Original Article

The pupils are the windows to sexuality: pupil dilation as a visual cue to others' sexual interest☆

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ARTICLE INFO

ABSTRACT

In order to ensure successful mating opportunities, it is critical that human perceivers accurately infer others' sexual interests. But how do perceivers achieve these inferences? For over 50 years, scientists have documented that the pupils dilate in response to sexual arousal. Despite the potential importance of this cue for mate selection, however, extant data have focused almost exclusively on the perspective of the individual experiencing arousal. Here, we demonstrate that outside observers exploit pupil dilation as a visible cue to others' sexual interests. We used reverse-correlation methods to derive facial images based on perceivers' mental representations of both state-based (sexually aroused, sexually unaroused) and trait-based (sexually promiscuous, sexually non-promiscuous) markers of sexual interest. Next, we explored the phenotypic features that differentiated these faces, specifically the dilation of the pupils contained within each reverse-correlation image. Consistent with the notion that pupil dilation is a reliable cue to sexual arousal, sexually interested faces contained objectively larger and darker pupils than did sexually disinterested faces. Moreover, these differences were perceptually obvious to naïve observers. Collectively, our results suggest that perceivers attend to an external cue – pupil dilation – when forming decisions about others' state-based and trait-based sexual interests.

1. Introduction

Artists and philosophers have long contended, "The eyes are the windows to the soul." The notion that the eyes convey important information about one's inner state to observers is also backed by scientific evidence. For instance, certain features of the eye – most notably, the pupils – have been shown to change in response to sexual arousal (Dabbs, 1997; Hess & Polt, 1960; Tombs & Silverman, 2004). Moreover, successful human mating requires that perceivers accurately interpret the sexual interests of those around them: The formation of close interpersonal relationships hinges upon inferences about others' sexual receptivity (Buss & Schmitt, 1993). Some have even argued that the motivation to select appropriate mates has shaped the progress of human evolution (Miller, 2000). Despite the weighty consequences of perceivers' inferences about others' sexual interests and the fact that the pupils reliably dilate in response to sexual arousal, it remains unclear whether perceivers exploit pupillary information when inferring others' sexual interests. Here, we examine the communicative function of pupil dilation by testing whether perceivers use the pupils as a marker of others' sexual interests.

The pupils readily adapt to perceptual environments, contracting and relaxing in response to physical changes such as light intensity (Lowenstein & Loewenfeld, 1962) or experiential changes such as habituation (Lowenstein, Feinberg, & Loewenfeld, 1962). Pupil size also covaries with internal psychological states (Janisse, 1977), including sexual interest. Indeed, a seminal study revealed that heterosexual women's pupils tended to dilate when viewing photographs of nude men whereas heterosexual men's pupils tended to dilate when viewing photographs of nude women (Hess & Polt, 1960). Although participants' pupils dilated in response to other visually salient images as well (e.g., mothers and babies), the effect was especially pronounced for sexually arousing stimuli. Subsequent studies replicated this basic pattern with more diverse stimuli, revealing that the pupils also dilate in response to imagined (Whipple, Ogden, & Komisaruk, 1992) and auditory sexual stimuli (Dabbs, 1997). For example, in one study, participants' pupils dilated significantly more to sexually provocative auditory stimuli (e.g., a couple having sex) than to other highly valenced auditory stimuli (e.g., a couple fighting) or controls (e.g., a greeting by a flight attendant; Dabbs, 1997).

The pupillary responses that coincide with exposure to sexually arousing stimuli respond to changes in both stimulus and perceiver. For example, pupil dilation reacts to variation in the sexual interest value of the stimulus itself. In several studies, heterosexual observers' pupil dilation increased linearly as the amount of clothing on opposite-sex models decreased (Hamel, 1974; Nunnally, Knott, Duchnowski, & Parker, 1967). Other studies have revealed that pupil

dilation is sensitive to perceivers' sexual orientations, insofar as gay men's pupils dilated more to photographs of nude men compared to nude women whereas straight men's pupils dilated more to photographs of nude women compared to nude men (Hess, Seltzer, & Shlien, 1965). Perhaps most compelling, pupil dilation is sensitive to hormonal fluctuations. In one recent study, women who were not using hormonal contraceptives experienced a marked increase in pupil dilation when viewing sexually relevant images (e.g., their boyfriends) but not when viewing sexually irrelevant images (e.g., same-sex actresses) during the fertile window of their ovulatory cycle (Laeng & Falkenberg, 2007).

Alongside the robust body of research documenting pupillary responses to sexually provocative stimuli are studies revealing that pupil dilation also coincides with the subjective experience of sexual arousal. For example, pupil dilation is positively correlated with self-reported sexual arousal among women (Hamel, 1974) and with self-reported erection among men viewing pornography (Bernick, Kling, & Borowitz, 1971). Animal models further corroborate this link between arousal and pupil dilation. In one study, copulation with a male rat induced pupil dilation among female rats, with the largest dilation occurring during the male's ejaculation. Severing the pelvic nerve that responds to genital stimulation greatly reduced female rats' pupillary responses to ejaculation, and completely eliminated pupillary responses to genital probing by an experimenter (Szechtman, Adler, & Komisaruk, 1985).

Thus, pupil dilation is a well-documented response to sexual arousal. It remains unclear, however, whether pupillary changes reliably communicate one's sexual interests to others. That is, scientists have yet to determine whether perceivers utilize pupil dilation as a valid cue when forming impressions of others' sexual interests. This possibility is feasible insofar as perceivers utilize the pupils to form more general impressions of others. For example, in two studies, perceivers provided more favorable evaluations of opposite-sex targets who displayed larger rather than smaller pupils (Hess & Petrovich, 1987; Tombs & Silverman, 2004). In another study, men and women who were asked to choose a partner from two confederates matched for attractiveness tended to prefer the confederate with artificially dilated pupils relative to the confederate with un-dilated pupils (Stass & Willis, 1967). These findings suggest that perceivers can and do attend to the pupils when forming impressions of others, although there has been no work on perceivers' use of pupillary information when judging sexual interest specifically.

In summary, prior research has yielded three important observations relevant to our work: (1) pupil dilation is an honest marker of sexual arousal, (2) perceivers use pupillary information to form general impressions of others, and (3) accurate impressions of others' sexual interests are critically important for mating success. Based upon these findings, we propose that perceivers may utilize pupillary information to judge others' sexual interests. We focus our investigation at two different levels of analysis. First, we examine state-based measures of sexual arousal, which assess whether observers believe a target to be aroused or unaroused in a given moment. Second, we examine trait-based measures of broader sexual strategies, which assess whether observers believe a target to be promiscuous or non-promiscuous in their sexual behavior more generally (Simpson & Gangestad, 1991). Recent evidence suggests that these indices of sexual interest may be related, insofar as expression of the dopamine D4 receptor gene is implicated in both behavioral promiscuity (Garcia et al., 2010) and basic sexual arousal processes (Ben Zion et al., 2006). Given this link between low-level physiological arousal and higher-level behavioral strategies, we contend that perceivers will expect sexually interested faces – whether interest is defined as state-based or trait-based – to contain more dilated pupils than sexually disinterested faces.

We used cutting-edge reverse-correlation techniques to test whether pupil dilation serves as a visual cue for inferring others' sexual interests. Reverse-correlation recently gained traction as a data-driven method for illustrating the visual cues that perceivers use to identify individuals belonging to particular social groups (Todorov, Dotsch, Wigboldus, & Said, 2011). In general, the method yields images that are

thought to represent the visual heuristics perceivers use to form impressions of other people. Here, it allowed us to visualize perceivers' mental representations of sexually interested others, limiting demand characteristics while providing a visual snapshot of the cues that differentiate people with varying levels of sexual arousal and promiscuity. In this way, reverse-correlation provided a powerful method for testing whether the pupils are implicated in perceptions of others' sexual interest.

2. Method and materials

The study involved three distinct phases of data collection: (1) a *classification phase*, during which participants completed a reverse-correlation task from which we derived their mental representations of sexually interested and disinterested others, (2) a *validation phase*, during which we tested whether these representations conveyed sexual interest to naïve observers as intended, and (3) an *analysis phase*, during which we examined objective and subjective differences in the pupils contained within images created during the classification phase.

2.1. Classification phase

We created two base images (one female, one male) using FaceGen Modeler, which estimates phenotypic features based upon parameters observed in three-dimensional face scans of the human population (Blanz & Vetter, 1999). We began with FaceGen's average base face and set all phenotypic features (e.g., caricature) at their anthropometric mean. We then used the gender-morphing tool to create one male face of average masculinity and one female face of average femininity while holding other features constant. Thus, the base faces depicted sexually dimorphic phenotypes evident in the human population, with the female face displaying a visibly higher brow line, higher cheekbones, wider eyes, smaller nose, and fuller lips than the male face.

Next, using MATLAB scripts from prior research (Dotsch, Wigboldus, Langner, & van Knippenberg, 2008), we created 700 pairs of faces for each sex by adding or subtracting randomly generated noise patterns from the base images. The noise patterns consisted of 60 sinusoids: 6 orientations (0°, 30°, 60°, 90°, 120°, and 150°) × 5 spatial scales (1, 2, 4, 8, and 16 sinusoid patches), each of which spanned 2 cycles per patch (0, π/2), with random contrasts. We weighted the noise patterns at 0.525 before superimposing them over the base images. The addition of these noise patterns systematically altered the appearance of the face, such that each pair of images looked slightly different despite the fact that they were derived from the same base face.

Finally, we used custom software to present each pair of faces side-by-side in random order to participants. We conducted this study twice: Once to derive mental representations of state-based sexual interest (arousal) and once to derive mental representations of trait-based sexual interest (promiscuity). We describe the methods and results for these two sets of images in tandem below. For the sake of parsimony, we refer to the aroused and promiscuous images collectively as "sexually interested," and the unaroused and non-promiscuous images collectively as "sexually disinterested."

To derive mental representations of state-based sexual interest, 38 undergraduates (32 women) from the University of California, Los Angeles were randomly assigned to evaluate either male ($n = 17$ participants) or female faces ($n = 21$ participants). For all 700 pairs of faces, participants identified the image that best represented a sexually aroused individual by pressing keys labeled *left* and *right*. To derive mental representations of trait-based sexual interests, 40 undergraduates (33 women) from the University of California, Los Angeles were randomly assigned to evaluate either the male ($n = 21$ participants) or female faces ($n = 19$ participants). For all 700 pairs of faces, participants identified the image that best represented a sexually promiscuous individual by pressing keys labeled *left* and *right* (see Fig. 1 for an example).