Vision Research 108 (2015) 33–40

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

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

Jennifer A. Walsh [a,b,*], Daphne Maurer [a,b], Mark D. Vida [a,b], Gillian Rhodes [b], Linda Jeffery [b], M.D. Rutherford [a,b]

[a] Department of Psychology, Neuroscience and Behaviour, McMaster University, Hamilton L8S 4L8, Canada
[b] ARC Centre of Excellence in Cognition and its Disorders, Department of Psychology, University of Western Australia, Crawley, Australia

ARTICLE INFO

Article history:
Received 7 August 2014
Received in revised form 3 November 2014
Available online 6 January 2015

Keywords:
Norm-based face coding
Facial identity
Face processing
Autism

ABSTRACT

It is unclear whether reported deficits in face processing in individuals with autism spectrum disorders (ASD) can be explained by deficits in perceptual face coding mechanisms. In the current study, we examined whether adults with ASD showed evidence of norm-based opponent coding of facial identity, a perceptual process underlying the recognition of facial identity in typical adults. We began with an original face and an averaged face and then created an anti-face that differed from the averaged face in the opposite direction from the original face by a small amount (near adaptor) or a large amount (far adaptor). To test for norm-based coding, we adapted participants on different trials to the near versus far adaptor, then asked them to judge the identity of the averaged face. We varied the size of the test and adapting faces in order to reduce any contribution of low-level adaptation. Consistent with the predictions of norm-based coding, high functioning adults with ASD ($n = 27$) and matched typical participants ($n = 28$) showed identity aftereffects that were larger for the far than near adaptor. Unlike results with children with ASD, the strength of the aftereffects were similar in the two groups. This is the first study to demonstrate norm-based coding of facial identity in adults with ASD.

1. Introduction

1.1. 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). Developing a clear understanding of the behavioural manifestations characteristic of ASD is an important area of scientific research as current diagnosis of ASD relies completely on behavioural observations.

Individuals with ASD have been shown to orient less to social stimuli than their peers from a young age (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Dawson et al., 2004; Zwaigenbaum et al., 2005). As faces are considered to be one of the most important categories of social stimuli, many studies have examined potential qualitative and quantitative differences in face processing abilities of individuals with ASD (see Harms, Martin, & Wallace, 2010; Sasson, 2006; Weigelt, Koldyn, & Kanwisher, 2012, for reviews). Few studies have examined the perceptual mechanisms underlying these face processing skills and how they may differ in the ASD population. The goal of the current study was to measure facial identity aftereffects in individuals with ASD in order to examine whether they show evidence of norm-based coding of facial identity. Norm-based coding is thought to underlie typical face perception but has not been examined in adult ASD populations.

1.2. Norm-based coding in typical face perception

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 & MacLeod, 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 et al., 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

* Corresponding author at: McMaster University, Department of Psychology, Neuroscience and Behaviour, 1280 Main St W, Hamilton, Ontario L8S 1N8, Canada. Fax: +1 905 529 6225.
E-mail address: walshj5@mcmaster.ca (J.A. Walsh).

http://dx.doi.org/10.1016/j.visres.2014.11.018
0042-6989/

adaptation, occurs when prolonged fixation on a face biases perception of subsequently viewed faces (see Webster & MacLeod, 2011 for review). For example, prolonged exposure to a male face biases perception of an ambiguously gendered face in the opposite direction: it is seen as female (Webster, Kaping, Mizokami, & Duhamel, 2004). Face aftereffects have also been demonstrated for emotional expression (e.g., Butler et al., 2008; Rutherford, Chattha, & Krysko, 2008; Skinner & Benton, 2010), facial attractiveness (e.g., Rhodes et al., 2003) and facial identity (e.g., Leopold et al., 2001; Rhodes & Jeffery, 2006).

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 Fig. 1), view 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 Fig. 1), and then categorize an average face as being either like Ted or Rob (Jeffery et al., 2011; Leopold et al., 2001; Rhodes & Jeffery, 2006; Robbins, McKone, & Edwards, 2007). Fig. 1 depicts two target identities (Ted and Rob) and their corresponding anti-identities (anti-Ted and Rob). The anti-identities and their corresponding target faces lie on the same identity trajectory, but are on the opposite side of the average face. Weaker versions of each identity can be created by morphing the average and target face by various amounts; for example, 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. 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 original 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 Jeffery et al., 2011; Robbins et al., 2007). The effect of more extreme adaptors is measureable as a larger bias in perception of subsequently viewed faces. This pattern of results has been demonstrated with expression aftereffects (Skinner & Benton, 2010), with facial feature-spacing aftereffects (Robbins et al., 2007) and with facial identity aftereffects in typical adults and children (Jeffery, Read, & Rhodes, 2013; Jeffery et al., 2011).

1.3. Face perception in autism spectrum disorder

Many studies have examined the ability of individuals with ASD to process facial identity, but have yielded equivocal results (see Weigelt et al., 2012, for review). For example, several studies that examined individuals with ASD's ability to discriminate recently

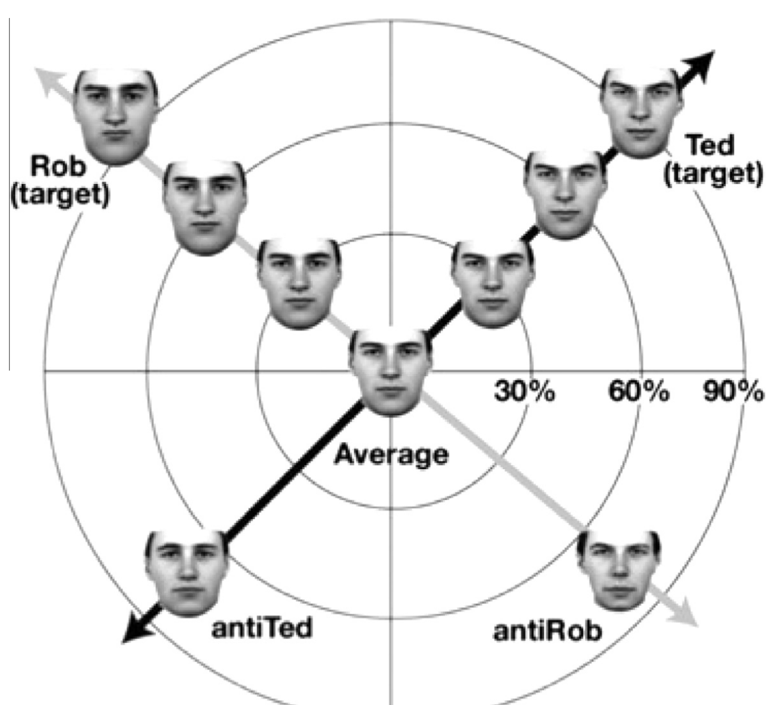

Fig. 1. Two target identities (Ted and Rob) and the anti-identities, which lie on the same identity trajectory but on the opposite side of the average. "Weaker" identity strengths of the target identities are created by morphing the average face and target face by varying amounts (e.g., 60% to create 60% Ted). The 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).

learned or familiar identities have reported measurable deficits compared to typical participants (e.g., Boucher & Lewis, 1992; Boucher, Lewis, & Collis, 1998; de Gelder, Vroomen, & van der Heide, 1991; Hauck et al., 1998; McPartland et al., 2011). Several studies examining face identity discrimination with experimental tasks that do not have significant memory demands (e.g., match-to-sample tasks) have reported typical performance by participants with ASD (e.g., Boucher & Lewis, 1992; Deruelle et al., 2004; Hauck et al., 1998), while others have reported significant deficits in ASD populations (Riby et al., 2009; Scherf et al., 2008; Wolf et al., 2008). It is important to examine not only the differences in performance in ASD populations on various face processing tasks, but also what may account for any reported deficits. An important question is whether the perceptual mechanisms that are thought to facilitate face perception and face identification abilities (e.g., adaptation and norm-based coding) are intact or deficient in ASD populations. Examining the perceptual mechanisms underlying face perception in ASD may provide an explanation for the underlying sources of deficits in facial identity processing that have been reported previously.

1.4. Face adaptation and facial aftereffects in ASD

The facial aftereffects paradigm is a useful experimental tool for examining norm-based coding of facial information and categories and has been employed extensively with typical populations (for example see Webster & MacLeod, 2011; Rhodes & Leopold, 2011 for reviews), but very few studies have examined facial aftereffects in ASD populations. Three studies have examined facial aftereffects in children with ASD. Pellicano et al. (2007) examined facial identity adaptation in 8- to 13-year-old children with ASD and matched typical participants. Participants learned two male identities and during the test phases were adapted to an 80% anti-identity face. While the ASD group was able to learn and discriminate the two identities as well as the typical group, 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. Ewing, Pellicano, and Rhodes (2013) measured face distortion aftereffects (Webster & Maclin, 1999) for upright and inverted faces as well as cars, in children with ASD. The authors reported diminished configural aftereffects in the ASD group compared to the typical group for upright faces, but not the other two categories of stimuli. Ewing, Leach, et al. (2013) reported diminished facial identity aftereffects in children with ASD when attention to adapting faces was controlled. Finally, Rhodes et al. (2014) specifically tested for evidence of norm-based coding of facial identity by measuring aftereffects for different strengths of adapting faces and found that children with ASD show evidence of norm-based coding of facial identity (i.e., modulation of size of aftereffects relative to strength of adapting face), but overall show smaller identity aftereffects compared to typical children. Together, the results of these studies suggest atypical face adaptation for upright faces in children with ASD.

Although deficits in face adaption have been demonstrated in children with ASD, it is not clear if this implies a delay in the development of face adaptation, or a stable deficit characteristic of the autism phenotype. One previous study found that adults with ASD show similar sized emotion and identity aftereffects as typical participants (Cook et al., 2014). That result suggests a change in face processing mechanisms between childhood and adulthood in individuals with ASD. However, finding identity aftereffects does not in and of itself provide evidence of norm-based coding of facial identity (Rhodes & Jeffery, 2006). The purpose of our study was to directly test norm-based coding of facial identity in adults with ASD.

1.5. The current study

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, 2013). Participants learned two male identities. Participants were then adapted to one of two 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). To reduce the effect of any adaptation based only on low-level retinotopic mechanisms (e.g., luminance), the test and adapting faces were of a different size. If adults with ASD have deficits in adaptive coding of facial identity similar to those found in children with ASD, 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 that their aftereffects for far and near adaptors will not show a typical-sized difference. However, if individuals with ASD were 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 or in the difference between aftereffects for near and far adaptors.

2. Method

2.1. Participants

Participants were 27 high-functioning adults (7 females, average age 29.07 years, *SD* = 8.70, range 18–58) with a diagnosis of autism spectrum disorders and 28 typical adults (6 females, average age 28.14, *SD* = 7.42, range 22–47). 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).

Participants with ASD were recruited from a local assisted-living group home and from a database of individuals who had previously participated in research. The typical participants were recruited off-campus, via online advertising. The participants with ASD had been given a diagnosis of autism or Asperger's syndrome by an

Table 1
Chronological age and IQ of participants.

	ASD (*n* = 27)			Typical (*n* = 28)			Group difference	
	Mean	SD	Range	Mean	SD	Range	*t*(37)	p
CA (years)	29.07	8.70	18–58	28.14	7.41	21–47	.428	.67
Verbal IQ	97.2	13.6	76–134	95.3	13.4	70–118	.523	.603
Performance IQ	98.6	14.3	69–138	99.3	16.2	70–125	−.168	.868
Full Scale IQ	97.3	11.6	83–121	97.4	14.5	70–120	−.007	.995

CA = chronological age.

Table 2
ADOS scores for ASD participants.

	Mean	SD	Range
Communication	4.3	2.4	0–9
Reciprocal social interaction	8.7	2.8	3–16
Imagination/creativity	1.5	0.8	0–3
Stereotyped behaviours and restricted interests	0.4	1.1	0–2

independent clinician, and were also evaluated for this study using the ADOS-G (Lord et al., 2000) Module 4. All ASD participants' previous diagnoses were confirmed (see Table 2). Of the 28 participants in the ASD group, 18 were classified as having autism and 7 were classified as having autism spectrum disorder using the ADOS-2 classifications. Two participants were classified as non-spectrum. These two participants had an existing clinical diagnosis of ASD from outside agencies. We analyzed the data with and without these two individuals. Excluding them did not significantly change any of our results, so we have included them in our final analysis. All participants had normal or corrected-to-normal vision. Participants received a small honorarium for their participation in the study. Informed consent was obtained from all participants prior to beginning the experiment. The current research was carried out in compliance with the McMaster Research Ethics Board's guidelines for research with human subjects and complied with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.2. 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") first at full strength and then at weaker identify strengths. 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 average face was created using Gryphon Morph software which applies a face morphing algorithm that uses point by point correlation to create a face with the average shape and colour of all the faces included in the algorithm. The average face was a blend of 20 grey-scale images of young adult, male, Caucasian faces (see Fig. 2a). These 20 images did not include the training or adapting faces included in this experiment (i.e., Ted, Rob, anti-Ted, or anti-Rob).

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. 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 differs from the average face in a way that is opposite to how the target deviates from the average. For example, if the target has thinner than average lips the anti-face will have thicker than average lips. 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 Fig. 2b). The test faces consisted of an average male face or an 80% identity face of either Ted or Rob (see Fig. 2a). The 80%

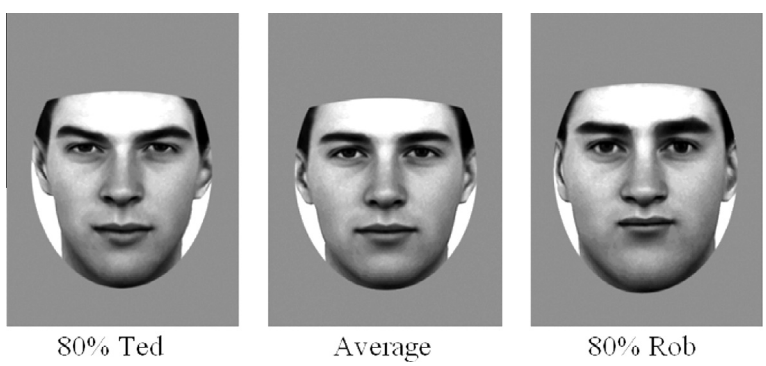

Fig. 2a. Test stimuli used in the experimental adaption phase. The 80% identity strength test faces were created by morphing between the average (0% identity) and the original (100% Ted/Rob) identity.

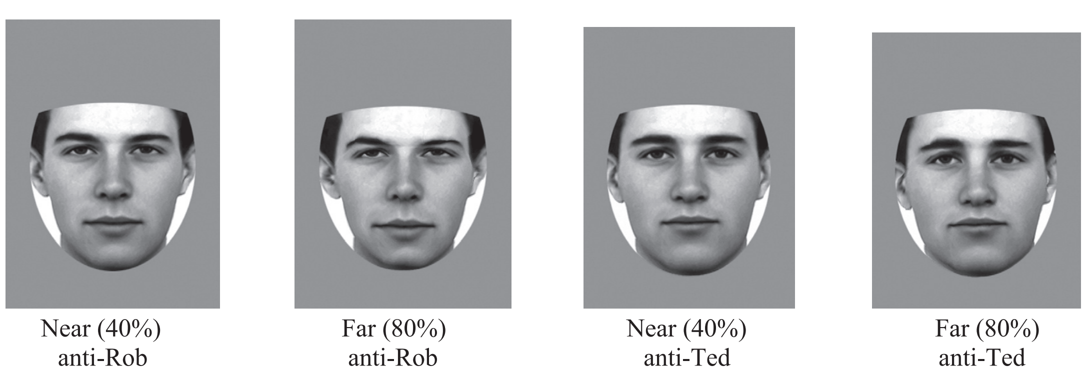

Fig. 2b. Anti-faces were used as adapting faces in the experimental adaptation phase. Near adaptors were 40% anti-identities and far adaptors were 80% anti-identities.

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 et al., 2009). Test stimuli were 5.1 cm (height) by 4.8 cm (width) and subtended a visual angle of $5.9° \times 5.5°$ when viewed at a distance of 50 cm. Adapting stimuli were 6.4 cm by 6.4 cm and subtended a visual angle of $7.3° \times 7.3°$. The size change was included to reduce the contribution of low-level visual adaptation effects.

2.3. 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 of 55 cm. Throughout the experiment, the lights in the testing room were on and an experimenter sat behind a divider out of the participant's sight.

The experiment consisted of three phases: two training phases and an experimental adaptation phase, all of which were 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.

2.3.1. 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, either of Ted or Rob, and were asked to identify if it was Ted or Rob. 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 they 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.

2.3.2. Experimental adaptation phase

Once participants had completed both training tasks, they proceeded to the experimental adaptation task. Participants were first shown the two "robbers", who 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. The next trial began immediately after the participant pressed the spacebar. There was no fixation point at the start of the adaptation trial, but participants were instructed to pay close attention to each face. 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 adapting trials; 80 in which the test face was the average face (0% identity), and 40 in which the test face was either 80% Rob or 80% Ted (equally likely). The trials were divided into five pseudo-randomized blocks of 24 trials each, constrained so that no more than two adapting faces of the same identity (e.g. anti-Ted) appeared sequentially, to avoid accumulating adaptation to one anti-face. All participants received the same pseudo-random order. The adapting faces were either near (40% anti-Ted or anti-Rob) or far (80% anti-Ted or anti-Rob) from the average face, with each type of adaptor appearing on 30 trials in the same/different random order for each participant. Together, the two training phases and experimental adaptation phase took approximately 30 minutes to complete.

3. 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 ($M = .99$, $SD = .022$), $t(53) = 1.26$, $p = .213$, a result indicating an equally high level of recognition of the target identities during the test in the two groups.

The size of the aftereffect was calculated for each participant using responses to the 0% identity strength faces. The proportion of "Ted" responses after adapting to "anti-Rob" were subtracted 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

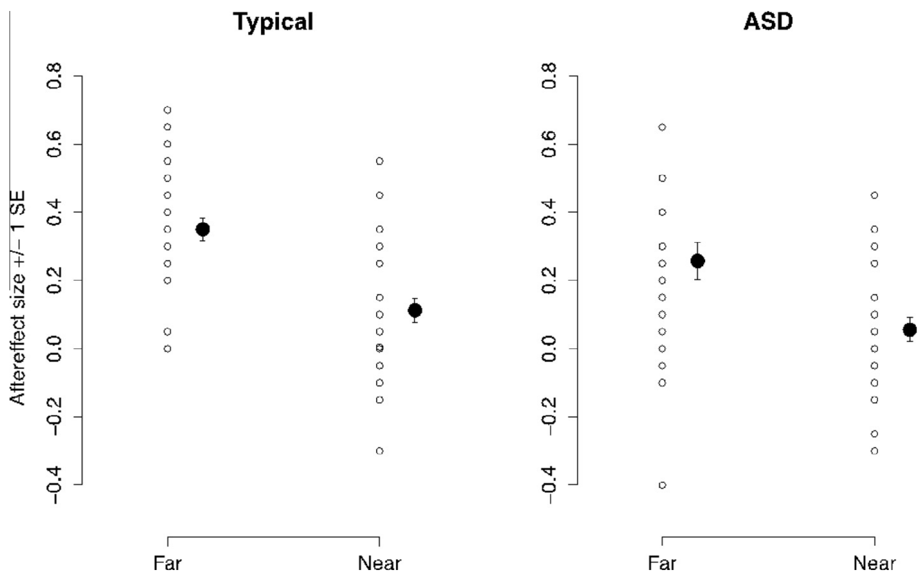

Fig. 3. Aftereffects for near (40% anti-identity) and far (80% anti-identity) adaptors for the ASD and typical groups. The unfilled circles represent the individual participant scores, while the filled black circles represent the group means. Error bars represent the standard error of the mean.

like Ted while adapting to anti-Rob should make the average look more like Rob and less like Ted.

Fig. 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. 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 resultsrevealed a significant main effect of strength of adaptor; $F(1,53) = 53.70$, $p < .001$, $\eta_p^2 = .503$.

Across the two groups, participants showed a larger aftereffect for far (80% adapting faces), $M = .31$, $SD = .24$, compared to near (40% adapting faces), $M = .09$, $SD = .19$. The main effect of group was not significant, $F(1,53) = 2.40$, $p = .13$, $\eta_p^2 = .043$ and neither was the interaction between strength of adaptor and group, $F(1, 53) = .35$, $p = .56$, $\eta_p^2 = .007$.

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, $t(26) = 4.76$, $p < .001$, $d = 1.31$, but the near aftereffect was not, $t(26) = 1.56$, $p = .13$, $d = .42$.

We conducted post hoc tests comparing the size of the near and far aftereffects between the two groups. Although the interaction between group and adapting strength was not significant, the near aftereffect for the ASD group was not significantly different from zero. Therefore, we wanted to confirm that there was no significant difference between the two groups in the size of either aftereffect. The planned comparison independent samples t-test revealed no significant difference between the groups for the near adapting condition, $t(53) = 1.13$, $p = .26$, $d = .26$ or the far adapting condition, $t(53) = 1.48$, $p = .15$, $d = .51$.

In addition, we conducted a difference of proportions test (Blalock, 1972), to compare the proportion of participants who showed an aftereffect across the two adapting conditions. Any participant whose calculated size of aftereffect was numerically greater than zero was regarded as showing an aftereffect for this analysis. For the typical participants, 27 out of 28 participants showed an effect in the far condition, while 20 out of 28 showed an aftereffect in the near condition, a significant difference in proportions ($z(27) = 2.55$, $p = .005$, $\Phi = .34$). Similarly, for the ASD group, 22 out of 27 participants showed an aftereffect in the far condition, while 17 out of 27 showed an aftereffect in the near condition, a significant difference ($z(26) = 1.79$, $p = .04$, $\Phi = .24$). Finally, the difference of difference of proportions test (Blalock, 1972) showed no group by condition interaction; the two groups performed similarly on the two types of adapting trials ($z(53) = .43$, n.s.).

4. Discussion

The goal of the current experiment was to measure the extent to which adults with ASD show evidence of norm-based coding of facial identity. Employing a commonly used aftereffects paradigm, participants were adapted to two anti-identity strengths, which varied in how much they differed from the average face. The norm-based coding 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 typical 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 perception (Robbins et al., 2007) and has previously demonstrated in typical adults (Robbins et al., 2007; Skinner & Benton, 2010) and typically developing children (Jeffery et al., 2011; Jeffery et al., 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 is similar to that of Cook et al. (2014). They reported typical identity and emotional expression aftereffects in high-functioning adults with ASD. Together, the results of the current study and those reported by Cook et al. suggest that high-functioning adults with ASD show typical face adaptation and use of norm-based coding of facial identity. Therefore, by adulthood, there appears to be no qualitative difference between typical adults and high-functioning adults with ASD in the adaptive coding mechanisms that underlie face identity perception. These results contrast those of previous studies examining facial adaptation (Pellicano et al., 2007; Ewing, Leach, et al., 2013; Ewing, Pellicano, et al., 2013) and norm-based coding of facial identity (Rhodes et al., 2014) in children with ASD, all of which reported smaller aftereffects, or diminished adaptation, in children with ASD.

There are several possible explanations for the differences in results between the current study and those of previous studies demonstrating diminished aftereffects in ASD populations. (Pellicano et al., 2007; Ewing, Leach, et al., 2013, Ewing, Pellicano, et al., 2013; Rhodes et al., 2014). Perhaps the most obvious difference between the current study and the previous studies is the age of the participants. It may be that the reduced facial adaptation reported in previous studies reflects a developmental delay in facial adaptation 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 typical face adaptation. Previous studies have demonstrated that children with ASD orient to social stimuli, including people, less than typical children (Dawson et al., 1998, 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 typical face adaptation. It is important to note that while studies with children with ASD have reported diminished face aftereffects, they all demonstrate that children with ASD show evidence of face adaptation or norm-based coding of facial identity, just not to the same extent as typical children. Alternatively, it may take longer for them to develop an accurate norm on which to centre face processing because the norm is not updated as efficiently as in typical children, in part, because the child with ASD attends less often to faces. 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 unlikely that differences in attention during the task can account for differences in facial adaptation between children and adults with ASD. As with other types of visual adaptation, face aftereffects are modulated by attention to the adapting face stimulus (e.g., Rhodes et al., 2011). Rutherford, Troubridge, and Walsh (2012) recorded eye-tracking data from adults with ASD and typical participants during an emotion aftereffects experiment and reported no group differences in attention to adapting faces, indicating that ASD participants in that study showed no differences in their overt visual attention to the adapting faces compared to typical participants. Although previous studies examining face adaptation in children with ASD did not include eye-tracking data, Ewing et al. (2013) manipulated attention to adapting faces by including a facial feature change detection task in addition to measuring identity aftereffects. Although children with ASD were as accurate at detecting changes in the lips or eyes of the adapting stimuli, indicating that they attended well to the adapting faces, they still showed reduced identity aftereffects in comparison to typical children. These results suggest that reduced attention to adapting faces is not likely to account for diminished face aftereffects in populations of children with ASD. It is important to note that a limitation in the current study is that we did not include a specific measure of attention to the adapting faces, although we instructed the participants to attend to the faces. However, this is not an issue because there was no difference between groups in the size of the aftereffects, the proportion of participants showing them, or their modulation by adaptor strength. Had the ASD group not attended to the face adaptors as well as the control group, they would have been expected to show weaker aftereffects.

It is worth noting 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 near (40% anti-identity) adapting faces, the ASD group only had a significant aftereffect after adapting to the far adapting faces. Unlike the case for the typical group, the size of aftereffects for the less extreme adapting faces was not significantly different from zero at the group level for the ASD group. However, the difference of proportions analysis suggested that there were no differences between groups in the proportion of participants who showed significant aftereffects for either the near or far adapting conditions. Also the post hoc planned comparisons revealed no significant differences between groups in the size of the aftereffect for 40% adapting faces. Overall, the evidence suggests normal aftereffects in the ASD group. Note also that Rhodes and colleagues (2014) used three adapting anti-identity strengths (60%, 100%, and 140%) with children with ASD and reported significant aftereffects in the ASD group for all three adapting anti-identity strengths. Future studies should use stronger adaptors (e.g., 60% and 100%) with adults with ASD to ensure that significant aftereffects are obtained.

The results of the current study are consistent with the conclusions of Weigelt et al. (2012) who argue that there is little evidence for a qualitative difference between typical individuals and those with ASD in facial identity processing abilities. Specifically, they 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, than typical individuals. If the deficits in facial identity processing that are characteristic of ASD are related to reduced efficiency rather than a different manner of processing as Weigelt and colleagues 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 found no evidence for a qualitative difference in the coding mechanisms underlying face identification, as there were no group differences in the pattern 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.

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. 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.

Acknowledgments

This study was supported by a grants given to M. D. Rutherford from the Social Sciences and Humanities Research Council of Canada and to Gillian Rhodes from the Australian Research Council Centre of Excellence in Cognition and its Disorders (CE110001021), an ARC Professorial Fellowship to Rhodes (DP0877379), and an ARC Discovery Outstanding Researcher Award to Rhodes (DP130102300). The authors wish to thank all of the participants for their generous participation in this study.

References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Blalock, H. M. (1972). *Social statistics*. New York: McGraw-Hill.Capps, Ltd.

Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry, 33*, 843–859.
Boucher, J., Lewis, V., & Collis, G. (1998). Familiar face and voice matching and recognition in children with autism. *Journal of Child Psychology and Psychiatry, 39*, 171–181.
Butler, A., Oruc, I., Fox, C. J., & Barton, J. J. (2008). Factors contributing to the adaptation aftereffects of facial expression. *Brain Research, 1191*, 116–126.
Cook, R., Brewer, R., Shah, P., & Bird, G. (2014). Intact facial adaptation in autistic adults. *Autism Research*. http://dx.doi.org/10.1002/aur.1381.
Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders, 28*, 479–485.
Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., et al. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology, 40*, 271.
de Gelder, B., Vroomen, J., & van der Heide, L. (1991). Face recognition and lip-reading in autism. *Eurorpean Journal of Cognitive Psychology, 3*, 69–86.
Deruelle, C., Rondan, C., Gepner, B., & Tardif, C. (2004). Spatial frequency and face processing in children with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders, 34*, 199–210.
Ewing, L., Leach, K., Pellicano, E., Jeffery, L., & Rhodes, G. (2013). Reduced face aftereffects in autism are not due to poor attention. *PLoS One, 8*, e81353.
Ewing, L., Pellicano, E., & Rhodes, G. (2013). Atypical updating of face representations with experience in children with autism. *Developmental Science, 16*, 116–123.
Fiorentini, C., Gray, L., Rhodes, G., Jeffery, L., & Pellicano, E. (2012). Reduced face identity aftereffects in relatives of children with autism. *Neuropsychologia*.
Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review, 20*, 290–322.
Hauck, M., Fein, D., Maltby, S., Waterhouse, L., & Feinstein, C. (1998). Memory for faces in children with autism. *Child Neuropsychology, 4*, 187–198.
Jeffery, L., Read, A., & Rhodes, G. (2013). Four year-olds use norm-based coding for face identity. *Cognition, 127*, 258–263.
Jeffery, L., Rhodes, G., McKone, E., Pellicano, E., Crookes, K., & Taylor, E. (2011). Distinguishing norm-based from exemplar-based coding of identity in children: Evidence from face identity aftereffects. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 1824.
Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience, 4*, 89–94.
Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr, Leventhal, B. L., DiLavore, P. C., et al. (2000). The Autism Diagnostic Observation Schedule- Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*, 205–223.
McPartland, J. C., Wu, J., Bailey, C. A., Mayes, L. C., Schultz, R. T., & Klin, A. (2011). Atypical neural specialization for social percepts in autism spectrum disorder. *Social Neuroscience, 6*, 436–451.
Nishimura, M., Maurer, D., Jeffery, L., Pellicano, E., & Rhodes, G. (2008). Fitting the child's mind to the world: Adaptive norm-based coding of facial identity in 8-year-olds. *Developmental Science, 11*, 620–627.
Pellicano, E., Jeffery, L., Burr, D., & Rhodes, G. (2007). Abnormal adaptive face-coding mechanisms in children with autism spectrum disorder. *Current Biology, 17*, 1508–1512.
Pimperton, H., Pellicano, E., Jeffery, L., & Rhodes, G. (2009). The role of higher level adaptive coding mechanisms in the development of face recognition. *Journal of Experimental Child Psychology, 104*, 229–238.
Rhodes, G., Ewing, L., Jeffery, L., Avard, E., & Taylor, L. (2014). Reduced adaptability, but no fundamental disruption, of norm-based face-coding mechanisms in cognitively able children and adolescents with autism. *Neuropsychologia*.
Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research, 46*, 2977–2987.
Rhodes, G., Jeffery, L., Evangelista, E., Ewing, L., Peters, M., & Taylor, L. (2011). Enhanced attention amplifies face adaptation. *Vision Research, 51*, 1811–1819.
Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W., & Nakayama, K. (2003). Fitting the mind to the world face adaptation and attractiveness aftereffects. *Psychological Science, 14*, 558–566.
Rhodes, G., & Leopold, D. A. (2011). Adaptive norm-based coding of face identity. In The. Oxford (Ed.), *Handbook of face perception* (pp. 263–286). Oxford: Oxford University Press.
Rhodes, G., Robbins, R., Jaquet, E., McKone, E., Jeffery, L., & Clifford, C. W. (2005). Adaptation and face perception: How aftereffects implicate norm-based coding of faces. In *Fitting the mind to the world: Adaptation and after-effects in high-level vision* (pp. 213–240). Oxford: Oxford University Press.
Riby, D. M., Doherty-Sneddon, G., & Bruce, V. (2009). The eyes or the mouth? Feature salience and unfamiliar face processing in Williams syndrome and autism. *The Quarterly Journal of Experimental Psychology, 62*, 189–203.
Robbins, R., McKone, E., & Edwards, M. (2007). Aftereffects for face attributes with different natural variability: Adapter position effects and neural models. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 570.
Rutherford, M. D., Chattha, H. M., & Krysko, K. M. (2008). The use of aftereffects in the study of relationships among emotion categories. *Journal of Experimental Psychology: Human Perception and Performance, 34*, 27.
Rutherford, M. D., Troubridge, E. K., & Walsh, J. (2012). Visual afterimages of emotional faces in high functioning autism. *Journal of Autism and Developmental Disorders, 42*, 221–229.
Sasson, N. J. (2006). The development of face processing in autism. *Journal of Autism and Developmental Disorders, 36*, 381–394.
Sasson, N., Tsuchiya, N., Hurley, R., Couture, S. M., Penn, D. L., Adolphs, R., et al. (2007). Orienting to social stimuli differentiates social cognitive impairment in autism and schizophrenia. *Neuropsychologia, 45*, 2580–2588.
Scherf, K. S., Behrmann, M., Minshew, N., & Luna, B. (2008). Atypical development of face and greeble recognition in autism. *Journal of Child Psychology and Psychiatry, 49*, 838–847.
Skinner, A. L., & Benton, C. P. (2010). Anti-expression aftereffects reveal prototype-referenced coding of facial expressions. *Psychological Science, 21*, 1248–1253.
Webster, M. A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature, 428*, 557–561.
Webster, M. A., & MacLeod, D. I. (2011). Visual adaptation and face perception. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*, 1702–1725.
Webster, M. A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review, 6*, 647–653.
Weigelt, S., Koldyn, K., & Kanwisher, N. (2012). Face identity recognition in autism spectrum disorders: A review of behavioral studies. *Neuroscience & Biobehavioral Reviews, 36*, 1060–1084.
Wolf, J. M., Tanaka, J. W., Klaiman, C., Cockburn, J., Herlihy, L., Brown, C., et al. (2008). Specific impairment of face-processing abilities in children with autism spectrum disorder using the Let's Face It! skills battery. *Autism Research, 1*, 329–340.
Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience, 23*, 143–152.