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Norm-based coding of facial identity in adults with autism spectrum disorder

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Abstract

Face identification is thought to involve implicit evaluation of how an individual face differs from a face prototype (norm-based coding). We examined the extent to which adults with ASD use norm-based coding during face identification. Participants were adapted to faces that differed from the average in the physically opposite way from the target face, and then asked to categorize the identity of the average face. The adapting faces were either very different from the average face or closer to the average face. Both groups displayed larger identity aftereffects for more extreme adapting faces compared to weaker adapting faces, consistent with norm-based coding. The current results provide the first evidence of norm-based coding of facial identity in high-functioning adults with ASD.

Keywords: Autism, Asperger’s, norm-based face coding, facial identity, face processing
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The norm-based coding model of face perception suggests that face identification involves implicit evaluation of how an individual face differs from a face prototype (Rhodes & Leopold, 2011; Webster & McLeod, 2011). This model suggests that the prototype face is refined by our experience with faces. Norm-based coding provides a model for how individuals are able to efficiently distinguish individual faces that subtly differ from one another (Rhodes, Robbins, Jaquet, McKone, Jeffery, & Clifford, 2005).

Evidence supporting a norm-based coding model of facial identity perception comes from studies that employed a variant of an adaptation paradigm. Face adaptation, like other kinds of visual adaptation, occurs when prolonged fixation on a face biases perception of subsequently viewed faces (see Webster & McLeod, 2011 for review). For example, prolonged exposure to a male face biases perception of an ambiguously gendered face in the opposite direction: it would be seen as female (Webster, Kaping, Mizokami, & Duhamel, 2004). Face aftereffects have also been demonstrated for emotion expression (e.g., Rutherford, Chattha, & Krysko, 2008; Skinner & Benton, 2010; Butler, Oruc, Fox, & Barton, 2008), facial attractiveness (e.g., Rhodes et al., 2003) and facial identity (e.g., Rhodes & Jeffery, 2006; Leopold, O'Toole, Vetter, & Blanz, 2001).

Previous studies have investigated norm-based coding of facial identity using facial identity aftereffects. In a common paradigm, participants learn a set of target identities (e.g., Ted and Rob, see Figure 1), fixate on an “anti-identity”, a face which physically differs from an average face in the opposite way from the target face (e.g., anti-Ted or anti-Rob; see Figure 1), and then categorize an average face as being either like Ted or Rob (Jeffery et al., 2011; Leopold, O’Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006; Robbins, McKone, &
Edwards, 2007). Figure 1 depicts two target identities (Ted and Rob) and anti-identities (anti-Ted and Rob). The anti-identities lie on the same identity trajectory, but are on the opposite side of the average face. Weaker versions of each identity were created by morphing the average and target face by various amounts; e.g., morphing Rob and the average face by 60% creates 60% Rob. When individuals are adapted to the anti-identities (e.g., Anti-Rob) weaker identity strengths and the average face are more likely to be perceived as the original identity (e.g., Rob) (Rhodes & Jeffery, 2006). Norm-based coding theory predicts that after adapting to an anti-identity, one’s average face prototype will be recalibrated in the direction of the adapting anti-identity face. This shift in the prototype has effects on the perception of faces along vectors going through the prototype such that faces on the opposite side of the prototype from the adapting face now look more distinctive (less average and more Rob-like in this example).

Notice that in our example, the average face is intermediate between the target identity and its anti-identity, and this is critical in the test for norm-based coding. To demonstrate norm-based coding, one could not use two faces that lie on separate continua, equally different from the average, but not in opposition to each other. Previous studies have demonstrated that although adapting to an anti-identity enhances recognition of the original identity, adapting to a non-opposite face (a face that lies on a separate identity continuum) does not facilitate recognition of the same face to the same degree (Leopold et al., 2001; Rhodes & Jeffery, 2006). This pattern provides evidence for the norm-based coding model of facial identity, as it suggests that facial identity is coded in relation to an average, or norm.
Further evidence of norm-based coding of facial identity comes from experiments looking at differences in the magnitude of facial aftereffects created by varying how much a face differs from the norm or average face (extremeness). The norm-based coding model predicts that more extreme adapting faces (i.e., adapting faces that are very different from the average face) will produce a greater amount of adaptation and hence pull the prototype of the average face more towards the direction of the adapting face, leading to a larger shift in the perception of the average face (for a detailed description of why the norm-based coding model predicts these patterns of results, see Robbins, McKone, and Edwards, 2007; Jeffery et al., 2011) This is measureable as a larger bias in perception of subsequently viewed faces. This pattern of results has been demonstrated with expression aftereffects (Benton and Skinner, 2010), face feature aftereffects (Robbins, McKone, and Edwards, 2007) and with facial identity aftereffects in typical adults and children (Jeffery et al., 2011; Jeffery, Read, and Rhodes, 2013)

Face perception in Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder in which affected individuals have measureable anomalies in two key areas: 1) social interactions and communication and 2) restrictive and repetitive interests or behaviours (American Psychiatric Association, 2013). Many studies have examined potential qualitative and quantitative differences in face processing abilities of individuals with ASD (see Sasson, 2006; Harms, Martin, & Wallace, 2010; Weigelt, Koldewyn, & Kanwisher, 2012, for reviews). While many studies have examined face processing in ASD (see Weigelt, Koldewyn, & Kanwisher, 2012, for review), few have examined the perceptual mechanisms underlying these face processing skills and how they may differ in the ASD population. Pellicano, Jeffery, Blurr, and Rhodes (2007) examined norm-based coding of facial identity in 8- to 13-year-old children
with ASD and matched controls. Participants learned two male identities and during the test phases were adapted to an 80% anti-identity adapting face. While the ASD group was able to learn and discriminate the two identities as well as the control group was, they showed smaller identity aftereffects in comparison to the typical children. The authors suggested that the abnormal norm-based coding of facial identity might be one explanation for other face processing deficits characteristic of autism.

The current study

The current study was designed to test the extent to which high-functioning adults with ASD show evidence of norm-based coding of facial identity, which may be a fundamental coding mechanism related to typical face processing. It is unknown whether the group differences described by Pellicano et al. (2007) represent a delay in the development of norm-based coding of facial identity, or a group difference that persists throughout the lifespan, as norm-based coding of facial identity has yet to be tested in adults with ASD.

In the current study, we used a paradigm similar to that used in previous studies exploring norm-based coding in typical children (Jeffery et al., 2011; Jeffery, Read, and Rhodes, 2013). Participants learned two male identities. Participants were then adapted to anti-identities, and were then asked to categorize the average face as one of the two previously learned identities. Adapting faces were either extreme adaptors, which were far from the average (i.e., 80% anti-identity) or less extreme adaptors, which were closer to the average (i.e., 40% anti-identity). If adults with ASD have deficits in adaptive coding of facial identity similar to those found in children with ASD by Pellicano et al. (2007), we would expect group differences in the magnitude of identity aftereffects. If norm-based coding is atypical in adults with ASD, we might also expect differences between individuals with ASD and controls in the difference in size of
aftereffects created by far and near adaptors. However, if individuals with ASD are simply delayed in developing typical norm-based coding mechanisms of facial identity, we would expect no group differences in the magnitude of the identity aftereffects.

Method

Participants

Participants were 27 high-functioning adults (7 females, average age 29.07 years, $SD = 8.70$, range 18 to 58) with a diagnosis of autism or Asperger’s syndrome and 28 typical adults (6 females, average age 28.14, $SD = 7.42$, range 22 to 47). Three additional participants (two ASD) were tested but not included in the final analysis as their full scale IQ scores were more than two standard deviations below the mean (i.e., below 70). The groups did not differ in chronological age or IQ (see Table 1 for demographic information).
Materials

The experiment consisted of two training phases and an experimental adaptation phase, during which aftereffects were tested. In the training phases, participants learned two male identities ("Ted" and "Rob"). The test phase was designed to measure participants’ identity aftereffects. All face stimuli were presented as greyscale images and were created using Gryphon Morph (see Rhodes & Jeffery, 2006).

The faces used in the training phases consisted of two male faces, referred to as “Ted” and “Rob,” and two weaker identity strengths (40% or 60% Ted; 40% or 60% Rob). These weaker identity faces were created by morphing each original identity (Ted or Rob) with the average face, which was constructed by averaging across 20 individual male faces (see Figure 1a). The resulting weaker identities are then intermediate between the original identity and the average.

The experimental adaptation phase included adapting faces and test faces. Adapting face stimuli were “anti-identities” created by extrapolating beyond the average face away from the target along the same identity trajectory. The resulting anti-identity face is as physically different from the original face as the average face is, but in the opposite way. There were two types of adaptors: near adaptors (40% anti-Ted and anti-Rob faces) and far adaptors (80% anti-Ted and anti-Rob) (see Figure 1b). The test faces consisted of an average male face or an 80% identity face of either Ted and Rob (see Figure 1a). The 80% identities were included to verify that participants remembered the identities. Only the data from the average face were used to measure the strength of identity aftereffects.

All the faces used in the current experiment have been validated and used in other
identity aftereffect experiments (e.g., Fiorentini et al., 2012; Jeffery et al., 2011; Nishimura et al., 2008; Pellicano et al., 2007; Pimperton, Pellicano, Jeffery, & Rhodes, 2009). Test stimuli were 5.1 cm (height) by 4.8 cm (width) and subtended a visual angle of 5.9° x 5.5° when viewed at a distance of 50 cm. Adapting stimuli were 6.4 cm by 6.4 cm and subtended a visual angle of 7.3° x 7.3°. The size change was included to reduce low-level visual adaptation effects.

Procedure

Participants were tested individually on a 17-inch desktop Macintosh Dual 2.7 GHz PowerPC G5 computer with OS X operating system. Participants used a chin rest to maintain a constant viewing position. The lights in the testing room were on throughout the experiment and an experimenter sat behind a divider out of the participant’s sight throughout the experiment.

The experiment consisted of three phases: two training phases and an experimental adaptation phase, which were all presented in the context of a game. Participants were told that the experiment was originally designed for children but that we were interested in validating it with adults.

Training Phases. The first training phase was designed to ensure that participants learned and were able to accurately identify the two male identities (Ted and Rob) at full identity strength. The second training phase was designed to allow participants to practice categorizing weaker identity strengths of Ted and Rob, so that they understood how to respond to weak impressions of each identity. The latter was necessary to ensure participants could respond appropriately when experiencing an aftereffect while viewing an average test face (i.e.
experiencing only a weak impression of identity).

During the first training phase, participants were presented with the 100% identity strength Ted and Rob faces side by side. They were told that Ted and Rob were both police team captains who specialize in catching robbers. Participants were allowed to look at the two identities until they felt they could tell them apart. Participants were then presented one 100% identity strength face at a time and asked to identify if it was Ted or Rob. Each training trial presented participants with either Ted or Rob’s face. The face remained on the screen until the participant made his or her response by pressing the “x” key for Ted or the “.” key for Rob. These keys were labeled with stickers reading “T” and “R” respectively. Participants were instructed to press the spacebar to begin the next trial. Feedback for each practice trial was given to participants in both training phases. Participants completed six of these practice trials (3 for each identity) in randomized order. Had any participant not been 100% correct on these trials, he or she would have repeated another six trials; no participant in either group needed to repeat the trials. Next participants completed 12 training trials that presented one of the 100% identity strength faces for 400 ms and then were prompted to identify whether the face was Ted or Rob. Had any participant been incorrect on more than two trials, he or she would have been asked to complete an additional six trials; no participants in either group had to complete additional trials.

In the second training phase, participants were shown “Team Ted” and “Team Rob.” Each team consisted of two weaker identity strength faces (40% and 60%) as well as the 100% identity strength faces of either Ted or Rob. They were told that the weaker identity strength faces were other members of Ted/Rob’s police team. Participants were presented with one “team” until they felt they could identify all the team members. Participants were instructed that they did not need to be able to tell the team members apart, but only be able to recognize that
they were all on the same team. Once the participant felt they knew the first team, they were
shown the second team. Participants completed 12 training trials in which one of the six
identities was presented until the participant responded. Participants were instructed to press the
spacebar to begin the next trial. If participants were incorrect on four or more of these training
trials, they would have been asked to complete an additional 12 practice trials. No participants in
either group had to complete additional trials. Next participants completed another 12 trials in
which one of the six identities was presented for 400 ms. If participants had been incorrect on
four or more of these trials, they would have been asked to complete an additional 12 practice
trials. No participants in either group had to complete additional trials.

Experimental Adaptation Phase. Once participants had completed both training tasks,
they proceeded to the experimental adaptation task. Participants were presented with two
“robbers” which were the anti-identities. Participants were instructed to identify the test face that
followed as belonging to which team (Ted or Rob), as this was the team that caught the robber.
Each trial began by presenting one of the robber’s faces (an adapting face) displayed for 5000
ms, followed by a 150 ms ISI and finally a test face displayed for 400 ms. Once the participant
responded, the next trial immediately began after the participant pressed the spacebar.
Participants were told to watch the robber’s face carefully, but they were only to identify whose
team the second face belonged to. No feedback was given to participants during this phase.
Participants completed a total of 120 trials; 80 in which the target face was the average face (0%
identity), and 40 in which the target face was either 80% Rob or 80% Ted (equally likely). The
trials were divided into five randomized blocks of 24 trials each. The adapting faces were either
near (40% Anti-Ted or Anti-Rob) or far (80% Anti-Ted or Anti-Rob) from the average face.
Together, the two training phases and experimental adaptation phase took approximately 30
Results

To assess participants’ ability to identify the two target identities (i.e., “Ted” and “Rob”), we compared ASD participants’ and typical participants’ proportion of correct responses on trials where the target face was at 80% identity strength during the test. An independent samples t-test revealed no difference between the ASD group (\( M = .97, SD = .064 \)) and the typical group (\( M = .99, SD = .022 \)), \( t (53) = 1.26, p = .213 \); indicating that the ASD participants could identify strong identity strength targets as well as the typical controls could.

The size of the aftereffect was calculated for each participant by subtracting the proportion of “Ted” responses after adapting to “anti-Rob” from the proportion of “Ted” responses after adapting to “anti-Ted” for each adapting condition (near vs. far) separately. An aftereffect in the predicted direction would yield a positive difference, since adapting to anti-Ted should make the average face look more like Ted while adapting to anti-Rob should make the average look more like Rob.

A 2 (strength of adaptor; near vs. far) by 2 (Group; ASD vs. typical) repeated measures mixed-model ANOVA was conducted on the size of participants’ aftereffects. The results revealed a significant main effect of strength of adaptor; \( F (1,53) = 53.70, p < .001, \eta^2_p = .503 \). Across the two groups, participants showed a larger aftereffect for far (80% adapting faces), \( M = .31, SD = .24 \), compared to near (40% adapting faces), \( M = .09, SD = .19 \). Figure 2 illustrates this effect. The main effect of group was not significant, \( F (1, 53) = 2.40, p = .13, \eta^2_p = .043 \) and neither was the interaction between strength of adaptor and group, \( F (1, 53) = .35, p = .56, \eta^2_p = .007 \). Figure 3 displays the mean size of identity aftereffects for each position of adapting anti-identities (80% (far) and 40% (near)) for the typical and ASD groups.
We conducted separate one sample t tests for each group to test whether the near and far aftereffects were significantly greater than zero. For the typical group, both the far \( t(27) = 10.69, p < .001, d = 2.91 \) and the near \( t(27) = 3.16, p < .01, d = .84 \) aftereffects were significantly greater than zero. For the ASD group, the far aftereffect was significantly greater than zero \( (t(26) = 4.76, p < .001, d = 1.31) \), however the near aftereffect was not \( (t(26) = 1.56, p = .13) \).

Discussion

We examined the extent to which adults with ASD show evidence of norm-based coding of facial identity. Employing a common aftereffects paradigm, participants were adapted to one of two anti-identity strengths, which varied in how much they differed from the average face. The norm-based model of face perception predicts that more extreme anti-identity adaptors will lead to larger aftereffects in comparison to less extreme adaptors. The results of the current study suggest that high-functioning adults with autism spectrum disorder use norm-based coding in face identification, and that this norm-based coding functions similarly to that of the control group. Participants in both groups showed larger identity aftereffects when adapted to more extreme adapting faces (i.e., 80% anti-identity faces) compared to when they were adapted to less extreme adapting faces (i.e., 40% anti-identity faces). This pattern of results is predicted by the norm-based model of face processing (Rhodes, Brennan, & Carey, 1987; Valentine, 1991; Leopold et al., 2001) and has been previously demonstrated in typical adults (Robbins et al., 2007; Skinner & Benton, 2010; Jeffery et al., 2011Jeffery, Read, and Rhodes, 2013) and
typically developing children (Jeffery, 2011; Jeffery, Read, and Rhodes, 2013). The current study is the first to demonstrate this pattern of results in a group of adults with ASD.

The finding that adults with ASD show similar sized identity aftereffects to those observed in typical adults contrasts with the results of Pellicano and colleagues (2007), who found that young boys with ASD showed reduced facial identity aftereffects in comparison to matched peers. As well as demonstrating an identity aftereffect, the results of the current study also demonstrate that adults with and without ASD show the same pattern of modulation of the size of identity aftereffects depending on the strength of adapting face, or how much the adapting face differs from the average face. This pattern provides evidence of norm-based opponent coding of facial identity by those with ASD, and suggests that, by adulthood, there is not a qualitative difference in the coding mechanisms underlying face identity perception in this group.

There are several possible explanations for the differences in results between the current study and that of Pellicano et al. (2007). Perhaps the most obvious difference between the two studies is the age of the participants. It may be that the reduced identity adaptation that Pellicano et al. reported reflects a developmental delay in the norm-based coding of their young participants with ASD. It may be that reduced attention to faces early in development in children with ASD leads to a delay in the maturation of norm-based coding of facial identity. Previous studies have demonstrated that children with ASD orient to social stimuli, including people, less than typical children (Dawson et al., 1998; Dawson et al., 2004). Although this difference continues into adulthood (Sasson et al., 2007), it may be that eventually individuals with ASD accumulate enough experience with faces to develop norm-based coding. More sensitive developmental studies, with either a larger range of age groups, or a longitudinal design are
needed to map out the developmental trajectory of norm-based coding in ASD from childhood through to adulthood.

It is interesting to note the group difference in the results of the single-sample t-tests for each aftereffect. While the typical group showed non-zero aftereffects for both the far (80% anti-identity) and less near (40% anti-identity) adapting faces, the ASD group only had a significant aftereffect after adapting to the more extreme adapting face. The aftereffect for the less extreme adapting face was not significantly different from zero. This floor effect in the ASD group for the less extreme adapting face may suggest a small quantitative difference in the size of aftereffects between groups, despite the absence of an interaction between adaptor strength and group in the ANOVA.

The results of the current study are consistent with the conclusions of Weigelt, Koldewyn, and Kanwisher (2012) suggesting that there is a lack of evidence for a qualitative difference between typical individuals and those with ASD in facial identity processing abilities. Specifically, the authors suggest that previous studies examining facial identity processing in ASD support the notion that individuals with autism may process facial identity less efficiently, but not in a completely different manner, compared to typical individuals. If the deficits in facial identity processing that are characteristic of ASD were related to less efficiency rather than a different manner of processing as Weigelt, Koldewyn, and Kanwisher suggested, then we would expect the basic coding mechanisms of facial identity to be similar to those of typical individuals. In the current study we demonstrated that there is not a qualitative difference in the coding mechanisms underlying face identification, as there were no group differences in the direction of identity aftereffects. The results of the current study suggest that adults with ASD use norm-based coding of facial identity, just as typical adults do.
The current results appear to contrast with the results of Fiorentini, Gray, Rhodes, Jeffery, and Pellicano (2012) who examined norm-based coding of facial identity in the broader autism phenotype, testing relatives of children with ASD. Although relatives of those with ASD had larger identity aftereffects after adapting to extreme (far) adapting faces compared to when they adapted to less extreme (near) adapting faces (just as our group did), the ASD relatives showed smaller aftereffects overall compared to matched controls. While the ASD participants in the current study did not show a statistically significant difference in the size of identity aftereffects, it is interesting to note that in the current study the means for both far and near aftereffects in the ASD group appear to be slightly smaller compared to those of the typical group. Future studies with individuals with ASD using similar methods to measure identity aftereffects are needed to clarify this difference in results.

In conclusion, the current study provides evidence that high-functioning adults with ASD use norm-based coding in a facial identity task. ASD participants showed larger aftereffects for more extreme anti-identity adapting faces compared to less extreme adapting faces, a pattern of results that has been previously demonstrated in typical populations and is taken as evidence for norm-based coding. According to this perspective, facial information is encoded in relation to an average face representation. This is the first study that has explored norm-based coding of facial identity in an adult population of individuals with ASD. The results of the current study suggest that previously reported deficits in facial identity processing in adults with ASD are not likely to arise from deficits in the norm-based perceptual coding mechanisms that underlie these face processing abilities.
References


Figure Captions

Figure 1

Figure 1 illustrates two target identities (Ted and Rob) and the anti-identities, which lie on the same identity trajectory but on the opposite side of the average. “Weaker” identity strengths of the target identities are created by morphing the average face and target face by varying amounts (e.g., 60% to create 60% Ted). Norm-based coding model predicts that adapting to an anti-identity will bias perception of the weaker identity targets, as well as the average face, towards the original identity target (i.e., adapting to anti-Ted will lead to the perception of the average face as Ted).

Figure 2

A.

Test stimuli used in the experimental adaption phase. The 80% identity strength test faces were created by morphing between the average (0% identity) and the original (100% Ted/Rob) identity.

B.

Anti-faces were used as adapting faces in the experimental adaptation phase. Near adaptors were 40% anti-identities and far adaptors were 80% anti-identities.

Figure 3

Aftereffects for near (40% anti-identity) and far (80% anti-identity) adaptors for the ASD and control groups. The unfilled circles represent the individual participant scores, while the filled black circles represent the group means. Error bars represent the standard error of the mean.