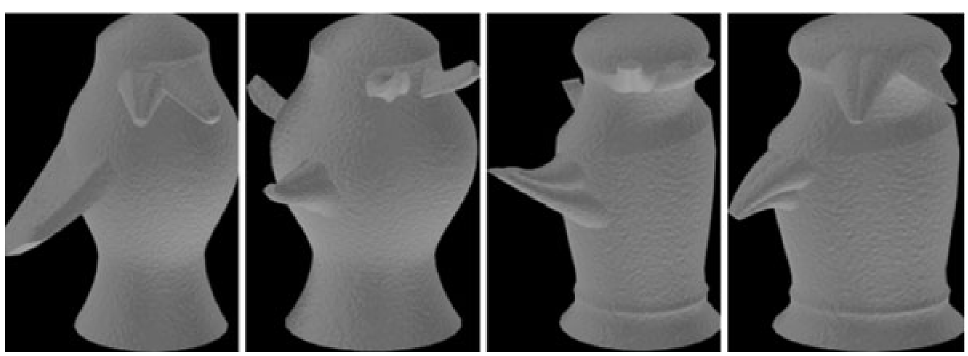

Figure 1. Examples of individual Greebles used in the training program and inversion effect tasks. Greebles can be categorized on the "family" level according to the shape of their main body or on the "individual" level according to the shape and positioning of their appendages. From left to right: "Biff" (from the "Nalli" family), "Harga" (from the "Nalli" family), "Zadra" (from the "Yuju" family), and "Uster" (from the "Yuju" family).

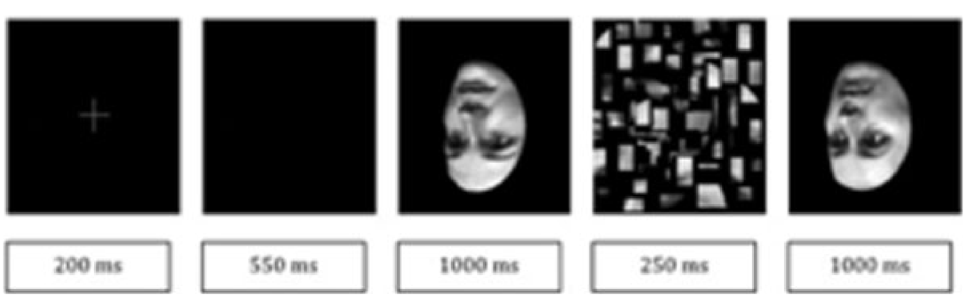

Figure 2. Each trial in the inversion effect task consisted of 200 msec of a centered fixation cross, 550 msec of a blank screen, 1,000 msec of an upright or inverted face or Greeble, 250 msec of a scrambled mask to prevent retinal persistence, and 1,000 msec of a second upright or inverted face or Greeble. The second stimulus was always the same orientation and type as the first stimulus.

more than one session per day). Five Greeble families were introduced in the first session and five individual Greebles were introduced in each of the first four sessions. Each session included a combination of seven tasks described in detail by Gauthier et al. [1998]. These tasks involved: (1) association of a Greeble with a name, (2) recognition of the correct Greeble name pairing, (3) recall of a Greeble name with and without feedback, and (4) the "verification task" which tested participants' level of expertise by asking them to identify correct Greeble name pairings without feedback. To maintain participants' attention and motivation remotely, participants were offered a cash bonus for accurate performance during training sessions.

Post-training inversion effect task. The post-training task was identical to the pre-training task yet with an unfamiliar set of stimuli (20 new Greebles and 20 new faces).

Data Analysis

To achieve expertise, at least two blocks of a session had to be characterized by a mean response time (RT) for individual categorization that was statistically equivalent ($P > 0.05$) or significantly faster than the mean RT for family categorization ($P < 0.05$) [Tanaka & Taylor, 1991]. RTs less than 100 msec or greater than 5,000 msec and blocks in which accuracy was less than chance were excluded. Each of the four blocks in a session was designated as a fraction of the session number (e.g. 1.0, 1.25, 1.5, 1.75 for first, second, third, and fourth blocks, respectively). Blocks before all Greebles were introduced (blocks before 4.25) were not included in analyses.

A repeated measures ANOVA was conducted with the between-subject factor of group (ASC vs. typical) and within-subject factors of session (pre- vs. post- training), type (Greeble vs. face), and orientation (upright vs. inverted). Any significant interactions of the omnibus ANOVA were further investigated with repeated measures ANOVAs and paired *t*-tests to detect the presence of a GIE or FIE before or after training. An inversion effect was defined as a significant difference between performance with upright and inverted stimuli. RTs occurring after the presentation of the subsequent trial (i.e. greater than 2,800 msec) and incorrect responses were excluded from analyses. Median RTs were used in statistical tests to reduce the influence of outliers [Ratcliff, 1993].

Results

Sample Characteristics

Six individuals with ASC and six typical individuals withdrew from the study. Two typical controls were also excluded for not meeting pre-specified criterion for expertise. The final sample included 12 individuals with ASC (six females and six males) and 12 typical individuals (six females and six males). The groups did not differ significantly in age or IQ (Wechsler Abbreviated Scale of Intelligence; Wechsler [1999]), *t*-test, all Ps > 0.05 (Table 1). The ASC group included nine individuals with AS and three with high-functioning autism. The ASC and typical groups differed significantly on Autism Spectrum Quotient scores [Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001], *t*-test, $P < 0.001$.

Greeble Training Program

The mean point of expertise during the verification task was not significantly different between the ASC and typical groups, $t = -1.47$, $P = 0.16$ (Fig. 3) with a mean of 5.75 sessions (SD = 2.34) for the ASC group and 4.71 sessions (SD = 0.73) for the typical group. The mean accuracy for the ASC group during training ($M = 91.75$, SD = 11.85) was not significantly different from

Table 1. Participant Information for Typical and ASC Groups

	Group	
	Typical group ($n = 12$) (Mean (±SD))	ASC group ($n = 12$) (Mean (±SD))
Age (yr)	28.92 (±6.42)	32.42 (±12.79)
Sex	Six females, six males	Six females, six males
Full-scale IQ	117.67 (±8.28)	116.00 (±12.58)
Verbal IQ	115.42 (±8.91)	118.00 (±13.17)
Performance IQ	115.42 (±10.24)	110.92 (±15.92)
Autism Spectrum Quotient (AQ)	17.92 (±6.41)[a]	37.25 (±5.75)[a]

[a]$P < 0.001$.

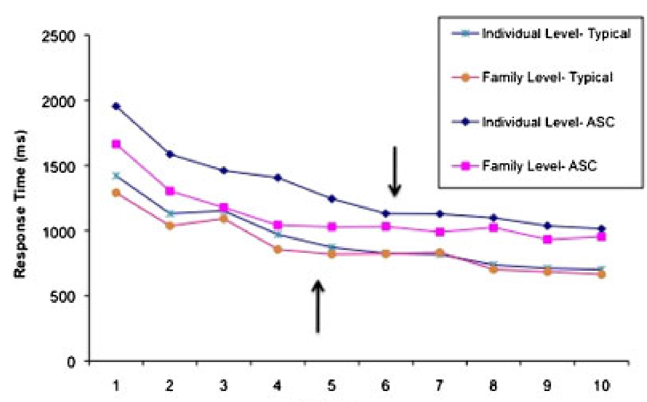

Figure 3. The point where the mean RT for family level categorization was either statistically equivalent or significantly greater than the mean RT for individual level categorization (i.e. the point when Greeble expertise was acquired) was not significantly different between the ASC group and the typical groups. Blocks before session 4.25 (before all Greebles were introduced) were not included in the analysis. Arrows indicate the point of expertise for each group. RT, response time.

Table 2. Mean Response Times and Standard Deviations (in msec) for Upright and Inverted Faces and Greebles in the Inversion Effect Task Before and After Expertise Training

		Typical group		ASC group	
		Before training	After training	Before training	After training
Type	Orientation	(Mean (±SD))		(Mean (±SD))	
Faces	Upright	649.15 (±98.23)	593.34 (±117.93)	689.92 (±199.22)	639.79 (±226.50)
	Inverted	735.15 (±115.34)	666.84 (±126.06)	799.43 (±217.89)	727.83 (±227.29)
Greebles	Upright	717.10 (±104.94)	641.57 (±133.46)	802.01 (±225.88)	715.77 (±235.07)
	Inverted	723.73 (±103.56)	660.49 (±133.93)	786.08 (±222.60)	726.96 (±217.10)

the typical group ($M = 90.37$, SD = 10.79), $t = -0.30$, $P = 0.77$.

Inversion Effect Task

RT results are displayed in Table 2. A repeated measures ANOVA revealed main effects for session, $F(1, 22) = 9.48$, $P = 0.005$, type, $F(1, 22) = 15.44$, $P = 0.001$, and orientation, $F(1, 22) = 65.13$, $P < 0.001$. Significant interactions were detected for session × orientation, $F(1, 22) = 51.44$, $P < 0.001$, and session × type × orientation, $F(1, 22) = 12.79$, $P = 0.002$. A second set of repeated measures ANOVAs with the factors of session and orientation was conducted for each stimulus type (Greebles and faces) to understand the source of the session × type × orientation interaction. This ANOVA revealed a significant session × orientation interaction for Greebles, $F(1, 23) = 7.41$, $P = 0.01$, but not for faces, $F(1, 23) = 3.61$, $P = 0.07$. To determine the source of the session × orientation interaction, *t*-tests were conducted to detect differences between RTs for upright and inverted Greebles. These tests revealed that a significant GIE was detected after training, $t(23) = -2.80$, $P = 0.01$, $d = -1.17$, but not before, $t(23) = 0.66$, $P = 0.52$, $d = 0.28$.

A high level of accuracy was detected across conditions for both the ASC group ($M = 83.92$, SD = 12.32) and the typical group ($M = 88.06$, SD = 8.16). Significant negative correlations were detected among all conditions (upright/inverted, Greeble/faces, and before/after training), $r(24) = -0.48$ to -0.74, $P = 0.001$ to 0.018, suggesting that faster RTs were associated with higher accuracy (i.e. no evidence for a speed-accuracy trade-off).

Discussion

The results of the current study suggest that adults with ASC were able to develop perceptual expertise with complex objects following the same expertise training program as typical adults. Further, both individuals in the typical group and the ASC group were able to acquire perceptual specialization with upright Greebles (as evidenced by faster RT for upright vs. inverted Greebles), reflecting the development of configural processing. Yet, expertise development did not impact face processing, suggesting that the development of expertise with non-face objects (i.e. circumscribed interests) may not negatively affect the development of face expertise.

In line with these findings, previous research also suggests that the development of some degree of configural processing may be possible in this population. Specifically, high-functioning adolescents and adults with ASC demonstrate configural processing with faces in some experimental tasks [Lahaie et al., 2006; Teunisse & de Gelder, 2003]. Because many socially important processes are known to be disrupted by inversion, including identity recognition [McKelvie, 1995], emotional discrimination [Fallshore & Bartholow, 2003], visual speech perception [Rosenblum, Yakel, & Green, 2000], and gaze processing [Jenkins & Langton, 2003], high-functioning individuals may eventually realize the adaptive value in developing and practicing this skill even if faces are not intrinsically rewarding stimuli.

A clear limitation of this study is the small sample size. While we started with larger sample sizes, individuals in each group withdrew due to high time demands of the training program. Second, although a systematic training program with novel objects controlled for quantity and quality of experience across groups, this approach was also difficult to implement remotely and created another potential limitation: the use of an internet-based training program. However, because the variable of interest from training was a difference score calculated for each participant individually, we were able to control for any stable variability due to different operating systems or connection speeds. We recommend that future replications of this work test these effects in larger samples, compare laboratory vs. online training programs, and include ASC and typical groups that did not complete any type of training program to control for practice effects of the task.

The results of this study indicate that individuals with ASC are able to acquire perceptual expertise and configural processing strategies following the same quantity and quality of experience as typical individuals; yet children with ASC do not naturally develop expertise with faces or a FIE [Grelotti et al., 2002]. One potential explanation for this apparent contradiction may be that children with ASC do not have the same motivation to attend to faces as typically developing children and thus have different experiences with faces. It may also be that children with ASC lack the cognitive capacity to develop expertise and configural processing with any complex objects. Yet, further research with children is needed to investigate these possible explanations.

Although Greeble expertise is only a simple model for the complex processes involved in face expertise development and further research in children with ASC is needed, we can conclude from these results that adults with ASC are able to significantly enhance their ability to identify complex objects and develop some degree of configural processing through a 2-week intervention involving subordinate level processing. However, since some individuals with ASC may lack the motivation to gain sufficient experience with faces, interventions may need to focus on enhancing the reward value of attending to faces. Yet, because expertise training did not significantly impact face-processing strategies in either group, these results suggest that interventions involving complex objects may not lead to a domain-general enhancement in configural processing skills.

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References

APA. (1994). DSM-IV diagnostic and statistical manual of mental disorders, 4e. Washington, DC: American Psychiatric Association.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. Journal of Autism and Developmental Disorders, 31, 5–17.

Fallshore, M., & Bartholow, J. (2003). Recognition of emotion from inverted schematic drawings of faces. Perceptual and Motor Skills, 96, 236.

Freire, A., Lee, K., & Symons, L.A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. Perception, 29, 159–170.

Gauthier, I., & Tarr, M.J. (1997). Becoming a ''greeble'' expert: Exploring mechanisms for face recognition. Vision Research, 37, 1673–1682.

Gauthier, I., Williams, P., Tarr, M.J., & Tanaka, J. (1998). Training ''greeble'' experts: A framework for studying expert object recognition processes. Vision Research, 38, 2401–2428.

Gauthier, I., Skudlarski, P., Gore, J.C., & Anderson, A.W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. Nature Neuroscience, 3, 191–197.

Grelotti, D.J., Gauthier, I., & Schultz, R.T. (2002). Social interest and the development of cortical face specialization: What autism teaches us about face processing. Developmental Psychobiology, 40, 213–225.

Golan, O., & Baron-Cohen, S. (2006). Systemizing empathy: Teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. Development and Psychopathology, 18, 591–617.

Hobson, R.P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. British Journal of Psychology, 79, 441–453.

Jenkins, J., & Langton, S.R.H. (2003). Configural processing in the perception of eye-gaze direction. Perception, 32, 1181–1188.

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and asperger syndrome faster than normal on the embedded figures test? Journal of Child Psychology and Psychiatry, and Allied Disciplines, 38, 527–534.

Lahaie, A., Mottron, L., Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2006). Face perception in high-functioning autistic adults: Evidence for superior processing of face parts, not for a configural face-processing deficit. Neuropsychology, 20, 30–41.

Langdell, T. (1978). Recognition of faces: An approach to the study of autism. Journal of Child Psychology and Psychiatry, and Allied Disciplines, 19, 255–268.

Maurer, D., Le Grand, R., & Mondloch, C.J. (2002). The many faces of configural processing. Trends in Cognitive Sciences, 6, 255–260.

McKelvie, S.J. (1995). Encoding operations and recognition memory for faces. Canadian Journal of Experimental Psychology, 49, 437–459.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced visual search for a conjunctive target in autism: A research note. Journal of Child Psychology and Psychiatry, 39, 777–783.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. Psychological Bulletin, 114, 510–510.

Rosenblum, L.D., Yakel, D.A., & Green, K.P. (2000). Face and mouth inversion effects on visual and audiovisual speech perception. Journal of Experimental Psychology, 26, 806–819.

Rossion, B., Gauthier, I., Goffaux, V., Tarr, M.J., & Crommelinck, M. (2002). Expertise training with novel objects leads to left-lateralized facelike electrophysiological responses. Psychological Science, 13, 250–257.

Tanaka, J.W., & Taylor, M. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? Cognitive Psychology, 23, 457–482.

Teunisse, J.P., & de Gelder, B. (2003). Face processing in adolescents with autistic disorder: The inversion and composite effects. Brain and Cognition, 52, 285–294.

Troje, N., & Bülthoff, H.H. (1996). Face recognition under varying poses: The role of texture and shape. Vision Research 36, 1761–1771.

Wechsler, D. (1999). Wechsler abbreviated scale of intelligence. San Antonio, TX: The Psychological Corporation.