Memory for facial expressions on the autism spectrum: the influence of gaze direction and type of expression

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Abstract: Face memory research in autism has largely neglected memory for facial expressions, in favour of memory for identity. This study in three experiments examined the role of gaze direction and type of expression on memory for facial expressions in relation to the autism spectrum. In the learning phase, four combinations of facial expressions (joy/anger) and gaze direction (toward/away), displayed by 16 different identities, were presented. In a subsequent surprise test the same identities were presented displaying neutral expressions, and the expression of each identity had to be recalled. In Experiment 1, typically-developed (TD) individuals with low and high Autism Quotient (AQ) scores were tested with three repetitions of each emotion/gaze combination, which did not produce any modulations. In Experiment 2, another group of TD individuals with low and high AQ scores were tested with eight repetitions, resulting in a 'happy advantage' and a 'direct gaze advantage', but no interactions. In Experiment 3, individuals with high-functioning autism (HFA) and a matched TD group were tested using eight repetitions. The HFA group revealed no emotion or gaze effects, while the matched TD group showed both a happy and a direct gaze advantage, and again no interaction. The results suggest that in autistic individuals the memory for facial expressions is intact, but is not modulated by the person's expression type and gaze direction. We discuss whether anomalous implicit learning of facial cues could have contributed to these findings, its relevance for social intuition, and its possible contribution to social deficits in autism.

Lay summary: It has often been found that memory for someone's face (facial identity) is less good in autism. However, it is not yet known whether memory for someone's facial expression is also less good in autism. In this study, the memory for expressions of joy and anger was investigated in typically-developed (TD) individuals who possessed either few or many autistic-like traits (Experiments 1 and 2), and in individuals with high-functioning autism (Experiment 3). The gaze direction was also varied (directed either toward, or away from, the observer). We found that TD individuals best remembered expressions of joy, and remembered expressions of both joy and anger better when the gaze was directed at them. These effects did not depend on the extent to which they possessed autistic-like traits. Autistic participants remembered the facial expression of a previously encountered person as good as TD participants did. However, in contrast to the TD participants, the memory of autistic participants was not influenced by the expression type and gaze direction of the previously encountered persons. We discuss whether this may lead to

difficulties in the development of social intuition, which in turn could give rise to difficulties in social interaction that are characteristic for autism.

Keywords: facial expressions; gaze direction, social perception; autistic-like traits; high-functioning autism; memory.

Introduction

Facial expressions are one of the most salient aspects of non-verbal communication and may grant immediate insight into the other's state of mind (Keltner et al., 2003). Emotional expressions of joy and anger are particularly potent, as they signal approval or disapproval (D'Argembeau et al., 2003). Facial expressions have frequently been incorporated in research of memory for face identity (Chen et al., 2015; Conty & Grèzes, 2012; D'argembeau & Van der Linden, 2007; D'Argembeau et al., 2003; D'Argembeau et al., 2003; Liu et al., 2014), but were much less frequently studied in their own right in studies specifically devoted to memory for facial expressions (D'Argembeau & Van der Linden, 2007; D'Argembeau et al., 2003; D'Argembeau et al., 2003; Shimamura et al., 2006). Unlike the studies of memory for facial identity that rely on discrimination between previously encountered identities and newly presented ones, studies of memory for facial expressions present the same identities in the learning and test phases, and assess memory for the particular expression displayed by the face during the learning phase. Retrieving emotional connotations associated with a previously encountered identity is of great social value, as it can act to forecast approach-avoidance tendencies allowing to adjust one's behaviour (Adams & Kleck, 2005). However, so far conflicting results have emerged with some studies reporting expressions of joy and anger to be recalled equally well (D'argembeau & Van der Linden, 2007; D'Argembeau et al., 2003), while others reported a memory advantage for joy (D'Argembeau et al., 2003; Shimamura et al., 2006), often referred to as the 'happy advantage'.

Facial expressions are typically qualified by the concurrent gaze direction. Gaze direction distinguishes between behaviour directed toward the self (the observer) and behaviour directed elsewhere and therefore, facial expressions differ in meaning depending on the gaze direction (Adams & Kleck, 2003, 2005; Hudson & Jellema, 2011; Hudson et al., 2012; Artuso & Palladino, 2015). Direct gaze enhances the recognition/categorization of facial expressions/emotions denoting approach, such as joy and anger (Adams & Kleck, 2003, 2005; Sander et al., 2007; Artuso & Palladino, 2015).

Based on the studies of memory of facial identity, which tend to find memory advantages for faces displaying expressions of joy (‘happy advantage’, e.g. Liu, Chen & Ward, 2014) and for faces displaying direct gaze ('direct gaze advantage', Conty & Grèzes, 2012; Mason et al., 2004; Weisbuch et al., 2013), one might predict that expressions of joy accompanied by direct gaze would be remembered best. It is surprising that, despite the combinational nature of social perception, relatively little attention has been paid to the combined effects of facial expression and gaze direction on memory.

Individuals with Autism Spectrum Disorder (ASD) show a number of atypicalities in processing social stimuli, which may impact their memory for these stimuli. In particular memory for face identity seems to be impaired (Boucher & Lewis, 1992; Hauck et al., 1998; Tantam et al., 1989; Minio-Paluello et al., 2020; Weigelt et al., 2012). Such impairments have been argued to result from underdeveloped expertise in face processing due to reduced attention to faces (Grelotti et al., 2002; Schultz, 2005). Some eye-tracking studies suggest that individuals with ASD, in contrast to matched TD controls, allocate more attention to the mouth than to the eyes when exploring faces (Klin et al., 2002; Pelphrey et al., 2002), although other studies found no such differences (Rutherford & Towns, 2008; Van Der Geest et al., 2002). A reduced monitoring of the eye region and in particular of directed gaze, may underpin the absence of a direct gaze memory advantage in ASD (Senju & Johnson, 2009). The influence of gaze direction on memory for facial expressions has, however, not yet been studied in ASD.

An impaired memory for facial expressions may well have consequences for the development of social intuition. It has been argued that the automatic learning of social cues conveyed by particular individuals may form a basis for the development of social intuition (Lieberman, 2000; Hudson et al., 2012). If people encode social cues each time a particular person is encountered, one might expect these cues to bind to the representation of that person, especially when the cues are consistent across encounters, and guide future interactions with that person. Retrieving the right positive or negative emotional connotations associated with previously encountered individuals greatly affects one’s ability to forecast approach-avoidance tendencies and therefore one’s ability to successfully navigate the social world. This ability seems specifically impaired in ASD and may well extend into those TD individuals that are high in autistic-like traits (Baron-Cohen et al., 2001).

The current study investigated whether memory for facial expressions is influenced by specific combinations of gaze direction (away versus toward) and type of emotion (joy versus anger). We aimed to elucidate whether memory for facial expressions is differentially affected in individuals with varying degrees of autistic traits. Hereto we tested TD individuals with either low or high AQ scores (Experiments 1 and 2), and individuals with HFA compared to matched TD controls (Experiment 3). We hypothesised that the TD participants with low AQ scores would be better at recalling expressions of joy, especially when accompanied by direct gaze, and that these effects would be somewhat reduced in the high AQ group, and further reduced, or even absent, in the HFA group.

Methods

The methods described here apply to all three experiments. Details of participants partaking in each of the experiments are described in the experiment sections.

Stimuli

Experimental stimuli consisted of 16 images of faces (eight women, eight men) selected from the Warsaw set of Emotional Facial Expressions Pictures (WSEFEP; Olszanowski et al., 2015). Images depicted expressions of intense joy and anger, and a neutral expression, for each identity. The images in the WSEFEP set all exhibit direct gaze, therefore right-averted gaze images were generated, using Paint.Net software. To remove any effects due to differences in the memorability of particular faces, four different sets of the 16 images were used. Each set included eight happy and eight angry faces, each expression displayed by four male and four female identities, half of them with averted gaze and the other half with direct gaze. The four sets were counterbalanced across participants so that each identity was shown an equal number of times within each emotion-gaze category (happy-direct, happy-averted, angry-direct, angry-averted). In the Test phase, the same 16 identities were presented with neutral facial expression and with their eyes covered by small dark blue rectangles, resembling dark sunglasses. If test faces would have been presented with direct gaze, then low-level similarity/consistency with faces from the learning phase might bias recall (cf. Nakashima et al., 2012).

Procedure

Participants were seated in front of a PC monitor at approximately 60cm distance. The procedure consisted of two main phases: a learning phase and a test phase, separated by a retention interval.

Learning phase: faces were sequentially presented in random order in the centre of the monitor screen. Each face was presented for 1000ms in either a three-repetitions condition (each face presented three times, total of 48 trials, Experiment 1) or in an eight-repetitions condition (each face presented eight times, total of 128 trials, Experiments 2 and 3). Participants were asked to look at the faces carefully as they were told they would later be asked to judge them on trustworthiness. No mention was given of a subsequent memory test, thus any learning of facial expressions occurred in an accidental, unintentional manner (cf. Nakashima et al., 2012).

Retention interval: The learning phase was directly followed by a five-minute retention interval, during which participants did an online 50-piece jigsaw puzzle, depicting a neutral scene.

Test phase: Directly following the retention interval, the surprise test phase began. First participants were reminded that the identities they had observed before the break had either a happy or an angry facial expression. They were instructed that the same identities would be presented again but with neutral expression and their eyes covered, and that they had to recall their emotional facial expression by pressing one of two keyboard keys labelled ‘happy’ and ‘angry’. Each face remained on the screen until a response was entered. However, participants were instructed not to dwell on their responses and make a decision on the basis of their initial impression. Once this response had been given, the next face was presented.

All participants completed an online 50-item Autism Quotient questionnaire (AQ; Baron-Cohen et al., 2001). The AQ is a self-administered questionnaire, designed to measure the degree to which an adult with normal intelligence possesses autistic-like traits. To assign participants to either the low or high AQ group, a median split was performed.

The aim of Experiments 1 and 2 was to investigate the influence of autistic-like traits on memory for facial expressions, and to explore the effect of number of repetitions on memory formation. Experiment 3 aimed to investigate memory for facial expressions in individuals with HFA, and in matched TD controls. In this way the capacity for remembering facial expressions could be explored across a large part of the autism spectrum.

Data analysis

In all experiments, the memory for facial expressions was measured in terms of the percentage of accurately recalled facial expressions for each of the four emotion-gaze combinations. Percentages of correct responses were entered into a repeated measures ANOVA with Facial Expression (Joy/Anger) and Gaze Direction (Direct/Averted) as within-subject factors and Group as between-subject factor.

Experiment 1

Participants

Sixty-five undergraduate students at the University of Hull participated in the experiment in return for course credits. After applying data exclusion criteria (see below), 58 participants were included in the analysis. Their AQ scores ranged from 5 to 39 (M = 17.3, SD = 6.6). The median score was 17, resulting in 27 participants (19 females, 8 males) in the low AQ group (AQ scores < 17; M = 11.9, SD = 3.4) and 31 participants (17 females, 14 males) in the high AQ group (AQ scores > 16; M = 22.0, SD = 5.0). The high and low AQ groups did not differ in age (low AQ, M = 21.8, SD = 3.8; high AQ, M = 21.5, SD = 4.3; $t(56) = .30$, $p = .76$) nor gender ratio ($X_2(1, N = 58) = 1.48$, $p = .28$). All participants had (corrected-to) normal vision, and none reported to be suffering from any psychological or (neuro-)developmental conditions.

Results

The Test phase consisted of 16 trials, displaying each of the four emotion/gaze combinations by four different agents (thus four response times were obtained per emotion/gaze combination). A trial was excluded when responses were given within 150ms (0% of trials) or after 7s (6% of trials) following onset of the test stimulus. If following application of these exclusion criteria fewer than two of the four response times remained for one or more of the four emotion/gaze combinations, then the participant was excluded (5 low AQ, 1 high AQ). The mean response time of the included trials was 2793ms (SD = 1341ms). In addition, one participant was removed for failing to complete the AQ questionnaire.

None of the main effects and interactions in the ANOVA were significant: Emotion, $F(1,56) = .51$, $p = .48$, $\eta p^2 = .009$; Gaze, $F(1,56) = .59$, $p = .45$, $\eta p^2 = 0.010$; Group, $F(1,56) = 1.40$, $p = .24$, $\eta p^2 = .02$; Emotion by Group, $F(1,56) = 2.03$, $p = .16$, $\eta p^2 = .04$; Gaze by Group, $F(1,56) = .64$, $p = .43$, $\eta p^2 = .01$; Emotion by Gaze, $F(1,56) = .91$, $p = .34$, $\eta p^2 = .02$; Emotion by Gaze by Group, $F(1,56) = 1.41$, $p = .24$, $\eta p^2 = .03$ (see Fig. 1). Correct memory recall of the sample (low and high AQ groups combined, N = 58, M = 56.3%) was significantly above chance level (i.e. 50% correct) ($t(57) = 3.0$, $p = .004$).

We further assessed the relationship between individual AQ scores and memory performance by calculating Pearson correlations (2-sided) for the entire sample (N = 58). No significant correlations with AQ scores were found in any of the four conditions (Happy-toward, r = -.08, $p = .53$; Happy-away, r = .24, $p = .076$; Angry-toward, r = .10, $p = .46$; Angry-away, r = -.13, $p = .33$).

Even tough in Experiment 1, which used just three repetitions in the learning phase, some learning of the facial expressions took place, gaze direction and facial expression type failed to modulate memory recall of facial expressions. Therefore, in Experiment 2 we increased the number of repetitions to eight.

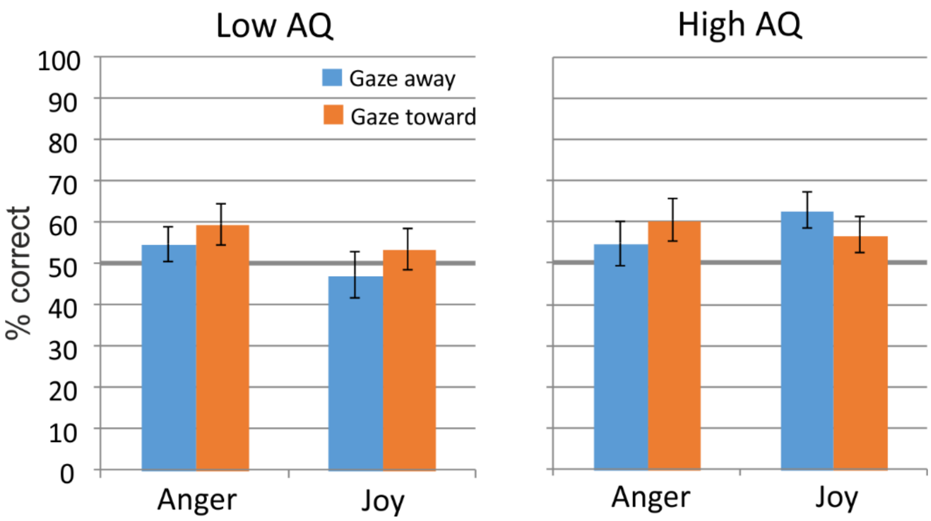

Figure1. Experiment 1. Three repetitions of each expression/gaze combination were presented during the learning phase. Mean percentages of correctly recalled facial expressions by the low AQ group (left panel) and high AQ group (right panel) are shown. Error bars represent SEM.

Experiment 2

Participants

Seventy-seven undergraduate students at the University of Hull participated in the experiment in return for course credits, none of which took part in Experiment 1. After applying exclusion criteria (see below), 74 participants were included in the analysis. Their AQ scores ranged from 7 to 35 (M = 17.2, SD = 6.4). The median score was 17, resulting in 38 participants (24 females, 14 males) in the low AQ group (AQ scores < 17, Mean AQ = 12.4, SD = 2.7) and 36 participants (22 females, 14 males) in the high AQ group (AQ scores > 16; Mean AQ = 22.3, SD = 5.2). The high and low AQ groups did not differ in age (low AQ, M = 20.8, SD = 1.6; high AQ, M = 20.7, SD = 2.2; $t(72) = .40$, $p = .69$) nor gender ratio ($X_2(1, N = 74) = .03$, $p = .86$). All participants had (corrected-to) normal vision and none reported any psychological or (neuro-)developmental conditions.

Results

As in the Test phase each of the four emotion/gaze combinations was presented by four different agents (16 trials in total), four response times were obtained per emotion/gaze combination. A trial was excluded when responses were given within 150ms (0% of trials) or after 7s (7% of trials) following onset of the test stimulus. If following application of these exclusion criteria fewer than two of the four response times remained for one or more of the four emotion/gaze combinations, then the participant was excluded (1 low AQ, 1 high AQ). The mean response time of the included trials was 2862ms (SD = 1390ms). In addition, one low AQ participant was removed for failing to follow test instructions.

The main effect of Emotion was significant ($F(1,72) = 8.12$, $p = .007$, $\eta p^2 = .10$), expressions of joy (M = 69.8, SD = 27.3) were significantly better remembered than expressions of anger (M = 62.1, SD = 28.1). However, the Emotion by Group interaction was non-significant ($F(1,72) = .49$, $p = .49$, $\eta p^2 = .007$), thus the low and high AQ groups experienced a similar 'happy advantage'. The main effect of Gaze was also significant ($F(1,72) = 10.55$, $p = .002$, $\eta p^2 = .13$), facial expressions where the gaze was directed at the observer (M = 70.3, SD = 24.7) were significantly better remembered than expressions where the gaze was directed away (M = 61.5, SD = 30.3). However, the interaction with Group was non-significant ($F(1,72) = 1.63$, $p = .21$, $\eta p^2 = .02$), indicating that the low and high AQ groups equally benefited from direct gaze. The main effect of Group was non-significant ($F(1,72) = .000$, $p = .90$, $\eta p^2 = .000$). The Emotion by Gaze interaction ($F(1,72) = .02$, $p = .90$, ηp2 = .000) and the three-way interaction ($F(1,72) = 1.41$, $p = .24$, $\eta p^2 = .03$) were also non-significant (see Fig. 2). Thus, with eight repetitions the factors Emotion and Gaze both significantly affected recall of facial expressions (happy advantage and direct gaze advantage), but these effects were equally strong in the low and high AQ groups. Memory recall of the sample (N = 74, M = 65.9%) was significantly above chance level (50%, $t(73) = 7.2$, $p < .001$).

To further assess the influence of individual AQ scores on memory performance we calculated Pearson correlations (2-sided) for the sample (N = 74). No significant correlations with AQ scores were found in any of the four conditions (Happy-toward, $r = .14$, $p = .24$; Happy-away, $r = -.19$, $p = .11$; Angry-toward, $r = .04$, $p = .71$; Angry-away, $r = -.04$, $p = .72$). Finally, an overall ANOVA encompassing Experiment 1 (N = 58) and Experiment 2 (N = 74) was performed with Number of repetitions as the between-subjects factor, which confirmed that eight repetitions (Experiment 2) produced significantly better memory retrieval of facial expressions than three repetitions

(Experiment 1). The main effect of Experiment was significant [$F(1,128) = 9.5$, $p = .009$, $\eta p^2 = .052$; Experiment 1, M = 56%; Experiment 2, M = 66%]. The main effect of Gaze was also significant [$F(1,128) = 9.5$, $p = .009$, $\eta p^2 = .052$; Gaze direct, M = 64%; Gaze averted, M = 58%]. However, the main effect of Emotion was non-significant [$F(1,128) = 1.7$, $p = .19$, $\eta p^2 = .013$]. The only other significant effect was for the Emotion by Number of repetitions interaction [$F(1,128) = 9.5$, $p = .009$, $\eta p^2 = .052$], which reflected that Happy expressions were better remembered than Angry expressions in Experiment 2 (eight repetitions; Happy, M = 69.8%; Angry, M = 62.1%), while they did not differ in Experiment 1 (three repetitions; Happy, M = 55.4%; Angry, M = 57.4%).

Since in Experiment 2, gaze direction and type of facial expression significantly modulated memory recall, in Experiment 3 the number of repetitions was kept at eight. Experiment 3 should reveal whether the advantages for direct gaze and happy expressions, seen in both the low and high AQ groups in Experiment 2, are also present in individuals diagnosed with HFA.

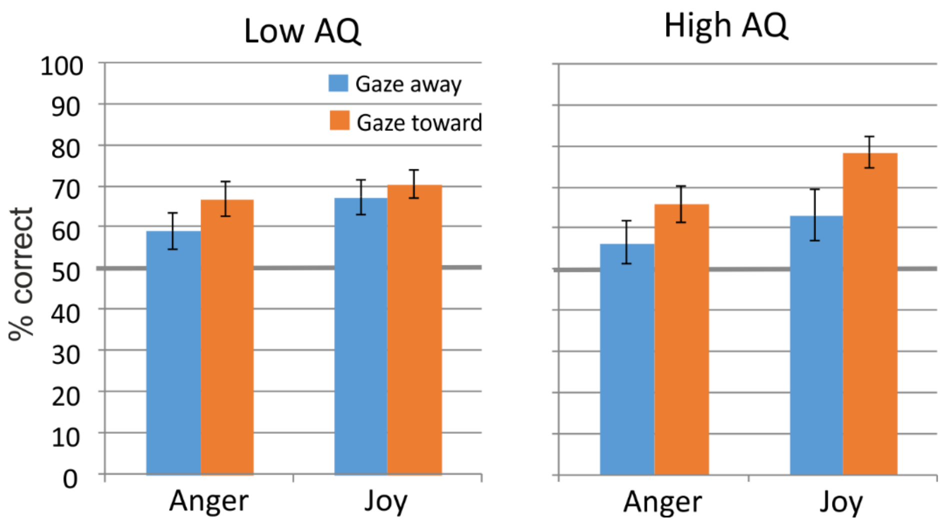

Figure 2. Experiment 2. Eight repetitions of each expression/gaze combination were presented during the learning phase. Mean percentages of correctly recalled facial expressions by the low AQ group (left panel) and high AQ group (right panel) are shown. Error bars represent SEM.

Experiment 3

Participants

The HFA group consisted of 17 undergraduate students at Hull University, which were recruited through University Disability Services (6 females, 11 males; no exclusions, see below). They received £20 for participating. Their mean age was 19.9 years (SD = 1.4; range 19 to 22). They all had previously received a diagnosis of HFA or Asperger's syndrome from a clinical psychologist or psychiatrist based on DSM-IV-TR (APA, American Psychiatric Association, 2013). Diagnosis of HFA was confirmed using the ADOS (Autism Diagnostic Observation Schedule, Module 4), administered by a qualified experimenter (SM). Three participants with HFA reported co-occurring conditions (one reported ADHD, one anxiety and one depression), the others did not report any. Analyses performed without these three participants did not yield different results, and therefore, they were included. The mean ADOS score of the HFA group was 9.28 (SD = 2.24). Their mean total IQ score, determined with a short version of the Wechsler Adult Intelligence Scale, 4th edition (WAIS-IV; Wechsler, 1997), was 114.2 (SD = 9.6). Their mean AQ score was 34.2 (SD = 7.8), with a range from 19 to 46 (median AQ score was 34).

The matched TD group consisted of 26 undergraduate students at Hull university, matched for age, sex and IQ to the HFA group (Table 1), who participated in return for course credits. Their mean age was 20.5 years (SD = 2.1), with a range from 18 to 27. Their mean AQ score was 17.1 (SD = 5.7), with a range from 7 to 28 (median AQ score was 17), and their mean total IQ score was 113.9 (SD = 6.16), measured with the short version of the WAIS-IV (Table 1). The HFA and matched TD groups did not differ in age ($t(41) = 1.1$, $p = .29$), gender ratio ($X_2(1, N = 43) = 0.02$, $p = .96$) and IQ ($t(40) = .12$, $p = .91$). The AQ scores were significantly higher in the HFA group than in the TD group ($t(36) = 7.6$, $p < .001$).

Table 1. Participants' characteristics. Mean values (± SD).

	Age	Sex	IQ-total	AQ	ADOS
ASD (n = 17)	19.8 (± 1.3)	5 women 15 men	114.2 (± 9.6)	33.4 (± 8.2)	9.28 (± 2.24)
TD (n = 26)	20.5 (± 2.1)	9 women 17 men	113.9 (± 6.2)	17.1 (± 6.4)	-

Results

Trials were excluded when responses were given within 150ms (0% of trials) or after 7s (4% of trials) following onset of the test stimulus. As each of the four emotion/gaze combinations was depicted by four different agents, four response times were obtained per emotion/gaze combination. If following application of the exclusion criteria fewer than two of four response times remained for one or more of the four emotion/gaze combinations, then the participant was excluded (0 TD, 0 HFA). The mean response time of the included trials was 2614ms (SD = 1126ms) for the HFA group and 2785ms (SD = 1201ms) for the matched TD group.

The main effect of Emotion was significant ($F(1,41) = 6.26$, $p = .016$, $np^2 = .13$), facial expressions of joy (M = 72.5, SD = 21.0) were significantly better remembered than expressions of anger (M = 61.9, SD = 23.2). The Emotion by Group interaction was non-significant ($F(1,41) = 2.2$, $p = .15$, $np^2 = .050$). The main effect of Gaze was not significant ($F(1,41) = 2.04$, $p = .16$, $np^2 = .047$), facial expressions where the gaze was directed at the observer (M = 70.7, SD = 21.5) were not significantly better remembered than expressions where the gaze was directed away (M = 63.7, SD = 22.5). The Gaze by Group interaction was also non-significant ($F(1,41) = 2.88$, $p = .097$, $np^2 = .07$). The main effect of Group was non-significant ($F(1,41) = 2.35$, $p = .13$, $np^2 = .05$), indicating that memory for facial expressions was similar across both groups, with HFA participants recalling on average 61.8% of facial expressions correctly and TD participants 70.8%. The Emotion by Gaze interaction was non-significant ($F(1,41) = .006$, $p = .94$, $np^2 = .00$), and the three-way interaction was also non-significant ($F(1,41) = .80$, $p = .37$, $np^2 = .02$; see Fig. 3).

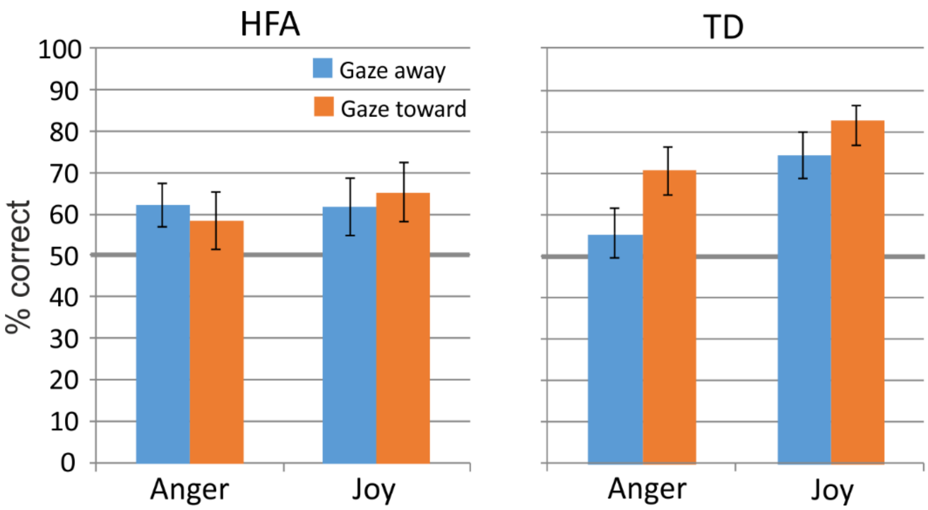

Figure 3. Experiment 3. Eight repetitions of each expression/gaze combination were presented during the learning phase. Mean percentages of correctly recalled facial expressions by the HFA group (left panel) and matched TD group (right panel) are shown. Error bars represent SEM.

We next analysed the groups separately in two 2x2 ANOVAs for explorative purposes. In the HFA group, no significant effects were found for the Emotion, Gaze, and Emotion by Gaze, factors (all *p*'s > .60). Memory recall of the HFA sample (N = 17, M = 62.2%) was significantly above chance level (50%; t(16) = 3.3, p = .005). In the TD group, the Emotion factor was significant (F(1,25) = 14.5, p = .001, np^2 = .37), reflecting a happy advantage. The factor Gaze was also significant (F(1,25) = 6.39, p = .018, np^2 = .20), reflecting a direct gaze advantage, but the interaction was non-significant (F(1,25) = .59, p = .45, np^2 = .02). Memory recall of the matched TD sample (N = 26, M = 70.8%) was significantly above chance level (t(25) = 5.4, p < .001).

Finally, we calculated Pearson correlations (2-sided) to further examine the relationship between individual AQ scores and memory performance in the matched TD group (N = 26) and HFA group (N = 17). No significant correlations were found in any of the four conditions in the matched TD group (Happy-toward, r = .35, p = .082; Happy-away, r = -.15, p = .45; Angry-toward, r = .11, p = .59; Angry-away, r = -.09, P = .68) nor in the HFA group (Happy-toward, r = -.03, p = .92; Happy-away, r = -.08, p = .77; Angry-toward, r = .35, p = .17; Angry-away, r = .21, p = .42). The ADOS scores of the HFA group also did not correlate significantly with memory performance (Pearson 2-sided, Happy-toward, r = .20, p = .45; Happy-away, r = .31, p = .22; Angry-toward, r = -.36, p = .16; Angry-away, r = -.19, P = .47).

Discussion

We investigated whether the memory formation of facial expressions displayed by specific individuals during an observation session was influenced by the type of emotion and by gaze direction. The spontaneous memory formation in TD individuals with low and high AQ scores, and in individuals with HFA, was examined using a surprise test. In Experiment 1 (three repetitions), facial expression, gaze direction, or a specific combination of these, had no impact on memory formation in the low and high AQ groups. In Experiment 2 (eight repetitions), the low and high AQ groups both better remembered happy compared to angry facial expressions, and both were better in remembering the facial expression when the gaze was directed at the observer. However, there was no interaction between facial expression and gaze direction. In Experiment 3 (eight repetitions), the only significant effect was a happy advantage across both groups. When analysing the groups separately, the HFA group revealed no emotion or gaze effects, while the matched TD group showed a happy advantage and a direct gaze advantage, but no interaction between the two.

Memory for facial expressions increased as a function of number of repetitions. It is important to note that participants were not instructed to remember the facial expressions displayed by the actors, instead they were told the face stimuli were part of a study into trustworthiness. Any memory formation was thus (largely) incidental and involuntary. Therefore, the associations between facial expression and identity that were learned are assumed to be (largely) implicit in nature. In case the stimuli are not exceptionally relevant (exciting/disturbing) but rather mundane as in our task, it seems likely that repeated presentations are required to form implicit memory. Indeed, depending on the specific implicit learning paradigm, many repetitions may be required for learning to occur (Reber, 1989). It thus seems plausible that the extent of implicit learning was insufficient to reveal itself in Experiment 1, but was sufficient to show up in Experiment 2.

Experiment 2

Experiment 2 revealed that expressions of joy were better recalled than expressions of anger, which effect was unrelated to autistic-like traits. An enhancement of facial identity memory for identities displaying positive expressions is well documented (e.g. D'Argembeau & Van der Linden, 2007; Kaufman & Schweinberger, 2004; Liu et al., 2014; Shimamura et al., 2006), but with respect to memory for expressions conflicting findings have emerged, with some studies showing better memory for positive than for negative expressions (D’Argembeau et al., 2003; Shimamura et al., 2006), and other studies finding no difference (D’argembeau & Van der Linden, 2007; D’Argembeau et al., 2003). However, these previous studies typically used a single presentation mode of five seconds, which may be insufficient for producing the effect (but see Shimamura et al., 2006, who found a happy advantage with single exposures of 3s). In the current study the happy advantage was present after eight 1s repetitions and was absent after three 1s repetitions. Thus, differences in total exposure times may partly account for the mixed findings.

Memory advantage for happy facial expressions might be explained by a self-enhancement bias (D’Argembeau et al., 2003). Even though joy and anger are both approach-oriented, there is a heightened likelihood to reciprocate the approach in the case of joy, and to avoid the approach in the case of anger (Stins et al., 2011; Marsh et al., 2005). Another explanation for the happy advantage relates to attentional scope. Negative expressions tend to attract most attentional resources (Öhman et al., 2001), which can disrupt the processing of other facial features due to narrowing of attentional focus. Consequently, the forming of associations between facial expression and facial identity may be hampered, resulting in worse memory performance for negative facial expressions (D’argembeau & Van der Linden, 2007). By contrast, positive affect was found to broaden the attentional scope, promoting global processing of the face, which could underpin the memory advantage for happy faces (D’argembeau & Van der Linden, 2007).

Experiment 2 also revealed that in both AQ groups, the facial expression displayed by a particular identity was better recalled if that agent's gaze was directed at, rather than away from, the observer. It has been well documented that eye-gaze direction can modulate the perception of facial expressions (Adams & Kleck, 2003; 2005; George & Conty, 2008; Sander et al., 2007). The gaze direction of others allows to infer their focus of attention, while directed gaze may indicate an intention to communicate (Kampe et al., 2003). Therefore, special attentional resources may be allocated to facial expressions accompanied by direct gaze, leading to enhanced memorability (Conty & Grèzes, 2012; Mason et al., 2004). It might also be that the emotional arousal induced by directed gaze (see Hamilton, 2016, for a review) enhances the strength of subsequent memory formation (McGaugh, 2000). If something in the environment appears to be emotionally charged or arousing, then this indicates that it requires further evaluation (Sander et al., 2007). The amygdala has been shown to act as an emotional relevance detector, with enhanced activation during processing of emotional facial expressions directed at the observer (Cristinzio et al., 2010; Sato et al., 2010). It is, in principle, also possible that the direct gaze advantage is related to an attentional bias induced by averted gaze. Averted gaze signals can result in overt/covert gaze following (Driver et al., 1999; Frischen et al., 2007). This may divert attention outside the face area, which, in turn, can diminish encoding of other facial features such as facial expressions and identity (Conty & Grèzes, 2012; George & Conty, 2008). However, such a covert shift of attention typically lasts for about 200ms (Friesen & Kingstone, 1998). As in the current experiment faces remained on screen for 1s, this explanation seems unlikely.

The memory capacities were not related to the extent to which the participants possessed autistic-like traits; low and high AQ groups were equally susceptible to the happy memory advantage and the direct gaze memory advantage. Thus, the presumed lower engagement with others' directed gaze in the TD individuals with high AQ scores, akin to what is often reported for individuals with ASD (e.g. Pelphrey et al., 2002), was not found. It should be noted though that we used a median-split to create the groups, without removing central scores.

The literature on the influence of combinations of facial expression and gaze direction on memory for face identity shows a peculiar dissociation when long-term memory (LTM) and working memory (WM) are compared. LTM works over minutes and longer, working memory works over a few seconds. Nakashima et al. (2012) reported that with respect to LTM, the angry face identities encoded with averted gaze were poorer remembered (compared to direct gaze), while memory for happy face identity was unaffected by gaze. Nakashima and colleagues (2012) suggested that gaze and expression information are combined in an analysis of the agent's behavioural intent, which influences the memory for faces. In contrast, regarding WM accuracy, angry faces were unaffected by gaze, while happy faces with averted gaze were better remembered (compared to direct gaze; Jackson, 2018). The working memory results have been replicated in Western but not Asian populations (Gregory et al., 2020). Our paradigm examined LTM as there was a five-minute break directly following the learning phase. However, our results regarding LTM for facial expressions did not replicate the results of the above studies on LTM for face identity. TD individuals displayed both a happy advantage and a direct gaze advantage but no interaction between them. This suggests that the memory encoding of facial expressions and of facial identity reflect distinct processes, each with their own requirements. Gaze direction qualifies the meaning and intensity of an observed facial emotional expression (e.g., direct gaze intensifies the perceived emotion; Kimble & Olszewski, 1980). Gaze direction may play a role in LTM and WM of face identity through interaction with emotion (Nakashima et al., 2012; Jackson, 2018), but not in LTM for facial expression (current study). Possibly, face identity memory is supported by a more elaborate neural representation, which also takes into account the behavioural intent of the identity, whereas memory of the facial expression of a particular agent reflects a narrower neural representation, incorporating the agent-expression association, but not necessarily other, more subtle, features linked to the particular identity such as behavioural intent conveyed by the gaze-emotion interplay. An anatomical separation of the neural processing of facial expression and facial identity is to some extent supported by neuroimaging (e.g. Bernstein & Yovel, 2015; Posamentier & Abdi, 2003) and computational (e.g. Dahl et al., 2016) review studies, but overlap is also reported.

Experiment 3

In Experiment 3, eight repetitions of each expression/gaze combination per agent were presented to HFA and matched TD groups, as this number of repetitions was found to be effective in Experiment 2. Correct expression recall was significantly higher for expressions of joy compared to anger, which effect was not modulated by gaze direction or group. When analysing the groups separately, the memory performance of the HFA individuals turned out to be not affected by the type of expression nor by direction of gaze, whereas the matched TD group did show the happy and direct gaze advantages. The literature provides conflicting evidence as to whether the HFA group would benefit from direct gaze in remembering the expressions. The well-documented reduced engagement with others' directed gaze (e.g. Pelphrey et al., 2002) suggests the absence of a direct gaze advantage. However, some studies have questioned the notion that individuals with ASD spend less time scanning the other's eye region than TD individuals (e.g., Vettori et al., 2020), and also questioned the notion that they specifically avoid directed gaze (e.g., Clin et al., 2020). The current finding that the HFA group showed no sign of a 'direct gaze advantage' is in line with the findings by Zaki and Johnson (2013) regarding memory for face identity in ASD. It seems to argue against the notion that HFA individuals do pay attention to the identities as long as gaze is averted, while actively avoiding paying attention to identities with direct gaze (e.g. Senju & Johnson, 2009). This should have led to enhanced memory for facial expressions accompanied by averted gaze, which was not the case. However, as discussed above, linking the results of studies of memory for facial expressions to those of memory for face identity can be misleading. Many studies of memory for face identity tested children and adolescents on the autism spectrum, while the current study looked at adults with HFA, who may have developed compensatory skills and may have better general memory skills.

Implicit learning and social intuition

The learned associations between facial expression and identity in the current free-viewing paradigm were most likely implicit in nature. It has been argued that social intuition is formed on the basis of implicitly learned social cue associations during social encounters (Bechara et al., 1997; Lieberman, 2000; Macinska & Jellema, 2016). Such social intuition allows one to make, on the basis of previous experiences, the quick, intuitive assumptions about the other's dispositions, and about the particular course of action to select, without any deliberate and effortful reasoning. This enables one to smoothly navigate the rapidly changing social world. Problems with social interactions are characteristic for ASD and might be caused partly by an implicit social learning deficit (Hudson et al., 2016; Macinska et al., 2015). This is to be contrasted with non-social implicit learning (as in serial reaction time tasks), which is not impaired in ASD (Foti et al., 2015). However, we did not find any learning differences between low and high AQ groups, and the differences between the HFA group and their matched controls only reached significance when the groups were analysed separately. Therefore, one could argue that the type of implicit learning in the current tasks, which is based on the physical characteristics of the stimulus (identity, gaze direction and facial expression), and which does not depend on understanding the underlying emotional values or behavioural consequences, is largely intact in ASD and may not be relevant *per se* for explaining impaired social intuition in ASD. However, importantly, in our tasks we did not enquire about the emotional disposition of the agent towards the observer. There are indications that the implicit learning of someone's emotional disposition towards the observer, which involves a representation of the agent's emotional state of mind, may be impaired in ASD (Macinska et al., 2015; Macinska & Jellema, 2016; Jellema et al., 2009). To the best of our knowledge, this was the first study to investigate how emotion-gaze combinations impact on the memory for another individual's facial expression in groups of individuals occupying markedly different positions on the autism spectrum dimension.

Limitations

The sample size of the HFA group in Experiment 3 was relatively small (N = 17), which negatively impacted on the power of the statistical tests. In the overall ANOVA of the TD and HFA groups, the interactions of Group (TD vs. HFA) with the factors Emotion and Gaze were not significant. The significant difference between HFA and TD groups only became apparent after analysing the groups separately. Even though these latter analyses showed quite convincingly an absence of main Emotion and Gaze effects on memory for facial expressions in the HFA group, and distinct Happy and Direct gaze advantages in the TD group, the lack of sufficient power remains a limitation of the current study. The results are very suggestive, but a replication study will be needed before we can unequivocally claim that the HFA group showed the effects described above.

The use of the median-split method to obtain low and high AQ groups in Experiments 1 and 2 inevitably meant that some information contained in the individual AQ scores was lost. However, the absence of any significant correlations of AQ scores with the percentages of correct memories in each of the conditions suggests that the information lost was not crucial to these results.

Ethical Considerations

The study conforms to the standards of the Declaration of Helsinki and was approved by the the Ethics Committee of the Department of Psychology of the University of Hull. Informed consent was obtained from all participants.

Authorship

SM collected the data, and conducted the data analyses. SM and TJ wrote the manuscript.

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