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Memory for incidentally perceived social cues: Effects on person judgment

Article

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Abstract

Dynamic face cues can be very salient, as when observing sudden shifts of gaze to a new location, or a change of expression from happy to angry. These highly salient social cues influence judgments of another person during the course of an interaction. However, other dynamic cues, such as pupil dilation, are much more subtle, affecting judgments of another person even without awareness. We asked whether such subtle, incidentally perceived, dynamic cues could be encoded in to memory and retrieved at a later time. The current study demonstrates that in some circumstances changes in pupil size in another person are indeed encoded into memory and influence judgments of that individual at a later time. Furthermore, these judgments interact with the perceived trustworthiness of the individual and the nature of the social context. The effect is somewhat variable, however, possibly reflecting individual differences and the inherent ambiguity of pupil dilation/constriction.

When we encounter another person, we gather important information about their internal state and likely actions by attending to their face. Dynamic cues, such as facial expression communicate emotional states and may broadcast upcoming behaviours (Horstmann, 2003). Static cues, such as the structure of a person's face can cause us to attribute certain traits to an individual, or make assumptions about their likely behaviours (Oosterhof & Todorov, 2008; Sutherland, Oldmeadow, Santos, Towler, Burt & Young, 2013; Vernon, Sutherland, Young & Hartley, 2014). These facial cues can rapidly influence whether we are inclined to approach or avoid a person (Siedel, Habel, Kirschner, Gur & Derntl, 2010; Stins, Roelofs, Vilan, Koijmann, Hagennaars & Beek, 2011), and cause us to make predictions about a stranger's personality from just a glimpse of their features (Todorov, Pakrashi & Oosterhof, 2009).

Importantly though, facial cues exert a lasting influence on our memories of others, creating or altering our longer-term impressions and guiding our future interactions. Affective learning, the process by which objects in the world, including people, take on a value or meaning because they predict a positive or negative outcome (For a review, see Wasserman and Miller, 1997), has been posited as a mechanism by which these long-term impressions are formed. Affective learning can be simply illustrated by studies examining the pairing of value carrying behaviours with faces or named identities. For example, when participants were told stories that described the good or bad behaviours of two characters, even participants for whom neurological reasons prevented recall of biographical information about the characters, could recall that they liked the character associated with good behaviours the most (Johnson, Kim & Risse, 1985; Blessing, Keil, Linden, Heim & Ray, 2006). Similarly, Bliss-Moreau and colleagues (2008) paired neutral faces with affectively charged social sentences (e.g. "Helped an elderly woman with her groceries"). They demonstrated that even after only two exposures to face/sentence pairings, participants' later snap judgments of the faces acquired the affective value of the statements with which they had previously been paired.

Affective learning can be seen in the way that facial cues shape our lasting impressions of others. In gaze cueing experiments for example, participants view faces which incidentally gaze left or right (e.g. Bayliss, Griffiths & Tipper, 2009; Bayliss and Tipper, 2006; Rogers et al., 2014). The gaze direction of the face may match or mismatch with the location of a simultaneously appearing target, which the participant is tasked with rapidly identifying. On trials in which the gaze direction and target location are congruent (helpful gaze) participants are faster to categorize the target than on trials where the target is in a location incongruent to the direction of gaze (unhelpful gaze). Importantly, the faces in these experiments gaze in a manner that is consistently helpful or unhelpful. The participants later rate faces that gazed unhelpfully as being less trustworthy than those who were helpful (Bayliss et al., 2009; Bayliss and Tipper, 2006), and show less willingness to financially invest in them (Rogers et al., 2014). Subsequent work (Manssuer, Pawling, Hayes & Tipper, 2015) demonstrated that emotional reactions during gaze cueing (as measured via facial electromyography), mediated the learning of trust

Facial cues can also transfer what we have learnt about one individual to influence our perception of another. In a series of experiments (Verosky & Todorov, 2010; Verosky & Todorov, 2013), participants learnt associations between faces and positive or negative behaviours. Next participants made character judgments of novel faces that had been morphed to varying degrees with faces from the learning phase to produce new unrecognizable facial identities. Regardless of whether the participants were or were not provided with behavioural information about these new faces, the presence of the learnt faces within the morphs modulated the participants' judgments. For example, a novel face morphed with a face previously associated with a negative behaviour would be rated as less trustworthy than a novel face morphed with an identity previously associated with neutral or positive behaviour. The experiments demonstrated that the physical properties of a face associated with particular social outcomes can influence the interpretation of new individuals who possess similar physical attributes. For example we may get a positive feeling about another person because they happen to bear a resemblance to a loved one with whom we hold positive associations (Kraus & Chen, 2010).

One facial cue that would be entirely novel in the affective learning literature, and which is the focus of the three experiments in this paper, is pupil size. It has long been known that pupil dilation is associated with arousal state (Ellermeier & Westphal, 1995; Hess & Polt, 1960), such that pupils dilate when viewing emotionally arousing stimuli (e.g., Bradley, Miccoli, Escrig & Lang, 2008), or with increases in cognitive demand (e.g., Kahneman & Beatty, 1966). Whilst the influence of pupil dilation on person perception was the subject of research as far back as the 1960s (e.g. Hess, 1965; Strass & Willis, 1967; Bull & Shead, 1979), it has never to date been studied in terms of affective learning or the updating of impressions of others.

Pupil size represents a very subtle cue that appears to influence observers without conscious perception. For example Harrison, Wilson & Critchley (2007) demonstrated that variation in pupil size influenced judgments of another person's emotions. Changes in pupil size also influence the activity of cortical and subcortical brain structures involved in social cognition, such as the amygdala (Harrison, Singer, Rotshtein, Dolan & Critchley, 2006; Demos, Kelley, Ryan, Davis & Whalen, 2008; Amemiya & Ohtomo, 2011). Furthermore, not only does pupil size influence the perception of another person's emotional state, it can be mirrored by the observer's own pupils and such embodied states may lead to emotional contagion (Harrison et al., 2006). These behavioural and neural effects were detected even though participants were unaware of the pupil size manipulation.

The first question addressed in the current paper is whether or not pupil size changes, despite their subtlety, leave a trace in memory that can influence person perceptions at a later time. As pupil size has been shown to be indicative of arousal, it's possible that over many encounters with aroused individuals, both positive and negative, pupil size change, despite its subtlety, comes to hold an affective value. As in the studies of Verosky and Todorov (2010, 2013) where the affective value of one individual can be carried forward to other similarly featured individuals, affective learning could explain why in the moment of viewing a novel face, pupil size change affects person perception (e.g Hess, 1965; Strass & Willis, 1967; Bull & Shead, 1979). Alternatively pupil dilation might represent a prepared stimulus that, due to evolved adaptations, evokes an affective response with little or no need for prior experience (see Seligman, 1970). Either way, in a manner similar to that seen in gaze cuing, could consistent changes in pupil size cause a change in the affective value of an individual, reflected in future judgments where that pupil cue is no longer present?

In Experiment 1 participants complete a task that requires them to remain vigilant to changes in facial identity. Whilst attending to the identity of the faces, the changes in pupil size that occur throughout the task are both task-irrelevant and generally unnoticed by the majority of participants. During a second task, participants make person judgments regarding the friendliness and level of interest in them they feel the faces possess. Importantly, on this occasion all the faces appear with pupils of a 'normal/average' size. Hence during this later retrieval stage, there are no physical properties of the face that distinguish prior pupil state. We hypothesise that pupil size changes will indeed be encoded, and will go on to influence later judgments of friendliness and interest. Due to the lack of pupil dilation/constriction cues in the second ratings task, any effects of pupil size on ratings must be the result of learning from the prior encounters with the faces.

Experiment 1

Method

Participants

Twenty-seven adult female participants were recruited from the School of Psychology at *********. All participants gave informed consent and received course credit for their participation. The mean age of the sample was 19.9 years (SD = 3.0 years), and all participants had normal or corrected to normal colour vision.

Stimuli

The stimuli presented consisted of 20 colour photographs of male and female faces, taken from a larger database of photographs of adult faces (Kramer and Ward, 2010). Ratings of attractiveness for a subsection of this database were collected from an independent group of participants. From this subsection, ten attractiveness-matched pairs were chosen, consisting of five female and five male pairs. The resulting twenty faces had been photographed under standardised studio lighting, against a white backdrop. The faces were cropped at the neck. Photo editing software was then used to create versions of the faces with average, constricted and dilated pupils (see Figure 1, for close up image of pupil manipulation). As the lighting under which the photographs were taken had been standardised, the actual pupil size in the photograph was taken as the average size, although the photographs were inspected to ensure no pupils were unusually large or small. The average pupils were then cut out and enlarged or made smaller by 33% to create the dilated and constricted pupils respectively.

************************ ******Figure 1 here ********************************

The final stimulus set therefore consisted of 60 face images. All images were presented at a size of 506 by 650 pixels, with the participant seated approximately 600 mm from computer screen, creating a visual angle of approximately 104 by 116 degrees. During the experiment each participant was exposed to ten faces (five male, five female) whose pupils would become consistently dilated during the vigilance task and ten faces whose pupils would become consistently constricted (five male, five female). To ensure attractiveness did not affect later ratings, one member of each attractiveness-matched pair appeared in each condition. Assignment to condition was random.

************************* ******Figure2 here ********************************

Procedure

The experiment consisted of two tasks; the first, a vigilance task, was designed to expose the participants to the faces, and unknowingly to the changes in pupil size. In this task each face identity possessed a consistent pupil change, always dilating or always constricting, over 10 exposures. The second task, where participants were asked to provide ratings of the faces, was designed to measure the participant's assessments of the faces, when the faces were presented once again, with average pupils. (See Figure 2).

Vigilance task. Participants initiated each trial with a space bar press. A blank screen with duration of 500ms was followed by the presentation of a face, which remained on screen for 2000ms. This initial face always appeared with average sized pupils, and was always followed by the presentation of a second face, duration 2000ms, whose pupils were either consistently dilated or constricted. A blank interval of 500ms was placed between the two faces. Previous studies of change blindness have confirmed that a 500ms interval is sufficient to block awareness of substantial changes to scenes, and of particular relevance here, changes to person identity (e.g., Simon & Levin, 1998). This procedure was therefore employed to prevent the majority of participants from gaining awareness of the subtle changes in pupil size (see Figure 2, Panel B). Participants completed 240 trials over five blocks. In 40 trials per block the second face to appear was identical to the initial face, except for the change in pupil size. In these trials participants passively observed the faces, making no response. In eight oddball trials per block, the second face to appear differed in identity from the first. Participants were told to respond to these oddball trials with a space bar press. Every face appeared twice in each block in standard trials, and twice over the course of the task in oddball trials; once as the first half of an oddball and once as the second half. Prior to starting the task participants undertook a short practice, with non-experimental faces as stimuli. Errors during the task resulted in a siren tone.

Ratings task. During the subsequent ratings task participants were re-exposed to the faces from the vigilance task, but importantly the faces now appeared exclusively with average sized pupils. Two questions were used to gauge the participant's assessments of the faces: 'How friendly is this person?' and 'How interested would this person be in you?' Responding required participants to use a set of seven colour coded keys which ranged from red, which corresponded to a 'not at all' response, through orange and yellow, to green, which corresponded to a 'very' response. The task consisted of two blocks of forty trials, with each face appearing once in relation to each question in each block. The order of faces and questions was randomised within block. At the start of each trial the question to be answered was presented, along with a graphic of the response keys. After a space bar press to initiate the trial followed by a 500ms blank, a face was presented for 750ms. The screen then went blank until the participant made their rating, and for 2000ms afterwards (see Figure 2, Panel C). Participants undertook a short practice before starting the task, during which non-experimental stimuli were presented.

Debriefing. After completing both tasks participants were given the opportunity to report what they thought the experiment was about. The experimenter also asked them whether they had spotted any changes or variations in the faces in the exposure task, which had been described in briefing as a sustained vigilance task. Of the 27 participants tested, 25 were naïve to the pupil manipulation. Only the data from these 25 participants were analysed.

Results and Discussion

Vigilance Task

Participants demonstrated a high level of accuracy when responding to both standard and oddball trials during the vigilance task. Participant's responses to standard trials were accurate 99% of the time (SD = 0.09%), with accuracy to oddball trials also at 99% (SD = 0.11%). From this it can be concluded that participants were attentive to the stimuli.

************************ ******Figure3 here *******************************

Ratings Task

The ratings participants gave the faces during the ratings task in response to the two questions (How Friendly? / How Interested?) were entered into separate within-subjects analyses of variance. Pupil size (dilated/constricted) and sex of face (male/female) were included as within subject factors. The data are illustrated in Figure 3.

Friendliness. There were significant main effects of sex of face [$F(1,24) = 59.13$, $p < .001$, $\eta^2_p = .71$], where participants gave higher ratings of friendliness to female faces than to male faces. Importantly a significant interaction was found between pupil size and sex of face, $F(1,24) = 7.60$, $p = .011$, $\eta^2_p = .241$ Post-hoc t-tests revealed that participants rated women whose pupils had enlarged (dilated) as more friendly than those whose pupils had become smaller (constricted) [$t(24) = 2.4$, $p = .026$, $d_z = .48$]. An opposite non-significant pattern was observed in male faces [$t(24) = 1.4$, $p = .16$, $d_z = .28$].

Interest. The main effect of sex was again significant [$F(1,24) = 33.2$, $p < .001$, $\eta^2_p = .58$] where female faces were considered to be more interested. There was again an interaction between pupil and sex [$F(1,24) = 4.3$, $p = .049$, $\eta^2_p = .15$]. Post hoc comparisons revealed neither the effect in male [$t(24) = .645$, $p = .525$] or female [$t(24) = 1.6$, $p = .122$] faces reached significance.

The results demonstrate that in an incidental-viewing task, where changes in pupil size are task-irrelevant and people are generally unaware of them, pupil size influenced later person perceptions. This is the case even though the pupils are presented at the average size at the time of test, and so the effects reflect retrieval from memory rather than direct perception. These results are suggestive of a process of affective learning, whereby the previously novel faces are imbued with a social value through consistent pairing with a stimulus (pupil size change), which already carries an affective quality.

Interestingly, in our participants the effect of pupil size is quite different when viewing male versus female faces. That is, when viewing previously encountered female faces, those who had shown dilated pupils were subsequently rated as more friendly. The same was not true for male faces, where the pattern of data were in the opposite direction.

As far as we are aware, this is the first demonstration that changes in pupil size can be encoded in to memory and affect later assessment of a person even though the pupil is irrelevant to the task of detecting changes in face identity.

Experiment 2

The effects we are investigating in this programme of research are clearly small and likely influenced by a range of factors. As the change in pupil size is irrelevant to the participants' task of identifying the faces, and the participants appear to be unaware of the pupil face identity relationships, it is perhaps not too surprising that the effects are subtle. Therefore it is necessary for further studies to provide enough evidence to determine whether such subtle social cues can be encoded into memory. Experiment 2 attempts to find such evidence.

This experiment also investigates why we might have seen a difference between male and female faces. In Experiment 1 females whose pupils dilated during the vigilance task were later perceived more positively than those whose pupils constricted. The same was not true however for male faces, where there was a trend for the opposite pattern.

This contrast between pupil dilation in male and female faces has been noted before, where, for example, Bull and Shead (1979) reported effects of pupil dilation in female but not male faces. Clearly, increased arousal state in another individual can have either positive or negative implications for the viewer. In a typical interaction, a cue to increased arousal might reflect friendliness and interest. However, when the intentions of an interaction partner are unknown or unpredictable, such cues might carry a negative affective value. Arousal may signal unwanted sexual interest or even aggression.

Related effects can be seen in affective and behavioural responses to facial expressions. For example, negative expressions such as anger are perceived as more negative when the expresser looks untrustworthy (Oosterhof & Todorov, 2009). Approach and avoidance behaviours elicited by positive and negative facial expressions respectively, can be reversed in the case of facial expressions made by the members of outgroups (Paulus & Wentura, 2014). In the pupil literature Tombs and Silverman (2004), in contrast to Bull and Shead (1979), demonstrated that for female's viewing unknown male faces, pupil dilation was indeed seen as less attractive.

It may be the case that such dimensions could have affected the way in which participants in Experiment 1 interpreted the pupil size changes in our male faces, causing ratings to be the opposite of those seen for female faces. This is particularly plausible given that models of social attributions to faces link masculinity and threat (Todorov, Olivola, Dotsch & Mende-Siedlecki, 2015). Furthermore, evidence from gaze cueing indicates that contextual factors can underpin affective learning of a kind similar to the current pupil effect. Bayliss et al. (2009) demonstrated that the lasting influences on perceived trustworthiness, caused by helpful versus hindering gaze were empowered when faces showed a happy expression during the initial interaction.

Therefore Experiment 2 replicates the pupil memory effect revealed in Experiment 1, and investigates possible reasons for the differences between observing male and female faces. There are three possible reasons for the differences observed in Experiment 1. First, encoding of pupil dilation in male faces may be generally weaker and thus harder to detect (e.g., Bull & Shead, 1979). Second, it may be the case that pupil dilation in male faces is encoded, and that unknown males with dilated pupils are rated less positively by females in later assessments, regardless of other factors (Tombs & Silverman, 2004). Third, the encoding of male faces might be context specific such that, in some circumstances, dilated pupils may be encoded and interpreted as reflecting friendliness and interest. In Experiment 2 male faces that had previously been rated as high or low trust were presented, to test between these alternative accounts.

Method

Participants

Recruitment (Thirty-one adult females, mean age 24.1 years, SD = 6.2 years). All participants gave informed consent and had normal or corrected to normal colour vision. The participants were compensated for their time with course credits.

Stimuli

Twenty colour photographs were selected from a larger database of adult male faces, which had been previously rated for trustworthiness and attractiveness. The stimuli chosen consisted of ten high-trust faces, and ten low-trust faces, with each group consisting of five attractiveness-matched pairs. The pupils of each face were then manipulated as described in Experiment 1. Faces were assigned to each condition in the same manner as in Experiment 1, with the independent variable of trustworthiness replacing sex of face.

Procedure

The procedure in Experiment 2 was identical to the procedure in Experiment 1.

Debriefing. At debriefing six participants were found to have noticed the pupil manipulation, and their data were removed from the analysis.

Results & Discussion

Figure 4 shows the rating scores for high and low-trust male faces. The participants' ratings for friendliness and interest were entered into separate within-subjects analyses of variance, with pupil size (dilated/constricted) and trustworthiness (high/low), as factors (see Figure 4).

Friendliness

Main effects were found for trustworthiness [$F(1,24) = 206.01$, $p < .001$, $\eta^2_p = .90$]. Participants gave trustworthy faces significantly higher ratings than untrustworthy faces. Importantly the interaction effect between pupil size and trustworthiness reached significance [$F(1,24) = 9.12$, $p =.005$, $\eta^2_p = .284$]. Post hoc comparison revealed that high-trust faces, whose pupils enlarged, were given higher ratings than those whose pupils became smaller [$t(24) = 2.4$, $p = .024$, $d_z = .48$]. In contrast, the opposite pattern was seen in the low trust faces, although this did not reach significance [$t(24) = 2.0$, $p =.06$, $d_z = .40$].

************************* ******Figure 4 here ********************************

Interest

The effect of trustworthiness was again significant [$F(1,24) = 53.02$, $p = .006$, $\eta^2_p = .69$]. Of most importance the interaction between pupil size and trustworthiness of the face was significant [$F(1,24) = 12.8$, $p =.001$, $\eta^2_p = .339$]. High trust faces with dilated pupils were rated as more interested [$t(1,24) = 3.46$, $p = .002$, $d_z = .69$] than those whose pupils became smaller. The opposite pattern was seen in the low trust faces, although the effect was not significant [$t(24) = 2.0$, $p = .057$, $d_z = .40$]

The results of Experiment 2 have confirmed the memory retrieval processes detected in Experiment 1. That is, while subsequently rating faces with no differences in pupil size, the prior experience of the face influences person judgments. Interestingly, these retrieval effects are influenced by the trustworthiness of the males. That is, judgments of high trust males are similar to judgments of females, where dilated pupils are encoded and the person is later rated as more friendly/interested. In contrast, for males who are less trusted, there is a trend for those who previously possessed dilated pupils to be perceived more negatively by the female participants

Experiment 3

The overall evidence from the previous two experiments would tend to support the idea that pupil size can be implicitly encoded in to memory and retrieved at a later time. However, the effects are clearly small and somewhat variable. There are a number of reasons why the effects might be less robust than one would hope. First, unconscious encoding of such a subtle social signal in to memory is likely to be difficult to detect. Second, the pupil dilation itself could signal a range of things, from effort when concentrating on a task to sexual arousal, and it is likely that participants interpret pupil size change in different ways. Third, and related to the above, individual differences may well change how pupil size is interpreted and may influence the degree to which such a subtle affective stimulus influences learning. For example, Tombs and Silverman (2004) identified two groups of female participants in their study. Although the majority rated unknown males with dilated pupils as less attractive than those with average sized pupils, a subgroup preferred the unknown males with dilated pupils. Other research has shown that females' preference for males with dilated pupils differs depending on their position in the menstrual cycle (e.g., Caryl et al., 2009). As we did not examine individual differences in these experiments different populations could add significant noise to the data.

Affective learning in other domains is undoubtedly influenced by the need state of the learner. For example sated individuals do not show the same learning effects as hungry individuals when food related odors are used as conditioning stimuli (Gottfried, O'Doherty & Dolan, 2003; Yoemans & Mobini, 2006). Furthermore, after fasting participants show improved memory for food stimuli, which drops off as hunger is sated (Morris & Dolan, 2001).

In learning about other people social exclusion has been demonstrated to influence the kinds of information we recall about others. Those feeling a need to belong remember more social and positive information about other people (Higgins & Tykocinski, 1992; Gardner, Pickett & Brewer, 2000). Socially excluded individuals also appear to be better at discriminating between subtlely different social cues, such as real and fake smiles (Bernstein, Young, Brown, Sacco, & Claypool, 2008) and engage in more affiliative behaviours such as mimicry (Lakin, Chartrand & Arkin, 2008) and we know from previous research that people are highly sensitive to the threat of exclusion from their group (Spoor & Williams, 2007), so such states can be primed.

Given the variation in participants' responses, it seems possible that the imposition of a need state will influence preferences for faces with previously dilated pupils. Therefore in this final study, we chose to manipulate perceived social exclusion. Social exclusion may influence how subtle social cues, such as pupil size changes, are encoded in to memory for retrieved at a later time. For example, it might be the case that females who have been primed to think about social exclusion have a more positive reaction towards other people with dilated pupils. The increased arousal signalling potential interest and friendliness towards an excluded individual might become more rewarding and may be more salient in the current need state. Therefore in Experiment 3, using the technique developed by Over and Carpenter (2009), we create two groups of participants: one group who were primed to feel socially excluded and another group who were primed to feel included.

Methods

Participants

Eighty adult female participants were recruited from ********. All received a cash payment of £6 or course credit for their participation. The mean age of the sample was 19.9 years, and all participants had normal or corrected to normal colour vision.

Stimuli

Facial Stimuli. All facial stimuli were identical to those used in Experiment 1.

Emotional Setting. Each participant was placed into a mildly emotive state at the start of the study; this was maintained throughout with the use of additional emotive picture cues. Half of the participants were assigned to an excluded state using an animation depicting a non-human interaction exclusion scenario. The remaining participants were assigned to an included state, again using an animation that depicted a non-human inclusion interaction scenario. Both animations were designed for use with young children, and were thus only mildly emotive in context (Over & Carpenter, 2009).

Additionally, participants were asked to recall either a) "a time when you were disappointed that your friends left you out of their activities" or b) "a time when you were pleased that your friends included you in their activities" (excluded and included groups respectively) (Zhong & Leonardelli, 2008). Participants were required to consider this situation for a minimum of 30 seconds before being permitted to continue with the study.

To further promote the assigned emotional context, images were presented prior to each testing block for a minimum of 20 seconds. The images for the excluded group showed situations of typical exclusion between children and young people; the included group saw images depicting strong social bonds and interactions. All emotional stimuli were mild, and all subjects were shown an emotionally positive animation at the end of the study to remove any possible negative feelings.

Procedure

All procedures and timings were identical to those in Experiment 1. Participants performed two tasks: a Vigilance task where responses were only required to oddball trials, and a Ratings task where participants rated each presented face using a Likert scale according to the questions of "How friendly is this person?" and "How interested would this person be in you?".

Debriefing. After completing both tasks participants were given the opportunity to report their thoughts on the study. Of the 80 participants tested, 52 did not note any pupil manipulation; the data of only these unaware participants were submitted for analysis. This resulted in 26 participants within each experimental group (inclusion and exclusion). We note that the increased proportion of 28 participants noticing the pupil manipulation may be the result of the social inclusion/exclusion manipulation increasing sensitivity to social signals.

Results and Discussion

The data from the friendly and interested questions (see Figure 5) were analysed in separate mixed-models analyses of variance, with within subjects factors of sex of face (female and male) and pupil size (small and large), and the additional between subjects factor of group (include and exclude).

Friendliness

A main effect of sex of face [F(1,50) = 227.33, $p < .001$, η^2_p =.80] confirms the results we have observed repeatedly where females are rated as more friendly than males. Also there was a significant interaction between pupil size and include/exclude group [F(1,50) = 7.07, p =.011, η^2_p =.12]. As can be seen in Figure 5, Panel A, each group of participants appeared to have opposite reactions to pupil dilation amongst male and female faces. Those people who were primed to feel included trended toward rating dilated pupils as less friendly [F(1,25) = 3.39, p =.077, η^2_p =.12], with further exploratory analysis of this group revealing a significant difference in ratings of male faces [t(25) = 2.28, p = .032, d_z = .45]. Whilst those people who were primed to feel excluded trended toward rating people with dilated pupils as generally more friendly [F(1,25) = 3.72, p =.065, η^2_p =.13].

Interest

A main effect of sex was again obtained, where females were rated as showing greater interest than male faces [F(1,50) = 18.84, *p* <.001, η^2_p =.27]. We did not detect any interactions of pupil size with group. On the other hand there was an effect of group observed in the interaction between include/exclude group and sex of viewed face [F(1,50) = 4.46, *p* =.040, η^2_p =.082]. In the include group, we again observed the main effect of sex, where females are perceived to be more interested than are males [F(1,25) = 45.92, p <.001, η^2_p =.65]. This higher rating in terms of interest and friendliness has been highly significant in all previous experiments. Therefore it is noteworthy that in the exclude group, for the first time, we see no significant difference in the assessment of interest when rating male versus female faces [F(1,25) = 1.61, *p* =.22, η^2_p =.060]. We did not predict this result and at this time, we have no clear explanation for it. However, note that it appears that interest assessment in females falls in the exclude group relative to the include group, while ratings of male interest tends to increase. We speculate that the method of evoking feelings of exclusion in our female participants, where they think about times when their friends excluded them, may be female focused. That is, it may evoke memories when their female friends rejected them, rather than boyfriends, where the latter focus is biased towards sexual, rather than friendship relationships. Hence the specific rejection by females rather than males reduces previous observed contrasts between male and female judgments of interest in the self.

************************ ******Figure 5 here *******************************

In sum, although the results of Experiment 3 are somewhat mixed, they have again provided evidence in support of the results of previous studies. That is, during initial viewing of a face, even though irrelevant to the task and generally not in awareness, encoding of pupil size in to memory appears to take place. At a later time when there are no physical cues to prior pupil size, there appears to be retrieval and this can affect ratings of friendliness. How the retrieved pupil size is interpreted appears to be influenced by whether a female participant was biased towards feeling socially included or excluded.

General Discussion

During face-to-face interactions with another person, dynamic facial features such as changes in emotional expression, gaze shifts to environmental loci, or particular facial structures provide important cues to the current state or likely attributes of another person. Such cues are highly salient, and often consciously recognised in observers. They have been shown to underpin not only responses to other people in the moment of an interaction, but also through affective learning, to influence lasting representations of others in memory. The focus of this article was to examine whether a far more subtle, and unconsciously perceived facial cue, pupil dilation, might also cause similar learning effects through encoding into long-term memory.

Pupil dilation during a face-to-face social exchange might be assumed to emerge from the current encounter. That is, while we are the focus of attention of another person during a face-to-face interaction, changes in pupil dilation might be interpreted as reflecting their reaction to us. The ability to detect these social signals will clearly be of use in facilitating a smooth social exchange as well as in detecting possible interest or threat. We argue that it would also be advantageous to encode such social cues into memory. Indeed, we have demonstrated for the first time such encoding. When an individual has been encountered on a number of occasions with consistent changes in pupil size, either dilating or constricting, subsequent assessment of this person some minutes later is biased. What is important is that during the subsequent assessment the pupils are of an average/normal size, hence there are no direct perceptual cues remaining during retrieval.

Furthermore, the majority of participants reported no awareness that pupil size varied in the initial vigilance task.[1] Hence, there appears to be a form of implicit learning of incidental structural properties of a face that cannot be verbally reported or consciously accessed, as has been proposed in non-social contexts (e.g., Reber, 1989; Seger, 1994). Our findings extend previous reports of implicit learning of regularities in the environment (e.g., Chun & Jiang, 1998) from visuocognitive and visuomotor processes as when searching for a target in cluttered environments, to social and emotional properties of another person.

It is also noteworthy that the state of pupils was task-irrelevant in our identity change detection task, confirming other reports that latent learning can take place while stimulus properties are irrelevant and ignored/subliminal during exposure (e.g., Goujon, Didierjean & Marmeche, 2009; Watanabe, Nanez, and Sasaki, 2001). The weight of our current evidence supports the idea of incidental learning of faces (e.g., Eitam et al., 2014). In our case people are able to learn about subtle cues reflecting cognitive/arousal states of another person.

One question that must be discussed is what is being encoded. Possibly pupil size changes themselves are being memorized and later recalled. Information carried in the eye regions is indeed highly salient and preferentially processed (e.g. Whalen et al., 2004). However it seems perhaps more likely that what is in fact encoded is the affective state associated with the change in pupil size. This might occur similarly to changes in liking caused by gaze behaviour (Bayliss et al 2009; Bayliss and Tipper, 2006), which appear to be driven by the participant's affective response to that behavior (Mansseur, et al 2015). Another possibility is that the pupil size effects reflect encoding of a trait. Indeed, recent studies suggest pupil size changes can lead to inferences of trustworthiness during interactions (Kret, Fischer & De Dreu, 2015). Such inferences might be driven by similar transference processes as those observed in Verkosky and Todorov (2010; 2013) – i.e. previous pairings of pupil size change and positive or negative behaviours.

Our initial assumption was that increased interest/arousal would typically be perceived as a positive cue, and such people would be represented as friendly and interested in the viewer. Certainly for the female participants in this study, other females are indeed generally encoded in this way, as seen in Experiment 1. That is, female faces encountered with dilated pupils are subsequently rated more positively in that they are perceived as being friendlier than those with constricted pupils. However, somewhat surprisingly, this was not the case when females viewed male faces, where there was a trend for males with dilated pupils to be recalled as less friendly/interested.

This latter result might reflect a negative response whereby females feel threatened by the interest of a male they do not know. This notion of perceived threat was supported by the results of Experiment 2, where a similar pattern of results was seen for trustworthy looking males, as was seen with females, but for low trustworthy males the pattern reflected that of the males in Experiment 1.

The more robust effects seen in female and high trust male faces in our experiments may reflect trends for stronger affective learning of positive information. Similar trends have been reported in experiments looking at affective learning from positive and negative behaviours (Bliss-Moreau et al., 2008). Also, it has been shown that participants are more likely to perceive behaviours in females and less masculine individuals as being driven by their internal emotional state (Barrett & Bliss-Moreau, 2009). It is possible the participants in our experiments were more likely to attribute the pupil size changes in the female and high trust male faces, to an emotional response, which might be directed toward themselves.

In Experiment 3, where we primed a state of social exclusion or inclusion, we predicted that the “need state” of the participant would influence the manner in which encoded pupil size affected later ratings. We did indeed see such a pattern of data for friendliness responses that reflected our belief that inducing an increased need for social inclusion would increase the positive salience of dilated pupils. Although our findings from this first study are somewhat tentative, we feel that this may be a promising avenue of future research. Social exclusion primes have been shown to sharpen memory for salient social information (Gardner et al., 2000) and the social behaviours of others (Hess & Pickett, 2010) and could thus boost affective learning from pupil size change.

In this study we probed the two questions of friendliness and interest in self. As noted, we probed with these questions because we felt they were qualitatively different. The “friendly” question concerns a property possessed by the viewed person. This is relatively unambiguous, and participants had no problems making this response. In all cohorts except the exclusion group of Experiment 3, a consistent pattern was observed where dilated pupils were relatively more positive in female/high trust than male/low-trust faces.

Furthermore, the “friendliness” question also appears to reflect pupil processing in Experiment 3. That is, there was a significant interaction between pupil size change and whether participants were induced to feel socially included or excluded. The included group tended to show reduced friendliness ratings when viewing faces that had previously exhibited dilated pupils, especially when viewing male faces; whereas those who were socially excluded showed the opposite pattern, with higher friendliness ratings for dilated pupils, especially in female faces.

In contrast the interest in self question is more intimate and complex as it is focused on the complex assessment of the potential interaction between self and other. That is, it asks how interested the viewed person would be in the participant. This complex assessment can possess many aspects, and this was reflected in participant responses. In many cases participants asked for clarification of what this question meant. It could relate to general interest, the likelihood they had similar hobbies and interests, or be interpreted as asking about sexual attraction. Participants’ interpretation of the meaning of this question might be affected by the sex of the viewed face. We provided no guidance on this interpretation, and hence the data is likely to be highly variable.

There are two ways we observe the contrast between the “friendliness” and “interest” question. First, ratings in the “interest” question were always significantly lower than those given to the “friendliness” question in all experiments. Second, Experiment 3 revealed different patterns of data for each question. When considering how friendly a person was there was an interaction between pupil dilation and social inclusion/exclusion. In contrast, the “interest” question did not detect an effect of pupil, but rather showed that after social exclusion females did not differentiate between male and female faces, which contrasted with all our previous experimental findings.

Other factors may have added variability to our findings. Firstly, as addressed in Experiments 2 and 3, pupil size is likely to be interpreted in the context of the apparent traits of the person being observed, and the current state of the observer. Pupil size can represent a person's state of arousal (Bradley et al., 2008), but also non-social cognitive load (e.g., Kahneman & Beatty, 1966) or decision-making (Einhauser, Koch & Carter, 2010). Pupils of course also change size due to changes in ambient light. Individual differences between the participants may have influenced their interpretations of the pupil size changes, and perhaps the likelihood of their causing an affective response. Future research could address further the extent to which pupil size changes are likely to be interpreted as socially meaningful. For example, where changing light levels could explain pupil size changes will people still unconsciously perceive affective value in this cue? Also, given that pupil size changes appear to influence how intensely emotional expressions are perceived (Harrison et al., 2007), do pupil cues interact with other dynamic cues when affecting long term perceptions of others? In our experiments pupil size was the only feature of the face to change during exposure, but would encoding effects still be visible if pupil size changes were paired with a far more overt cue such as emotional expression?

Extensions might also address the number of exposures required for pupil memory effects to occur. In the present study participants saw each face on ten occasions, but could this number be reduced, as effective learning can occur very rapidly from limited information (e.g., Todorov & Uleman, 2002; 2003; Bliss-Moreau et al., 2008).

Individual differences in our female participants may also complicate interpretation of our results. Tombs and Silverman (2004) report sub-groups of women who rate males with dilated pupils highly attractive, whereas others produce the opposite assessment.

Furthermore, we did not consider the female fertility cycle. During periods of high fertility females categorise male faces faster (e.g., Johnston, Arden, Macrae, & Grace, 2003) and male sexual orientation more accurately (Rule, Rosen, Slepian & Ambady, 2011) and might therefore encode the association between pupil size and face identity more accurately for male than female faces.

The current experiments also do not address the direction of the effects observed. For example we see female and high trust male faces whose pupils previously dilated receiving higher ratings for friendliness and interest in the participant than their counterparts whose pupils got smaller. Is this because over multiple exposures the participant's liking of these faces increases, whilst it decreases for those whose pupils constricted? Or could it be that one direction of pupil size has no effect on liking, while the other does? In an experiment included in the supplementary materials, we attempted to answer this question using pre- and post-exposure ratings. The change in design yielded no significant effects, but a strikingly similar pattern of data to that seen across the three included experiments. We believe further exploration of the direction of the pupil effects would be of interest.

Although we have discussed the limitations to our task there are also potential advantages in that the very simple passive viewing task could be easily applied to various clinical and developmental populations as a means of measuring encoding and memory retrieval of non-conscious social cues such as pupil dilation. For example, Williams syndrome (Bellugi, Lichtenberger, Jones & Lai, 2000) and autism (Baron-Cohen, 1995) present with quite different behaviours in social settings. The former Williams group being over friendly to strangers, whereas the latter autism population present with withdrawal and avoidance of social interactions. What is unknown is whether such populations are able to perceive and encode in to memory subtle and task-irrelevant cues such as pupil dilation. It is feasible that perhaps Williams syndrome, although skilled at face recognition (e.g., Rosen, Jones, Wang & Klima, 1995), are less able to detect dynamic social signals of another person's arousal/interest levels, and hence cannot adjust their behavior appropriately. In contrast, it could be the case that a feature of autism is better ability to detect subtle and weak perceptual signals such as pupil dilation (e.g., O'Riordan, Plaisted, Driver & Baron-Cohen, 2003; Plaisted, O'Riordan & Baron-Cohen, 1998; Shah & Frith, 1993). In this situation, they may be hyper sensitive to arousal states of others, which motivates increased withdrawal. Extending the current approach to these and other populations (e.g., schizophrenia, depression, anxiety disorders) could provide new insights in to perception and memory of subtle and incidental social signals.

Conclusion:

This research programme presents initial data to support the hypothesis that during social interactions the state of another person's pupils (either dilated or constricted) is encoded into memory. This encoding in to memory takes place even though pupils are irrelevant to the task of person identification, and most participants appear to be unaware of pupil dilation/constriction. The inferred arousal/interest state indicated by pupil dilation is linked to the identity of the person, and influenced by whether they can be trusted or not. The effect has been observed with explicit introspective reports where faces are rated for friendliness/interest, and there is initial evidence that social inclusion/exclusion can influence these memory and retrieval processes. The effects are clearly subtle and probably influenced by various factors such as interpretation of pupil dilation and individual differences, but the weight of evidence supports the hypothesis that implicit learning of associations between pupil state and person identity could serve a role in facilitating subsequent social interactions, potentially improving the ability to predict the future actions of another person.

References

Amemiya, S., & Ohtomo, K. (2011). Effect of observed pupil size on the amygdala of beholders. Social Cognitive and Affective Neuroscience, 7(3), 332-341. doi: 10.1093/scan/nsr013

Baron-Cohen, S. (1995). Mindblindness: An essay on autism and theory of mind. Boston, MA: MIT Press.

Barrett, L.F., & Bliss-Moreau, E. (2009). She's emotional. He's having a bad day. Attributional explanations for emotion stereotypes. Emotion, 9, 649-658. doi:10.1037/a0016821

Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgments. Psychological Science, 17, 514-520. doi: 10.1111/j.1467-9280.2006.01737.x

Bayliss, A. P., Griffiths D., & Tipper, S. P. (2009). Predictive gaze cues affect face evaluations: The effect of facial emotion. European Journal of Cognitive Psychology, 21, 1072-1084. doi: 10.1080/09541440802553490

Bellugi, U., Lichtenberger, L., Jones, W., Lai, Z & George, M.S. (2000). The neurocognitive profile of Williams syndrome: A complex pattern of strengths and weaknesses. Journal of Cognitive Neuroscience, 12, 7-29. doi: 10.1162/089892900561959

Bernstein, M. J., Young, S. G., Brown, C. M., Sacco, D. F., & Claypool, H. M. (2008). Adaptive responses to social exclusion: Social rejection improves detection of real and fake smiles. Psychological Science, 19, 981-983. doi: 10.1111/j.1467-9280.2008.02187.x.

Blessing, A., Keil, A., Linden, D.E., Heim, S., & Ray, W.J. (2006). Acquisition of affective dispositions in dementia patients. Neuropsychologia, 44, 2366-2373. doi:10.1016/j.neuropsychologia.2006.05.004

Bliss-Moreau, E., Barrett, L.F., & Wright, C.I. (2008). Individual differences in learning the affective value of others under minimal conditions. Emotion, 8, 479-493. doi: 10.1037/1528-3542.8.4.479

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. Psychophysiology, 45, 602-607. doi: 10.1111/j.1469-8986.2008.00654.x

Brewer, M.B. (2007). The importance of being we: human nature and intergroup relations. American Psychologist, 62(8), 728–738. doi: 10.1037/0003-066X.62.8.726

Bull, R., & Shead, G. (1979). Pupil dilation, sex of stimulus, and age and sex of observer. Perceptual and Motor Skills, 49, 27-30. doi: 10.2466/pms.1979.49.1.27

Caryl, P. G., Bean, J. E., Smallwood, E. B., Barron, J. C., Tully, L., & Allerhand, M. (2009). Women's preference for male pupil-size: Effects of conception risk, sociosexuality and relationship status. Personality and Individual Differences, 46(4), 503-508. doi: 10.1016/j.paid.2008.11.024

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. Cognitive Psychology, 36, 28–71. doi: 10.1006/cogp.1998.0681

Demos, K. E., Kelley, W. M., Ryan, S. L., Davis, F. C., & Whalen, P. J. (2008). Human amygdala sensitivity to the pupil size of others. Cerebral Cortex, 18, 2729-2734, doi: 10.1093/cercor/bhn034

Einhauser, W., Koch, C. & Carter, O. (2010). Pupil dilation betrays the timing of decisions. Frontiers in Human Neuroscience, 4, 1-9, doi: 10.3389/fnhum.2010.00018.

Eitam, B., Glass-Hackel, R., Aviezer, H., Dienes, Z., Shoval, R., & Higgins, E.T. (2014). Are Task Irrelevant Faces Unintentionally Processed? Implicit Learning as a Test Case. Journal of Experimental Psychology: Human Perception & Performance, 40(5), 1741-7. doi: 10.1037/a0037627.

Ellermeier, W., & Westphal, W. (1995). Gender differences in pain ratings and pupil reactions to painful pressure stimuli. Pain, 61, 435-439. doi: 10.1016/0304-3959(94)00203-Q

Gardner, W. L., Pickett, C. L., & Brewer, M. B. (2000). Social exclusion and selective memory: how the need to belong influences memory for social events. Personality and Social Psychology Bulletin, 26, 486–496. doi: 10.1177/0146167200266007

Gottfried, J., O'Doherty, J., & Dolan, R.J. (2003). Encoding predictive reward value in human amygdala and orbitofrontal cortex. Science, 301, 1104-1107. doi: 10.1126/science.1087919

Goujon, A., Didierjean, A. & Marmeche, E. (2009). Semantic contextual cueing and visual attention. Journal of Experimental Psychology: Human Perception & Performance, 35, 50-71. doi: 10.1037/0096-1523.35.1.50

Harrison, N.A., Singer, T., Rotshtein, P., Dolan, R.J. & Critchley, H.D. (2006). Pupilary contagion: central mechanisms engaged in sadness processing. SCAN, 1, 5-17. doi: 10.1093/scan/nsl006

Harrison, N. A., Wilson, C. E., & Critchley, H. D. (2007). Processing of observed pupil size modulates perception of sadness and predicts empathy. Emotion, 7(4), 724-729. doi: 10.1037/1529-3542.7.4.724

Hess, E.H. (1965). Attitude and pupil size. Scientific American, 212(4), 46-54. doi: 10.1038/scientificamerican0465-46

Hess, Y.D., & Pickett, C.L. (2010). Social rejection and self- versus other-awareness. Journal of Experimental Social Psychology, 46, 453-456. doi:10.1016/j.jesp.2009.12.004

Hess, E.H., & Polt, J.M. (1960). Pupil size as related to interest value of visual stimuli. Science, 132, 349-350. doi: 10.1126/science.132.3423.349

Higgins, T., & Tykocinski, O. (1992). Self-discrepancies and biographical memory: Personality and cognition at the level of psychological situation. Personality and Social Psychology Bulletin, 18(5), 527-535. doi: 10.1177/0146167292185002

Horstman, G. (2003). What do facial expressions convey: Felling states, behavioural intentions, or actions requests? Emotion, 3, 150-166. doi: 10.1037/1528-3542.3.2.150

Johnson, M.K., Kim, J.K., & Risse, G. (1985). Do alcoholic Korsakoff's syndrome patients acquire affective reactions? Journal of Experimental Psychology: Learning, Memory and Cognition, 11, 22-36. doi:10.1037/0278-7393.11.1.22

Johnston, L., Arden, K., Macrae, C.N., & Grace, R.C. (2003). The need for speed: The menstrual cycle and person construal. Social Cognition, 21, 89-100. doi: 10.1521/soco.21.2.89.21319

Kahneman, D., & Beatty, J. (1966). Pupil diameter and load on memory. Science, 154, 1583-1585. doi: 10.1126/science.154.3756.1583

Kramer, R. S. S., & Ward, R. (2010). Internal facial features are signals of personality and health. The Quarterly Journal of Experimental Psychology, 63, 2273-2287. doi: 10.1080/17470211003770912

Kraus, M. W., & Chen, S. (2010). Facial-Feature Resemblance Elicits the Transference Effect. Psychological Science, 21(4), 518-522. doi:10.1177/0956797610364949

Kret, M.E., Fischer, A.H., & De Dreu, C.K.W. (2015). Pupil Mimicry Correlates With Trust in In-Group Partners With Dilating Pupils. Psychological Science, 26(9), 1401-1410. doi: 10.1177/0956797615588306

Lakin, J. L., Chartrand, T. L., & Arkin, R. M. (2008). I am too just like you: nonconscious mimicry as an automatic behavioral response to social exclusion. Psychological Science, 19 (8), 816–822. doi: 10.1111/j.1467-9280.2008.02162.x.

Manssuer, L. R., Pawling, R., Hayes, A. E., & Tipper, S. P. (2015). The role of emotion in learning trustworthiness from eye-gaze: Evidence from facial electromyography. Cognitive Neuroscience, 1–21. doi:10.1080/17588928.2015.1085374

Morris, J. S., & Dolan, R. J. (2001). Involvement of human amygdala and orbitofrontal cortex in hunger-enhanced memory for food stimuli. *The Journal of Neuroscience :* The Official Journal of the Society for Neuroscience, 21(14), 5304–5310. doi:21/14/5304 [pii]

O'Riordan, M., Plaisted, K. Driver, J. & Baron-Cohen, S. (2001). Superior visual search in autism. Journal of Experimental Psychology: Human Perception & Performance, 27, 719-730. doi: 10.1037//0096-1523.27.3.719

Oosterhof, N. N. and Todorov, A. (2008). The functional basis of face evaluation. Proceedings of the National Academy of Sciences of the United States of America, 105, 11087-11092. doi: 10,1073/pnas0805664105

Oosterhof, N. N., & Todorov, A. (2009). Shared perceptual basis of emotional expressions and trustworthiness impressions from faces. Emotion, 9(1), 128–133. doi:10.1037/a0014520

Over, H., & Carpenter, M. (2009). Priming third-party ostracism increases affiliative imitation in children. Developmental Science, 12(3), F1-F8. doi: 10.1111/j.1467-7687.2008.00820.x.

Paulus, A., & Wentura, D. (2014). Threatening joy: Approach and avoidance reactions to emotions are influenced by the group membership of the expresser. Cognition and Emotion, 28, 656–677. doi: 10.1080/02699931.2013.849659

Plaisted, K., O'Riorden, M., & Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task.

Journal of Child Psychology & Psychiatry, 39, 765-774. doi: 10.1111/1469-7610.00375

Reber, A. S. (1989). Implicit learning and tacit knowledge. Journal of Experimental Psychology: General, 118, 219–235.

Rogers, R. D., Bayliss, A. P., Szepietowska, A., Dale, L., Reeder, L., Pizzamiglio, G., Czarna, K., Wakeley, J., Cowen, P. J., & Tipper, S. P. (2014). I want to help you, but I am not sure why: gaze cuing induces altruistic giving. Journal of Experimental Psychology: General, 143(2), 763-777. doi: 10.1037/a0033677

Rosen, M. L., Jones, W., Wang, P. P., & Klima, E. S. (1995). Face processing: Remarkable sparing in Williams syndrome. Genetic Counseling, 6, 138-140.

Rule, N.O., Rosen, K.S., Slepian, M.L., & Ambady, N. (2001). Mating interest improves women's accuracy in judging male sexual orientation. Psychological Science, 22, 881-886. doi: 10.1177/0956797611412394

Sacco, D. F., Young, S. G., Brown, C. M., Bernstein, M. J., & Hugenberg, K. (2012). Social exclusion and female mating behavior: Rejected women show strategic enhancement of short-term mating interest. Evolutionary Psychology, 10(3), 573-587.

Seger, C. A. (1994). Implicit learning. Psychological Bulletin, 115, 163–196. doi: 10.1037/0033-2909.115.2.163

Seligman, M. E. (1970). On the generality of the laws of learning. Psychological Review, 77, 406-418. doi: 10.1037/h0029790

Siedel, E.M., Habel, U., Kirschner, M., Gur, R.C., & Derntl, B. (2010). The impact of facial emotional expressions on behavioral tendencies in women and men. Journal of Experimental Psychology: Human Perception and Performance 36(2), 500-507. doi: 10.1037/a0018169.

Simon, D. J., & Levin, D. T. (1998). Failure to detect changes to people during a real world interaction. Psychonomic Bulletin & Review, 5, 644-649. doi: 10.3758/BF03208840

Shah, A. & Frith, U. (1993). Why do autistic individuals show superior performance on the block design test? Journal of Child Psychology & Psychiatry, 34, 1351-1364. doi: 10.1111/j.1469-7610.1993.tb02095.x

Spoor, J.R., & Williams, K.D. (2007). The evolution of an ostracism detection system. In J. P. Forgas, M. Haselton, & W. von Hippel (Eds.), The evolution of the social mind: Evolutionary psychology and social cognition (pp. 279–292). New York: Psychology Press.

Stins, J.F., Roelofs, K., Villan, J., Kooijman, K., Hagenaars, M.A., & Beek, P.J. (2011). Walk to me when I smile, step back when I'm angry: Emotional faces modulate whole-body approach-avoidance behaviors. Experimental Brain Research, 212, 603-611. doi: 10.1007/s00221-011-2767-z

Strass, K. W., & Willis, F. N. (1967). Eye contact, pupil dilation and personal preference. Psychonomic Science, 7(10), 375-376. doi:10.3758/BF03331131

Sutherland, C.A.M., Oldmeadow, J.A., Santos, I.M., Towler, J., Burt, D.M., & Young, A.W. (2013). Social inferences from faces: Ambient images generate a three-dimensional model. Cognition, 127, 105-118. doi: 10.1016/j.cognition.2012.12.001

Todorov, A., Olivola, C. Y., Dotsch, R., & Mende-Siedlecki, P. (2015). Social Attributions from Faces: Determinants, Consequences, Accuracy, and Functional Significance. Annual Review of Psychology, 66(1), 519–545. doi:10.1146/annurev-psych-113011-143831

Todorov, A., Pakrashi, M., & Oosterhof, N.N. (2009). Evaluating Faces on Trustworthiness After Minimal Time Exposure. Social Cognition, 27(6), 813-833. doi: 10.1521/soco.2009.27.6.813

Todorov, A., & Uleman, J. S. (2002). Spontaneous trait inferences are bound to actors' faces: evidence from a false recognition paradigm. Journal of Personality and Social Psychology, 83(5), 1051–1065. doi:10.1037/0022-3514.83.5.1051

Todorov, A., & Uleman, J. S. (2003). The efficiency of binding spontaneous trait inferences to actors' faces. Journal of Experimental Social Psychology, 39(6), 549–562. doi:10.1016/S0022-1031(03)00059-3

Tombs, S., & Silverman, I. (2004). Pupillometry: A sexual selection approach. Evolution and Human Behavior, 25, 221-228, doi: 10.1016/j.evolhumbehav.2004.05.001

Vernon, R.J.W., Sutherland, C.A.M., Young, A.W., & Hartley, T. (2014). Modeling first impressions from highly variable facial images. Proceedings of the National Academy of Sciences, 111(32), E3353-E3361. doi: 10.1073/pnas.1409860111

Verosky, S. C., & Todorov, A. (2010). Generalisation of affective learning about faces to perceptually similar faces. Psychological Science, 21, 779-785. doi: 10.1177/0956797610371965

Verosky, S. C., & Todorov, A. (2013). When physical similarity matters: Mechanisms underlying affective learning generalization to the evaluation of novel faces. Journal of Experimental Social Psychology, 49, 661-669. doi: 10.1016/j.jesp.2013.02.004

Wasserman, E. A, & Miller, R. R. (1997). What's elementary about associative learning? Annual Review of Psychology, 48, 573–607. doi: 10.1146/annurev.psych.48.1.573

Yoemans, M. R., & Mobini, S. (2006). Hunger alters the expression of acquired hedonic but not sensory qualities of food paired odours in humans. Journal of Experimental Psychology: Animal Behavior Processes, 32(4), 460-466. doi: 10.1037/0097-7403.32.4.460

Watanabe, T., Nanez, J. E., & Sasaki, Y. (2001, October 25). Perceptual learning without perception. Nature, 413, 844–848. doi: 10.1038/35101601

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., … Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. Science, 306(December), 2061. doi:10.1126/science.1103617

Zhong, C. B., & Leonardelli, G. J. (2008). Cold and lonely: Does social exclusion literally feel cold? Psychological Science, 19, 838–842. doi:10.1111/j.1467-9280.2008.02165.x

Footnotes

1. Scrutiny of those individuals who reported awareness of pupil size change revealed that they showed the same pattern of data.