Looking into your eyes: Observed pupil size influences approach-avoidance responses

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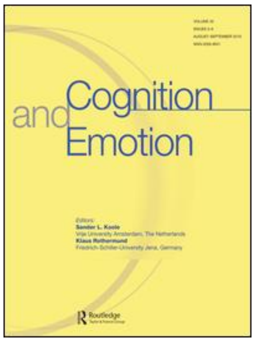

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BRIEF ARTICLE

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Looking into your eyes: observed pupil size influences approach-avoidance responses

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ABSTRACT
The eyes reveal important social messages, such as emotions and whether a person is aroused and interested or bored and fatigued. A growing body of research has also shown that individuals with large pupils are generally evaluated positively by observers, while those with small pupils are perceived negatively. Here, we examined whether observed pupil size influences approach-avoidance tendencies. Participants performed an Approach-Avoidance Task using faces with large and small pupil sizes. Results showed that pupil size influences the accuracy of arm movements. Specifically, individuals were less prone to approach a face with small pupils than a face with large pupils. Conversely, participants were less prone to avoid a face with large pupils than a face with small pupils. Collectively, these findings suggest that perceivers attend to a facial cue – pupil size – when interacting with others.

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A growing body of research has shown that person impressions are often formed rapidly and spontaneously from minimal information (Uleman, Newman, & Moskowitz, 1996). One rich source of information is facial appearance (Zebrowitz, 1997). Indeed, a mere 100 ms exposure to a face permits people to make a variety of person judgments such as trustworthiness, competence, and aggressiveness (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015). In a similar vein, with a glance, humans instantly categorise social targets according to their age (Wright & Stroud, 2002), race (Richeson & Trawalter, 2005), and sex (Macrae & Martin, 2007). Once perceived, these characteristics often alter subsequent person processing by activating stereotypical and prejudicial responses (Macrae & Bodenhausen, 2000).

Among the many facial cues that drive impression formation, the human eye region stands out as particularly salient and powerful. The morphology of the human eye is unique and attracts people's immediate attention from birth (Farroni, Csibra, Simion, & Johnson, 2002). Indeed, making eye contact provides the most powerful mode of establishing each other's emotions and intentions (Senju & Johnson, 2009). As a consequence, infants and adults continuously focus on their interaction partner's eyes and follow his or her gaze in order to grasp emotional signals (Farroni et al., 2002).

Beyond gaze, pupil size is an interesting automatic and uncontrollable but visible social signal (for reviews, see Kret, 2015; Laeng, Sirois, & Gredebäck, 2012; Prochazkova & Kret, 2017). The pupils adapt to the perceptual environment, constricting and dilating in response to light intensity (Laeng et al., 2012). A good deal of work has further shown that pupil size reflects much more than changes in light, as it covaries with different cognitive and affective states (Beatty & Kahneman, 1966; Hess & Polt, 1960; Laeng et al., 2012). For example, pupil dilation reflects interest. It has been shown that heterosexual women's pupils tend to dilate when exposed to photographs of nude men whereas heterosexual men's pupils tend to dilate when exposed to photographs of nude women (Hess & Polt, 1960). Moreover, pupillary responses are linked to fundamental cognitive

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mechanisms. As such, pupil size positively correlates with memory load (Beatty & Kahneman, 1966) and with the difficulty of mental calculations (Hess & Polt, 1964). As a case in point, it has been shown that the pupillary response is an indicator of how intensely the processing system is operating (Just & Carpenter, 1993).

Given that changes in pupil size are unconscious and automatic, people believe that such changes provide a veridical reflection of a person's inner state (Kret, 2015). Pupillary changes are indeed processed by observers and influence their evaluation of social targets. Specifically, partners with large pupils are perceived as positive and beautiful, and those with small pupils, cold and distant (Hess, 1965; Kret & De Dreu, 2017; Kret, Fischer, & De Dreu, 2015). In a seminal paper by Hess (1965), a group of men were shown a series of pictures, two of which showed an attractive young woman. One of them had been retouched to make the woman's pupils large and the other to make them very small. Participants liked the woman with the large pupils better than the woman with the small pupils. In line with these findings, more recent work has revealed that individuals ascribe positive traits (e.g. trustworthiness) to social targets with dilated pupils, and negative traits (e.g. untrustworthiness) to those with constricted pupils (Kret et al., 2015; Kret & De Dreu, 2017).Thus, these findings suggest that individuals with large pupils are perceived more positively than individuals with small pupils. Research has also investigated whether such an effect varies as a function of the facial expression. Results in this research area are mixed. Indeed, a set of studies revealed a selective effect of pupil size in sadness perception, such that sad faces with small pupils are perceived more negative than sad faces with large pupils (Harrison, Wilson, & Critchley, 2007). However, more recent work revealed that partners with large pupils are perceived more positively than those with small pupils when they display a positive expression (i.e. happiness) or a neutral expression as well as a negative (i.e. anger) facial expression (Kret et al., 2015; Kret & De Dreu, 2017; Van Breen, de Dreu, & Kret, 2018). In other words, both happy and angry faces with large pupils induce more positive feelings than happy and angry faces with small pupils. Although with interesting nuances, these findings collectively show that people use the pupil size of a partner as a source of social information to inform their global evaluations of the partner.

The present research sought to extend prior work on the social implications of pupil dilation by investigating whether pupil size influences basic behavioural reactions of approach and avoidance. Although extensive research has addressed what the pupil reflects, research investigating how people behaviourally react to their partner's pupil size is surprisingly limited. Thus, we aimed to complement and extend previous insights on the social implications of pupil dilation by testing the behavioural consequences of observed pupil dilation. In particular, we considered the arm movements associated with approach and avoidance tendencies (Laham, Kashima, Dix, & Wheeler, 2015). Across human evolution, people have been primarily interested in defining one another's positive or negative intentions and whether it is safe to approach or better to avoid a social target (Zebrowitz & Collins, 1997). In a similar vein, it has been shown that approach and avoidance behaviours are fundamental building blocks of behaviour that precede socially meaningful conduct (Elliot, 2006). Thus, addressing whether another's pupil size influences approach and avoidance responses in observers will help to provide a more comprehensive account of the relationship between facial cues and social perception.

Extensive research has shown that approach and avoidance responses are sensitive to valenced stimuli (for a review, see Laham et al., 2015). Indeed, people quickly approach positive stimuli and avoid negative stimuli. For example, participants' automatic evaluations of words facilitate congruent behavioural responses, such that negative words are avoided quickly whereas positive words are approached quickly (Chen & Bargh, 1999). In a similar vein, people are generally faster at performing avoidance motor movements toward negatively valenced groups, such as outgroups. By contrast, people tend to be quicker to approach positively valenced groups, such as ingroup members (Paladino & Castelli, 2008). Research on face perception has further revealed that negative facial cues (e.g. untrustworthiness) facilitate avoidance arm movements, while positive ones (e.g. trustworthiness) promote approach behaviours (Slepian, Young, Rule, Weisbuch, & Ambady, 2012).

Combining research showing that pupil dilation predicts valenced impressions (Hess, 1965; Kret et al., 2015) with findings showing that approach and avoidance behaviours are sensitive to valenced stimuli (Chen & Bargh, 1999; Paladino & Castelli, 2008;

Slepian et al., 2012; see also, Laham et al., 2015), we expected changes in pupil size to influence arm contractions producing approach and avoidance movements. Considering that individuals with large pupils are perceived positively while those with small pupils are perceived negatively, we expected that dilated and constricted pupils would potentiate approach and avoidance, respectively.

We tested these predictions by asking participants to react to novel faces with different pupil sizes. Specifically, participants viewed facial stimuli with dilated or constricted pupils and responded with either pushing a joystick away from the body (avoidance) or pulling it towards the body (approach) (Laham et al., 2015).

Method

Participants

Sample size was determined by a power analysis. The projected sample size needed to detect a medium effect size with 80% power is $N = 34$ for a within-subject ANOVA. Overall, we recruited 50 students.

Experimental stimuli

Twelve images of western European male ($N = 6$) and female ($N = 6$) faces with neutral expressions served as our experimental stimuli (Van der Schalk, Hawk, Fischer, & Doosje, 2011). Pictures were standardised in Adobe Photoshop, converted to gray scale, and cropped to reveal only the eye region. After cropping each stimulus, we erased everything between the eyelashes (eye white, iris, and pupil). Next, the average luminance and contrast were calculated for each picture, and each picture was adjusted to the mean. The eyes were then filled with new eye whites and irises, and an artificial pupil was added. The intermediate shade of the iris used in all new pictures was taken from the shade of one iris pair. To emphasise the convex shape of the eye and increase naturalness, we made the eye white around the iris brighter than the eye white in the outer edges of the eye. The exact same eye template (eye white, iris, and pupil) was used in all stimuli and all were in gray scale; this was done so that eye colour or contrast would not play a role in our findings (see, Kret & De Dreu, 2017). To manipulate pupil size, we created two sets of stimuli: in one set the 12 images had pupils 40% larger than the standard pupil. In the second set the 12 images had pupils 40% smaller than the standard pupil (See the supplementary materials for stimuli examples).

Procedure

Participants were seated in front of a computer screen and performed an Approach-Avoidance Task (AAT; Laham et al., 2015). Prior research has shown that approach/avoidance effects tend to emerge when individuals are asked to perform an explicit affective categorisation of stimuli (see, Phaf, Mohr, Rotteveel, & Wicherts, 2014). However, some other studies found reliable findings even when instructions did not require explicit appraisals of the affective valence of stimuli (for a review, Laham et al., 2015). Based on these latter findings, we employed a non-evaluative version of the task. As such, the explicit processing of the facial valence could have driven attention away from the pupils in favour of other facets of the eye-region (e.g. eyebrow, or the space between the eyes). Thus, participants were asked to either push or pull the joystick on the basis of the colour of a 15×15 pixels square, superimposed below the left eye[1] of a face stimulus. The experiment employed 48 stimuli: 12 faces $\times$ 2 (stimulus pupil size: dilated vs. constricted) $\times$ 2 (colour of the square: yellow vs. purple).

In one block, participants were asked to pull a joystick toward them (approach) when a face with a yellow square below the left eye appeared on the computer screen and to push the joystick away from them (avoidance) when a face with a purple square below the left eye appeared on the computer screen. In another block, the instructions were reversed. Thus, participants were asked to pull a joystick toward them when a face with a purple square appeared on the computer screen and to push the joystick away from them when a face with a yellow square appeared on the computer screen. The order of these blocks was counterbalanced across participants.

To eliminate ambiguity about the meaning of pushing versus pulling the joystick (see Slepian et al., 2012), the picture either grew or shrank in size as the joystick was moved. Indeed, prior research has shown that approach-avoidance tendencies from lever/joystick movements are critically dependent upon the evaluative meaning of the response labels that are used in the task (Eder & Rothermund, 2008).

In our task, when the joystick was pushed away, the image progressively shrank over the course of a second until reaching 10% of its original size and then disappeared – providing the illusion of pushing the face away. When the joystick was pulled toward the participant, the image progressively grew over the course of a second until reaching 200% of its original size and then disappeared – providing the illusion of pulling the face closer. This helped us to avoid that participants would re-categorise pull-responses as withdrawing the hand, i.e. avoidance, and push-responses as grasping, i.e. approach.

In each block we used the same 48 stimuli, yielding 96 trials per participant. No mentioning was made of the fact that the faces varied along pupil size. Each trial started with a 500 ms fixation cross appearing at the centre of the screen, followed by the stimulus. For each trial, participants were allowed 750 ms after the onset of the target stimulus to respond. If they did not respond within that limit, then a message indicating to pull/push the joystick faster appeared on the screen for 1500 ms before they were allowed to go on to the next trial.

Previous pilot testing ($N = 40$) with no response limit suggested that pupil size tends to influence the accuracy (i.e. error rates; De Houwer, Crombez, Baeyens, & Hermans, 2001) rather than the speed of approach and avoidance behaviours (i.e. reaction times). However, error rates were very low (below 5%) and we observed only a trend that was not significant (see the supplementary materials for the full set of analyses). Nevertheless, we considered such findings as preliminary evidence that pupil size might exert its effect on approach/avoidance responses in terms of accuracy rather than reactions times. Thus, in the current study we implemented a response deadline that channels the effect variance onto the error variable. Indeed, the response deadline was expected to increase the overall error rate and produce more variability that would allow a more powerful test of the effects of pupil size on the accuracy of approach and avoidance arm movements (for a similar argument, Payne, 2001).

Results

We computed response times (RT) and error rates. Trials with RT outliers identified with individual Tukey (1977) criterions were removed for analyses of reaction times (2.7% of the trials). On reaction times, we performed a 2 (task: push vs. pull) × 2 (stimulus pupil size: dilated vs. constricted) repeated measures analysis of variance (ANOVA). The analysis revealed no significant differences between conditions, $F < 1$, $p = .84$ (for the detailed findings, see the supplementary materials). This result is not surprising because the response deadline forced participants to respond within a narrow window of time, restricting the variance in RTs (for a similar argument, Payne, 2001).

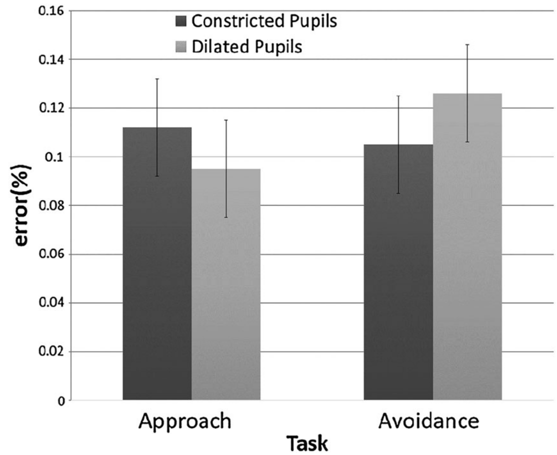

Figure 1. Error rates.

Error rates were, on average, 11%. On errors we computed a 2 (task: push vs. pull) × 2 (stimulus pupil size: dilated vs. constricted) repeated measures ANOVA.[2] We did not find the main effect of task, $F(1,49) = 1.54$, $p = .22$, $\eta_p^2 = .03$ and the main effect of pupil size, $F < 1$, $p = .73$. However, the analysis revealed an interaction effect between task and stimulus pupil size, $F(1,49) = 8.16$, $p = .006$, $\eta_p^2 = .14$ (Figure 1). Considering approach trials, participants were more likely to falsely push (avoid) the joystick in response to constricted pupils ($M = .112$; $SE = .025$) than to dilated pupils ($M = .095$; $SE = .022$), $t(49) = 2.04$, $p = .05$, $d = .29$. On avoidance trials, participants were more likely to falsely pull (approach) the joystick in response to dilated pupils ($M = .126$; $SE = .023$) than to constricted pupils ($M = .105$; $SE = .022$), $t(49) = 2.38$, $p = .02$, $d = .34$. Taken together, these findings revealed that pupil size influenced the accuracy (i.e. errors) of approach and avoidance arm movements. Specifically, participants were especially less prone to make an approach arm movement toward a face with constricted pupils, relative to a face with dilated pupils. In addition, participants were less prone to make an avoidance arm movement toward a face with dilated pupils, relative to a face with constricted pupils.

Discussion

In social interactions, humans look into one another's eyes, follow each other's gazes and grasp emotional signals (Farroni et al., 2002). The eye region largely owes its expressiveness to the pupils which express internal states of mind including emotions and social interest (Hess, 1965; Kret, 2015).

Combining research showing that pupil size predicts impressions (Hess, 1965; Kret et al., 2015; Kret & De Dreu, 2017) with findings showing that approach and avoidance behaviours are sensitive to valenced stimuli (Laham et al., 2015), we investigated whether pupil size predicts basic behavioural reactions of approach and avoidance. Our findings suggest that pupil size influences arm movements indicative of approach or avoidance motivation. In particular, we found that pupil size drives the accuracy rather than the speed of approach and avoidance behaviours. Thus, perceivers are reluctant to approach faces with small pupils relative to faces with large pupils. Moreover, perceivers are less prone to make an avoidance arm movement toward a face with eyes with large pupils, relative to a face with constricted pupils. This asymmetry may reflect an adaptive strategy, wherein it is advantageous to be cautious in approaching a disliked individual (i.e. small pupils; Kret et al., 2015) that may be perceived as threatening for the whole community. Indeed, keeping those individuals at distance may prevent negative consequences for survival. By contrast, it is advantageous to be more prone to approach liked individuals (i.e. large pupils; Kret et al., 2015) in order to foster cooperation.

Collectively, these findings extend prior research on the social implications of pupil dilation. Indeed, while a growing body of research has shown that pupil dilation impacts upon person impression and evaluation (Hess, 1965; Kret et al., 2015; Kret et al., 2015; Laeng et al., 2012; Van Breen et al., 2018), no prior research has investigated how people behaviourally react to their partners' pupil size. Thus, extending prior research, we found that pupil size predicts basic approach and avoidance responses in terms of arm flexion and extension (Laham et al., 2015). Given that previous research has shown that individuals with large pupils are perceived more positively than individuals with small pupils, an interesting avenue for future research would be to test whether pupil dilation of partners during a social interaction is related to actual character and therefore the behavioural consequences elicited by partners pupil size are adaptive. In a similar vein, it should be noted that we used facial stimuli with relatively neutral expressions. Thus, another interesting avenue for future research would be to investigate whether a joint manipulation of pupil size and emotional expressions exacerbates the effects that we found in the current study.

Our findings make a novel contribution to the literature on approach-avoidance actions. While a good deal of work has shown that face stimuli can influence motors cues to approach and avoid (for a review, see Laham et al., 2015), hardly any experimental work has investigated whether merely the pupil region of the stimulus is sufficient to induce arm flexion and extension responses. Our findings suggest that the approach-avoidance task is sensible enough not only to capture the processing of signals from the whole face, but also the processing of specific, subtle cues such as the size of the pupil. In a similar vein, although pupil size provides an implicit, subtle cue, our data show that pupil size has an effect on approach/avoidance motives. Considering that we continuously look into each other's eyes (Farroni et al., 2002), our data suggest that pupil size should be considered more in face perception studies.

Our study has one limitation. Although our findings suggest that pupil size influences the accuracy of approach/avoidance actions, a similar pattern was not reflected on the reaction times. This is somewhat atypical as previous studies on approach-avoidance behaviours did find effects on reaction times (Laham et al., 2015). Although we cannot be sure of how to explain this effect, it is possible that pupils have an early and immediate effect on responding that vanishes during later stages of processing. In that case, error rates could be key in addressing the behavioural consequences of pupil size, as errors typically are committed fast and reflect deviations of the information accumulation process during the early stages of processing (Ratcliff & Rouder, 1998). Although such an explanation sounds plausible, future studies should investigate more systematically how observed pupil size influences the accuracy and speed of approach and avoidance behaviours. Indeed, our study is the first investigating the approach and avoidance implications of pupil size. Clearly, more research is needed to gain more insights in the effects of pupil size and we hope that the present data will be a step on that path.

Ethical standards

All procedures were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Notes

1. We considered only the left eye, as the pilot study (supplementary materials) did not reveal any effect of the side of the square (left vs. right) on the task by pupil size interaction. Moreover, additional data collected in our Lab ($N = 77$; unpublished) revealed that the social implications of pupils size tend to be better captured when the left side of the visual field is taken into account.
2. Preliminary analyses revealed that the approach-avoidance task as a function of pupil size was not influenced by the block ($p = .42$).

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M. Brambilla, M. Biella, and M. Kret conceived the study idea. M. Brambilla and M Biella ran the study. M. Biella conducted the data analysis. M. Brambilla drafted the first version of the manuscript, while M. Biella and M. Kret read and commented on it.

Disclosure statement

No potential conflict of interest was reported by the authors.

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