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Beauty is in the iris: Constricted pupils (enlarged irises) enhance attractiveness

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ABSTRACT

Physical attractiveness profoundly affects a broad array of life experiences and outcomes, and the eyes are an important determinant of physical attractiveness. We investigated whether a particular feature of the eyes – pupil size – affects perceived attractiveness. We present competing theoretical predictions of whether dilated (larger) or constricted (smaller) pupils should appear more physically attractiveness. Youthful features tend to be attractive (i.e., neoteny), and pupil size decreases across the lifespan, so dilated (enlarged) pupils may be more attractive as a signal of youth. Alternatively, constricted (small) pupils may be more attractive because, by revealing more of the iris, they increase both color and brightness of the eyes. The present experiments demonstrate that people appear more attractive when their pupils are constricted (Experiments 1–3). This effect is equally large with black-and-white images, indicating that color per se is not necessary for the effect (Experiment 4). Rather, constricted pupils make eyes appear brighter, which in turn renders the face more attractive (Experiment 5), even when controlling for how colorful the eyes appear (Experiment 6). These results identify constricted pupils as a novel facial feature that enhances attractiveness.

1. Introduction

Beauty brings many social benefits. As Dion, Berscheid, and Walster (1972, p. 285) famously summarized, people infer that “what is beautiful is good.” Consequently, physically attractive people benefit from a halo effect (Batres & Shiramizu, 2022; Dion et al., 1972), and hence they tend to have more friends (Feingold, 1992), earn more money (Hamermesh & Biddle, 1994), and win more elections (Hamermesh, 2006). So then, what physical features are attractive? In this research, we focus on the face. Scholars have sought for decades, if not centuries, to identify physical characteristics that affect facial attractiveness, and they have identified several key features, such as prominent cheekbones and a small nose (Cunningham, 1986). In addition, the eyes have long been recognized as a key component of physical attractiveness. Relatively big eyes render children cute (Glocker et al., 2009; Lorenz, 1943) and adults attractive (Cunningham, 1986). The present research investigates whether a specific attribute of eyes – pupil size – affects attractiveness. As we elaborate below, decades of scientific studies have failed to produce a consensus on whether, how, or why pupil size affects attractiveness. The aim of the present research was to resolve those questions.

2. Why and how might pupil size affect attractiveness?

In this section we present competing theoretical predictions of whether dilated (larger) or constricted (smaller) pupils should appear more physically attractive.

2.1. Neoteny

Neoteny is the persistence of childish or juvenile appearance into adulthood, and neotenous features tend to be attractive in adults because they signal youth (Cunningham, 1986; Jones, 1995). The eyes have several neotenous features, the best-known being eyes that are big relative to the head. Human infants are born with relatively large eyes. As we mature, other facial features (e.g., the nose) grow more than the eyes do, making the eyes appear relatively smaller. Throughout adolescence and early adulthood, however, the horizontal eyelid fissure (i.e., the width of the visible part of the eye) increases, thereby maintaining the eyes' relatively large appearance. The horizontal fissure then

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Table 1
Prior studies of pupil size and physical attractiveness.

Study	Design	*N*	Result(s)
Hicks, Reaney, and Hill (1967)	Experimental	40	Constricted pupils were more attractive in same-sex faces but not in opposite-sex faces
Hess (1975)	Experimental	?	Dilated pupils were more attractive
Tomlinson, Hicks, and Pellegrini (1978)	Experimental	246	Constricted pupils were more attractive in same-sex faces but not in opposite-sex faces
Hicks, Pellegrini, and Tomlinson (1978)	Experimental	170	Constricted pupils were more attractive in attractive opposite-sex faces but not in average opposite-sex faces
Bull and Shead (1979)	Experimental	60	In female faces, 16- and 20-year-old (but not 10-year-old) females and 10-year-old males perceived constricted pupils more attractive, whereas 16- and 20-year-old males perceived dilated pupils more attractive. In male faces, pupil size did not affect attractiveness among either females or males of any age (10-, 16-, or 20-year-olds).
McAfee, Fox, and Hicks (1982)	Experimental	20	No effect of pupil size on attractiveness
Cunningham (1986)	Correlational	75	Faces with more dilated pupils were more attractive
Tombs and Silverman (2004), Study 1	Experimental	59	Dilated pupils were more attractive
Tombs and Silverman (2004), Study 2	Experimental	60	Dilated pupils were more attractive among women attracted to "bad boys" but not among other women.
Harrison, Singer, Rotshtein, Dolan, and Critchley (2006)	Experimental	31	No effect of pupil size on attractiveness
Harrison, Wilson, and Critchley (2007)	Experimental	33	No effect of pupil size on attractiveness
Demos, Kelley, Ryan, Davis, and Whalen (2008)	Experimental	27	No effect of pupil size on attractiveness
Amemiya and Ohtomo (2012)	Experimental	32	No effect of pupil size on attractiveness
Grundl et al. (2012)	Correlational	60	Faces with more dilated pupils were more attractive

Note. "?" indicates that Hess (1975) did not report *N* (or any other statistics).

decreases in middle age (van den Bosch, Leenders, & Mulder, 1999), making the eyes appear smaller. Additionally, the muscle that lifts the eyelid naturally stretches and weakens with age, causing the eyelid to droop and hence the vertical eyelid fissure to decrease. The result of these age-related changes is that eyes appear larger in early adulthood than in midlife and old age. Consequently, big eyes are attractive in adults because they are a signal of youth (Cunningham, 1986; Cunningham, Barbee, & Pike, 1990; Jones, 1995).

Aside from relative size, several specific features of the eye are also neotenous. The *sclera* is the white part of the eye, the *pupil* is the dark central circle, and the *iris* is the surrounding colored ring. Eyes may also contain a *limbal ring*, which is a thin, darker band on the outer edge of the iris. With old age and/or physical illness, the sclera dims and the limbal ring fades. Thus, white sclerae and dark limbal rings increase attractiveness because they indicate youth and health (Brown & Sacco, 2018; Russell, Sweda, Porcheron, & Mauger, 2014).

The pupil is also neotenous: Pupil size decreases across the lifespan, and hence younger people tend to have larger pupils than older people (Birren, Casperson, & Botwinick, 1950). Given that neotenous features tend to be attractive, then, dilated (large) pupils may be more attractive than constricted (small) pupils. Put simply, large pupils may be more attractive because they signal youth (Gründl, Knoll, Eisenmann-Klein, & Prantl, 2012).

2.2. Color and brightness

On the other hand, not all neotenous features are attractive in adults, and in fact there is reason to believe that constricted pupils may be more attractive. Specifically, note that the pupil and iris are complementary: Dilated and constricted pupils reduce and increase iris exposure, respectively. More technically, the iris is an antagonistic system of muscles that expand and contract, whereas the pupil is an opening in the iris. The iris expands or contracts to regulate the amount of light entering the eye through the pupil. Thus, when hypothesizing about pupil size, one implicitly also hypothesizes about iris size.

We suggest that, rather than asking whether pupil size affects attractiveness (as prior research has done), it may be more informative to consider whether iris size affects attractiveness. Pupils are black, emitting little or no light. In contrast, irises are colorful, emitting light and thus appearing bright. Unlike pupils, then, irises could be attractive because they are colorful and/or because they are bright. Indeed, when asked what features of the eye they find attractive, people rarely mention the pupil. Instead, people overwhelmingly mention eye color (i.e., the iris) as the source of attractiveness (Gründl et al., 2012). Moreover, bright eyes are generally more attractive than dim eyes (Provine, Cabrera, & Nave-Blodgett, 2013; Russell et al., 2014). So given that pupil and iris size are inversely related, constricted pupils may be more attractive simply because they reveal more iris, and hence they render the eye brighter and more colorful.

Thus, there are reasons to expect that pupil size affects attractiveness, but the expected direction of the presumed effect is equivocal. As a sign of youth, dilated pupils may be more attractive. Or because they reveal more color and brightness in the iris, constricted pupils may be more attractive. Next, we review the prior research to assess whether the extant literature supports one of these competing hypotheses over the other.

3. Does pupil size affect attractiveness?

In this section we review the prior research on the relation between pupil size and attractiveness. Table 1 summarizes the prior findings on this topic. Each study listed in the table included faces (or eyes) that varied in pupil size and included an explicit measure of physical attractiveness. As evident in the table, the prior results are rather mixed.

Early research by Hess (1965, 1975) was particularly influential, as he promoted a claim that dilated pupils are more attractive than constricted pupils. Hess (1975) described an unpublished study in which participants viewed two female faces, one with constricted pupils and one with dilated pupils. Participants were asked to choose which of the two women appeared happier, more selfish, more attractive, etc. Hess reported that negative traits were more likely to be attributed to whichever woman in the pair had constricted pupils, whereas positive traits were more likely to be attributed to the woman with dilated pupils. He claimed that this study provided evidence that dilated pupils are more attractive than constricted pupils. By most accounts, however, his evidence of a relation between pupil size and attractiveness was rather weak and overstated (see Hicks et al., 1978; Janisse, 1973; Tomlinson et al., 1978). For instance, he did not report any statistics testing his claim.[1]

[1] Hess (1965) promoted the same claim that dilated pupils increase attractiveness. We do not include that earlier study in Table 1, however, because it did not actually include any measure of attractiveness.

Despite legitimate empirical criticisms, other studies have supported Hess's claim. Cunningham (1986) and Gründl et al. (2012) provided direct evidence of a positive relation between pupil size and attractiveness. Notably, however, both of those studies were correlational, and because they did not manipulate pupil size within-faces, they are highly susceptible to stimulus sampling bias. For instance, Cunningham (1986) presented to participants a mixed set of female faces, some of whom were ordinary university undergraduates, and others of whom were contestants in a beauty pageant. Although Cunningham found that the faces with more dilated pupils were more attractive than faces with constricted pupils, this just indicates that the beauty pageant contestants had more dilated pupils in their photos. In our opinion, such correlational evidence is weak and should be interpreted cautiously. Tombs and Silverman (2004) instead supported Hess's claim with two experiments. They reported that dilated pupils are generally more attractive (Study 1), and that this preference was particularly strong among women attracted to "bad boys" rather than "nice guys" or "movers and shakers" (Study 2).

However, other experimental studies have reached the opposite conclusion of Hess (1975). Tomlinson et al. (1978) and Hicks et al. (1978) both manipulated pupil size within-faces, and both found that the faces were generally more attractive with constricted pupils than with dilated pupils. We have three concerns about the validity of those findings, however. First, the constricted pupils in those studies were considerably smaller than what is possible by the human eye.[2] Second and relatedly, the obvious and unnatural manipulation of pupil size may have induced participants to infer and conform to the experimenters' expectations. That is, we believe that these studies were highly susceptible to demand effects. Third, as summarized in Table 1, the finding that constricted pupils are more attractive was qualified by several moderations (Hicks et al., 1967; Hicks et al., 1978; Tomlinson et al., 1978). For instance, Bull and Shead (1979) found that in female faces, 16- and 20-year-old (but not 10-year-old) females and 10-year-old males perceived constricted pupils more attractive, whereas 16- and 20-year-old males perceived dilated pupils more attractive. In male faces, they found that pupil size did not affect attractiveness among either females or males of any age (10-, 16-, or 20-year-olds). In the end, this escalating series of moderations leaves us uncertain what exactly to conclude from this subset of studies, if anything.

McAfee et al. (1982) found no effect of pupil size on attractiveness, but they presented only line drawings of faces. Several other researchers also found no effect, instead using photos of real faces in which pupil size was manipulated (Amemiya & Ohtomo, 2012; Demos et al., 2008; Harrison et al., 2006; Harrison et al., 2007). However, those studies had relatively small samples of participants. In fact, of the five published failures to find an effect of pupil size on attractiveness (Table 1), none had a sample size > 33. Some of those small samples are understandable within their contexts, such as using fMRI (e.g., Amemiya & Ohtomo, 2012; Demos et al., 2008). Nonetheless, such small samples could only be expected to detect quite large effects, and any effect of pupil size on attractiveness may not be that large.

Another general limitation of the prior research is that many of the studies, from Hicks et al. in 1967 through to Cunningham in 1986, used black-and-white images. Again, it is understandable within the technological context of the time that the studies in the 1960s, 70s, and even the 80s used black-and-white images. But if eye color affects attractiveness, as commonly believed (Gründl et al., 2012), then black-and-white images simply are not sufficient for testing whether pupils (and hence irises) affect attractiveness.[3]

So, in summary, from our review of this literature, we conclude that the prior studies are individually and collectively inconclusive regarding whether and how pupil size affects attractiveness. New experiments with larger samples and more naturalistic and better-controlled stimuli are needed to address this question more convincingly.

4. Overview of experiments

As explained above, there are plausible competing hypotheses of whether dilated pupils, as a signal of youth, or constricted pupils, because they reveal more color and brightness in the iris, should be more attractive. Further, the prior literature has yielded extremely mixed evidence. Given the profound effects of physical attractiveness on people's life experiences and outcomes, we thus sought to answer this question more conclusively, and more generally, than the prior research. We present six preregistered experiments testing the effect of pupil size on attractiveness. We report all manipulations, all measures, and all participants in all experiments described herein. All preregistrations, materials, data, and code are available at https://researchbox.org/1829&PEER_REVIEW_passcode=KTRKVN.

Due to the longstanding ambiguity of prior results, we used a broad range of stimuli and methods to provide a more general and conclusive test of how pupil size affects attractiveness. Across experiments, we used both headshots and eyeshots of both female and male targets with either blue or brown irises, in both within- and between-participant designs. In all experiments, we manipulated photos of target people so that in one version they had constricted pupils and in another version, they had dilated pupils. Each participant saw only one version of each photo, and they evaluated the faces' attractiveness. Experiments 1–3 used divergent methods but produced convergent results, showing that people appear more attractive with constricted pupils than with dilated pupils. Experiments 4–6 tested whether constricted pupils are more attractive because they are more colorful, or because they render the eyes brighter. We found the same effect on attractiveness with both color and black-and-white images, indicating that the effect is not due to color (Experiment 4). Rather, constricted pupils make eyes appear brighter, which in turn increases their attractiveness (Experiment 5), even when controlling for how colorful the eyes appear (Experiment 6).

5. Experiment 1

Experiment 1 tested whether pupil size affects physical attractiveness. This study entailed a series of three stimulus pretests, a pilot experiment, and finally a preregistered confirmatory experiment. In Pretest 1, we identified two females and two males who varied in attractiveness (i.e., one attractive female, one average female, one attractive male, and one average male), to test the generality of the presumed effect. In Pretest 2, for each target person, we identified two photos (i.e., two different poses) that were similarly attractive. Next, we created two versions of each photo: one with constricted pupils and one with dilated pupils. This resulted in sixteen experimental photos (4 targets × 2 poses × 2 pupil sizes). Finally, in Pretest 3, we ensured that the constricted- and dilated-pupil versions of our photos appeared

[2] In humans, pupil diameter ranges from about 2–8 mm, and iris diameter ranges from about 10–13 mm (e.g., de Groot & Gebhard, 1952; Hollingsworth et al., 2009). Thus, the smallest pupil within the largest iris produces a minimum pupil size that is 15% of the iris diameter. In their small pupil conditions, Hicks and colleagues (Hicks et al., 1978; Tomlinson et al., 1978) manipulated the pupil to be only 6% of the iris diameter.

[3] A notable exclusion from Table 1 is a study by Kret and De Dreu (2019), who presented to participants a series of images in which a pair of pupils either dilated or constricted dynamically across the trial. In some trials, pupils that initially were constricted became dilated, whereas in other trials, pupils that initially were dilated became constricted. Kret and De Dreu found that dilating pupils were judged more attractive. However, this result is ambiguous for our study of static images: The greater attractiveness of dilating pupils could be due to (a) their initial constricted state, (b) their dynamic dilation, or (c) their final dilated state. That study thus does not address our question of whether constricted or dilated pupils are more attractive.

equally natural.[4]

In the Pilot Experiment ($N = 99$), participants viewed those four matched pairs of photos (4 targets × 2 poses), and for each pair they judged which photo made the person "appear more attractive". Critically, one photo within each pair had constricted pupils, and the other had dilated pupils (counterbalanced across two experimental lists). For instance, half the participants chose between the upper two photos in Fig. 1, and the other half chose between the two lower photos.

This choice-based method is similar to the classic study by Hess (1975). We calculated for each participant the proportion of trials (out of four) in which the photo with constricted pupils was chosen as more attractive. Participants chose the photo with constricted pupils significantly more often than chance ($M = 0.60$, $SD = 0.25$, $t(98) = 3.97$, $p < .001$, Cohen's $d = 0.40$). Finally, we conducted a preregistered, high-powered, confirmatory experiment (described below) that was identical to the Pilot Experiment. Based on the results of that Pilot Experiment, we predicted that the target people would be perceived as more attractive in whichever photos their pupils were constricted.

5.1. Methods

5.1.1. Participants

Sample size was based on power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007). Given the effect size obtained in the pilot experiment ($d = 0.40$), a two-tailed one-sample t-test would require 84 participants to achieve power of 0.95. Because we were concerned that the pilot experiment may have overestimated the true effect size, however, we tripled that recommended N. Thus, we recruited 252 respondents ($M = 33.04$ years, $SD = 11.66$; 41% males) from Prolific online research panel. All reported current residence in the US, UK, or Canada. They were paid £0.20 for participating.

5.1.2. Stimuli

Three stimulus pretests yielded four target people varying in sex and attractiveness, and for each target, two different poses that were similarly attractive. We then manipulated the targets' pupil sizes in those eight photos, and tested whether the two edited versions of each photo appeared equally natural. See the web appendix for details of the three stimulus pretests and the pilot experiment.

After selecting from the pretests two photos for each of four target people, we edited the targets' pupils to be constricted or dilated. Pupil size is often measured as a percentage of iris size. For instance, a pupil with a 4-mm diameter in an 8-mm iris has a pupil size of 50%. Under ordinary conditions of daily life, pupil size ranges from approximately 20% to 70% (Hollingsworth, Bowyer, & Flynn, 2009). We created two versions of each target picture: one in which the pupils were constricted (20% of the iris diameter) and one in which the pupils were dilated (50%). These pupil manipulations are consistent with previous studies (e.g., Kret & De Dreu, 2019), and they are within the typical range of pupil sizes in daily life (Hollingsworth et al., 2009). The pictures were modified in Adobe Photoshop. The original pupils in the photos were erased, the coloring of the iris was copied and pasted into the vacated space, and then the new pupils were pasted into the center of the iris. This resulted in sixteen experimental photos (4 targets × 2 poses × 2 pupil sizes). See Table 2 for pretest and pilot results, and see Fig. 1 for example stimuli.

5.1.3. Procedure

Participants first reported their age and sex, and completed an attention check. All participants passed the attention check, so as preregistered, all were included in the analysis. Participants then completed four trials of a 2-alternative forced choice task. Each trial consisted of one of the four target people shown in two different poses. Within each trial, the target's pupils were constricted in one photo and dilated in the other. To counterbalance the combination of poses and pupils, we created two experimental lists, so that the photos with constricted pupils in one list were dilated in the other list. Each participant saw only one version (constricted or dilated) of each photo. Participants were randomly assigned to one of the lists, the four trials appeared in random order, and the left/right position of the pictures was also randomized. On each trial, participants were asked "In which photo do you think the person appears more attractive?" (cf. Hess, 1975).

5.2. Results and discussion

Results are illustrated in Fig. 2.

5.2.1. Preregistered analyses

We calculated for each participant the proportion of trials in which the photo with constricted pupils was chosen as more attractive. As predicted, a one-sample t-test revealed that participants chose the photo with constricted pupils significantly more often than chance ($M = 0.60$, $SD = 0.27$, $t(251) = 5.54$, $p < .001$, $d = 0.35$). Moreover, following our preregistered analysis plan, we tested whether the targets' sex and general attractiveness affected participants' choices. We conducted a logistic regression on choice (constricted vs. dilated), including the target's sex (female vs. male) and general attractiveness (attractive vs. average) as predictors, clustering standard errors by participants. Neither the target's sex nor attractiveness significantly predicted participants' choices (both $p > .49$). Thus, constricted pupils were judged as more attractive regardless of the target person's sex and overall attractiveness (Fig. 2).

5.2.2. Robustness checks

The small number of trials in this experiment ($N = 4$ trials per participant) renders the result susceptible to false positive, Type I error. We therefore tested the robustness of the result in two ways. First, in addition to testing the effect (i.e., 60% choice of the photo with constricted pupils) against 50% (i.e., chance), here we tested it against the more conservative 55% recommended for studies with few trials (Pollet & Little, 2017; Solomon & Lyons, 2020). The result remained significant even in this more stringent test, $t(251) = 2.63$, $p = .009$, $d = 0.27$). Second, we simulated the likelihood of obtaining our result by chance (Pollet & Little, 2017). Across 100,000 simulations with 252 individuals making four binary choices, the likelihood of obtaining our result (i.e., 60%) by chance approximated zero (i.e., 0 out of 100,000 simulations produced 60% choice or higher). That is, it would be exceedingly rare for participants to choose constricted pupils 60% of the time by chance. Thus, our finding that people appear more attractive with constricted pupils than with dilated pupils was highly robust. Because this finding is novel, however, we sought to conceptually replicate and extend it in Experiment 2.

6. Experiment 2

Many prior studies on pupil size have used stimuli cropped closely around the eyes (e.g., Gründl et al., 2012; Kret & De Dreu, 2019). Whereas our Experiment 1 used headshots (Fig. 1), Experiment 2 instead used such "eyeshots" (see Fig. 3). We also included more stimuli ($N = 40$), used a different paradigm (i.e., rating task), and tested for generalizability across eye colors (i.e., blue, brown). We again conducted a series of pretests and studies. First we developed a set of 20 female eyeshots, half with blue irises and half with brown irises. As in

[4] When manipulating pupil size, it is important to ensure that the different pupil sizes appear equally natural, or else this could confound the manipulation and affect the results. Unfortunately, none of the prior studies on pupil size and attractiveness (see Table 1) has done so, and we believe that this confound may explain some of the prior results (e.g., Hicks et al., 1967, 1978; Tomlinson et al., 1978).

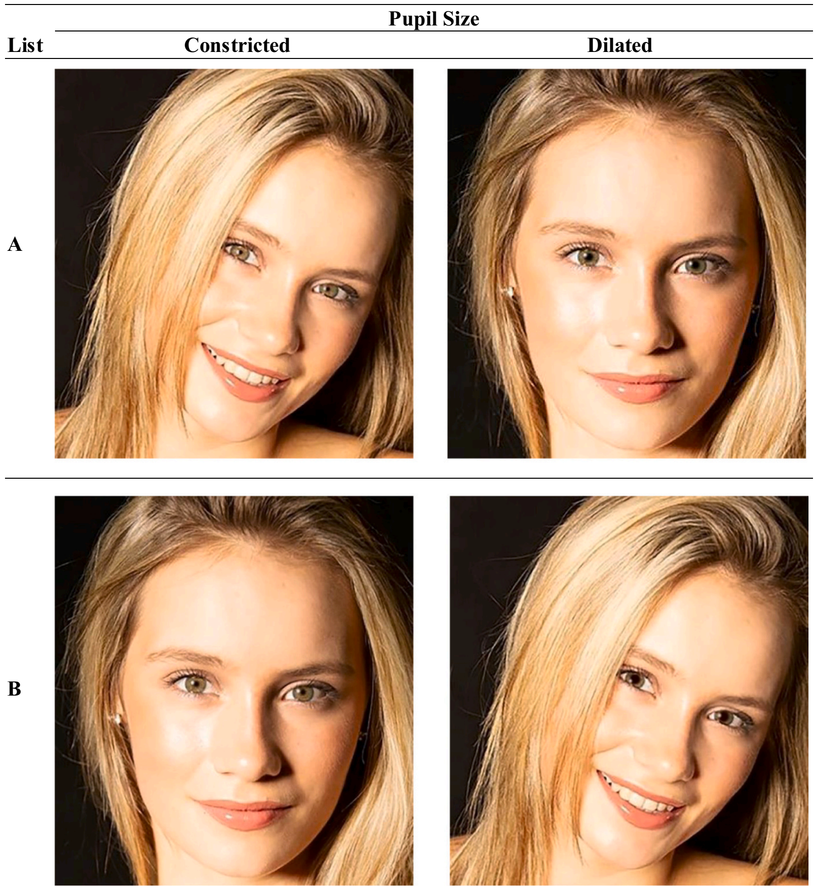

Fig. 1. Examples of stimuli (attractive female) used in Experiment 1.

Table 2
Results of the Stimulus Pretests, Pilot Experiment 1, and Preregistered Experiment 1.

		Pretest 1			Pretest 2		Pretest 3		Pilot Experiment	Preregistered Experiment
		Rated Attractiveness			Attractive		Editing Quality		Attractive	Attractive
Sex	Attractiveness	*M*	*SE*	Pose	Choice	Pupil Size	*M*	*SE*	Choice	Choice
Female	Attractive	5.78	0.14	A	50%	Constricted	2.92	0.23	43%	54%
						Dilated	2.82	0.22	36%	29%
				B	50%	Constricted	2.94	0.23	64%	71%
						Dilated	3.00	0.21	57%	46%
	Average	4.63	0.17	A	31%	Constricted	2.94	0.21	50%	32%
						Dilated	2.96	0.25	16%	22%
				B	69%	Constricted	2.50	0.22	84%	78%
						Dilated	2.86	0.24	50%	68%
Male	Attractive	5.12	0.18	A	49%	Constricted	2.72	0.25	41%	52%
						Dilated	2.60	0.21	36%	35%
				B	51%	Constricted	3.36	0.23	64%	65%
						Dilated	3.00	0.20	59%	48%
	Average	3.57	0.18	A	48%	Constricted	2.38	0.23	57%	49%
						Dilated	2.90	0.26	33%	25%
				B	52%	Constricted	3.12	0.26	67%	75%
						Dilated	3.70	0.28	43%	51%

Note. In Pretest 1 ($N = 49$), participants rated the attractiveness of two female and two male faces on a 1–7 scale. In Pretest 2 ($N = 100$), participants chose which of two unedited poses made the person "appear more attractive." In Pretest 3 ($N = 100$), after editing the faces to have constricted or dilated pupils, participants rated the extent to which "the editing makes the person appear unnatural" on a 1–7 scale (note: lower scores indicate more natural-looking photos). In the Pilot Experiment ($N = 99$), participants chose which of two edited poses (constricted vs. dilated pupils) made the person "appear more attractive." One pose within each pair had constricted pupils, and the other had dilated pupils (counterbalanced across two experimental lists). The Preregistered Experiment ($N = 252$) was identical to the Pilot Experiment.

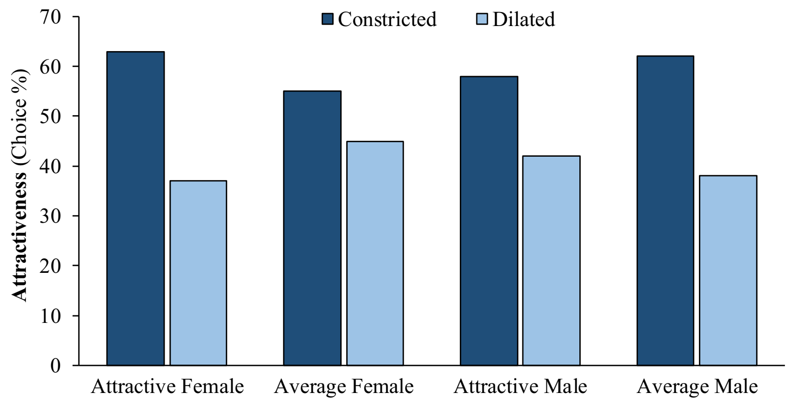

Fig. 2. Results of Experiment 1.

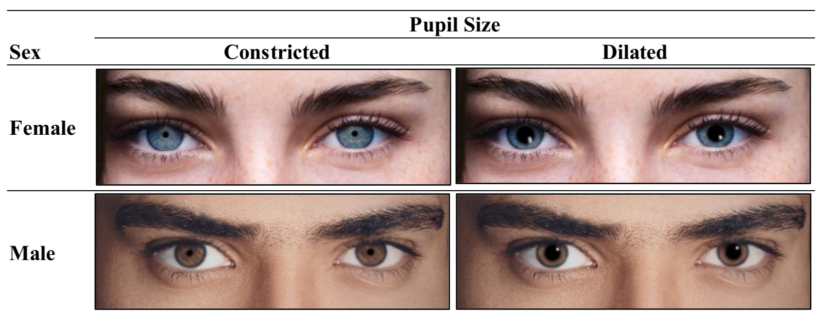

Fig. 3. Examples of stimuli used in Experiment 2.

Experiment 1, we created constricted- and dilated-pupil versions of each face, and a pretest confirmed that they appeared equally natural. In a Pilot Experiment ($N = 141$), we then asked participants to rate the faces on a 3-item measure of physical attractiveness (adapted from Ohanian, 1990; Cronbach $\alpha = 0.91$), using a 1–7 scale. The faces were judged more attractive with constricted pupils ($M = 4.84$, $SD = 0.83$) than with dilated pupils ($M = 4.74$, $SD = 0.83$), $F(1, 140) = 4.64$, $p = .033$, $d = 0.17$. See the web appendix for further details of the Pretests and the Pilot Experiment.

Next we conducted a preregistered, high-powered, confirmatory experiment that was similar to the Pilot Experiment, but with a new set of both female and male eyeshots that were pretested to appear equally natural across pupil sizes. In this main experiment (described below), participants evaluated the attractiveness of opposite-sex faces on a slider scale from 0 ("very unattractive") to 100 ("very attractive").[5]

6.1. Method

6.1.1. Participants

As preregistered, we included our entire participant allocation for the semester in which the study was conducted. Thus, 257 students ($M = 20.98$ years, $SD = 1.61$; 39% males) participated for course credit. Based on the effect size in the Pilot Experiment ($d = 0.17$; see the web appendix), power analysis (G*Power; Faul et al., 2007) indicated that 102 participants would suffice to achieve power of 0.95.

6.1.2. Stimuli

Stimuli consisted of 40 pairs of faces. We categorized the iris color of each face via the Iris Classification System (Seddon, Sahagian, Glynn, Sperduto, & Gragoudas, 1990), which is based on the proportion of the total iris area with brown pigment. Each of the 40 selected faces had predominantly blue or predominantly brown irises.[6] The 40 pairs of faces included 10 females with blue irises, 10 females with brown irises, 10 males with blue irises, and 10 males with brown irises. The faces were cropped closely around the eye region (see Fig. 3), and for each face we created one version in which the pupils were constricted (20–25% of the iris diameter) and one in which the pupils were dilated (50–55%), as in Experiment 1. Thus, there were 80 stimuli in total (2 sexes × 2 iris colors × 10 targets × 2 pupil sizes). As in Experiment 1, the faces were selected from an Editing Quality Pretest ($N = 97$). The constricted ($M = 4.00$, $SD = 1.08$) and dilated versions ($M = 3.89$, $SD = 0.98$) of the faces were matched for editing quality, $p = .251$. That is, the constricted- and dilated-pupil versions appeared equally natural. See Table 3 for a summary of the pilot testing and pretesting results.

6.1.3. Procedure

After indicating their sex and age, participants were funneled to an experimental list including only opposite-sex faces. Within each target-sex condition, the stimuli were further divided among two experimental lists. Each list included the constricted-pupil version of 10 faces and the dilated-pupil version of the other 10 faces. The two versions of each face were counterbalanced across lists, so that each participant evaluated only one version (either dilated or constricted) of each face. Within each list, half of the faces had blue irises, and half had brown irises. Thus, each list included 20 different opposite-sex eyeshots: 5 constricted blue

[5] It is common among studies of attractiveness to include only opposite-sex targets (e.g., Cunningham, 1986; Demos et al., 2008), as some male participants are reluctant to rate male targets as attractive.

[6] In this iris classification system, iris color is graded (1–5) by comparing each target face with a set of four standard photographs (Standards A-D). Standards A-B represent predominantly blue irises (low percentage of brown pigment), whereas Standards C—D represent predominantly brown irises (high percentage of brown pigment). Grades 1–2 indicate a predominantly blue iris, and grades 3–5 indicate a predominantly brown iris.

Table 3
Results of the Stimulus Pretests, Pilot Experiment 2, and Preregistered Experiment 2.

			Pilot Experiment				Preregistered Experiment			
			Pretest 1		Pilot Experiment		Pretest 2		Experiment 2	
Target Characteristics			Editing Quality		Attractiveness		Editing Quality		Attractiveness	
Sex	Iris Color	Pupil Size	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Female	Blue	Constricted	4.19	0.21	4.99	0.09	4.43	0.17	62.82	1.48
		Dilated	3.99	0.21	4.90	0.08	4.39	0.18	58.84	1.35
	Brown	Constricted	3.87	0.22	4.69	0.09	3.97	0.17	49.84	1.48
		Dilated	4.11	0.21	4.56	0.08	3.87	0.15	45.47	1.55
Male	Blue	Constricted	–	–	–	–	3.82	0.18	46.08	1.19
		Dilated	–	–	–	–	3.73	0.18	41.89	1.09
	Brown	Constricted	–	–	–	–	3.78	0.18	48.61	1.19
		Dilated	–	–	–	–	3.57	0.16	45.72	1.25

Note. Pretest 1 ($N = 80$) served to ensure that the stimuli used in the Pilot Experiment 2 were equal in editing quality across pupil sizes. In the Pilot Experiment ($N = 141$), participants rated the faces on a 3-item measure of physical attractiveness on a 1–7 scale. Pretest 2 ($N = 100$) served to ensure that the stimuli used in Experiment 2 were equal in editing quality across pupil sizes. In the Preregistered Experiment 2 ($N = 257$), participants evaluated the attractiveness of opposite-sex faces on a slider scale from 0 ("very unattractive") to 100 ("very attractive").

eyes, 5 constricted brown eyes, 5 dilated blue eyes, and 5 dilated brown eyes.

On each trial, the face first appeared on-screen alone for 5 s, during which time participants were prevented from advancing to the next page. After 5 s, the question "How attractive is this face?" appeared below the face. Participants responded on a slider scale from 0 ("very unattractive") to 100 ("very attractive"). The slider was preset on 50 at the beginning of each trial. After rating all 20 faces, participants reported their own eye color (options: blue, green, or brown; as in Laeng, Mathisen, & Johnsen, 2007).

6.2. Results and discussion

Results are illustrated in Fig. 4.

6.2.1. Preregistered analyses

We conducted a 2 (target iris color: blue vs. brown; within) × 2 (pupil size: constricted vs. dilated; within) × 2 (target sex: male vs. female; between) mixed ANOVA. As predicted, faces appeared more attractive with constricted pupils ($M = 51.84$, $SD = 13.08$) than with dilated pupils ($M = 47.98$, $SD = 13.32$), $F(1, 255) = 46.74$, $p < .001$, $d = 0.45$. The effect of pupil size did not interact with target iris color ($p = .65$) or target sex ($p = .57$), nor was the 3-way interaction significant ($p = .40$). Thus, faces appeared more attractive with constricted pupils, regardless of the target's sex and iris color (see Fig. 4).

The interaction of the target's sex and iris color was significant, $F(1, 255) = 117.42$, $p < .001$, $d = 0.59$. As evident in Fig. 4, male participants rated female targets more attractive with blue eyes ($M = 60.83$, $SD = 12.85$) than with brown eyes ($M = 47.65$, $SD = 13.45$, $t(100) = 11.03$, $p < .001$, $d = 1.00$). In contrast, female participants rated male targets more attractive with brown eyes ($M = 47.17$, $SD = 13.13$) than blue eyes ($M = 43.98$, $SD = 12.99$, $t(155) = 3.40$, $p < .001$, $d = 0.24$).

Prior research has found that effects of eyes on perceived attractiveness may depend on the respondent's own eye color (Laeng et al., 2007). Of our 257 participants, 171 had brown eyes and 86 had blue or green eyes. Following our preregistered plan, we conducted a 2 (target iris color) × 2 (target pupil size) × 2 (participant iris color: blue/green vs. brown; between) mixed ANOVA. Participant iris color did not interact with target iris color or pupil size, both $p > .27$. Thus, regardless of the participant's eye color and the target's eye color, faces appeared more attractive with constricted pupils than with dilated pupils.

6.2.2. Robustness check

In the analyses above, we used the Iris Classification System (Seddon et al., 1990) to classify the targets' irises as either predominantly blue or predominantly brown. To test the robustness of our results, we replicated our analyses, using an alternative measure of iris color: the targets' objective iris hue values obtained from digital image processing software (Adobe Photoshop). As in prior research, we selected a squared area within the iris, and we calculated the average hue value based on the HSB system (Gründl et al., 2012). In this system, all hues have a value between 0° and 360°, with 0°, 120°, and 240° respectively

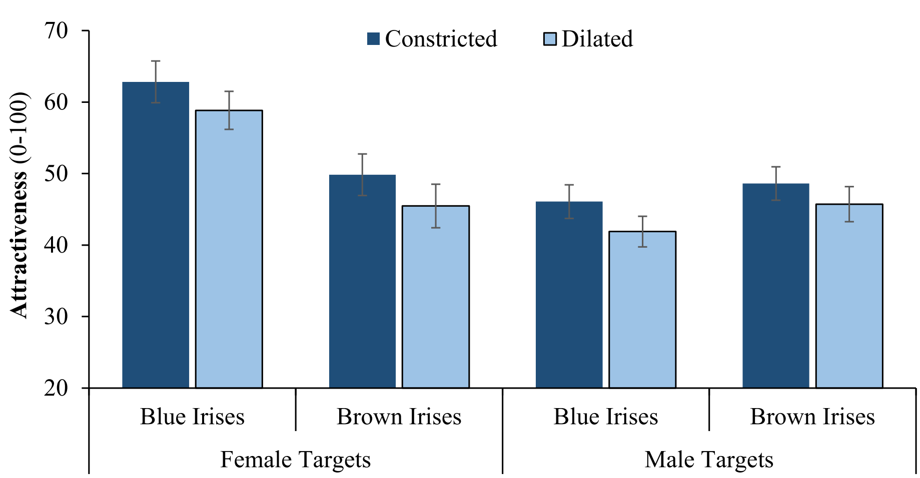

Fig. 4. Results ($M \pm CI_{95}$) of Experiment 2.

indicating pure red, pure green, and pure blue. We regressed attractiveness ratings on pupil size, target sex, this continuous measure of iris hue, and their interactions, clustering standard errors at individual level. As in the main analysis reported above, pupil size again significantly predicted attractiveness, $B = 3.33$, $SE = 1.26$, $t(256) = 2.65$, $p = .009$, $CI_{95} = [0.85, 5.80]$. Thus, our results are robust to alternative eye color measurements. See the web appendix for further detail.

7. Experiment 3

Experiments 1 and 2 demonstrate that people appear more attractive when their pupils are constricted than when they are dilated, but those studies do not reveal whether constricted pupils increase attractiveness and/or dilated pupils decrease it. Experiment 3 therefore included constricted (25% of iris diameter), neutral (40%), and dilated (55%) pupils, as shown in Fig. 5. We predicted that the face would appear more attractive with constricted pupils than with dilated pupils, but we were theoretically agnostic regarding the relative effect of the neutral-pupil condition. This experiment also provides the first fully between-participants test of the effect.

7.1. Method

7.1.1. Participants

We conducted this experiment with two independent samples on Prolific. Sample 1 included 602 respondents. Because the predicted effect was directional but nonsignificant, we conducted a direct replication with 605 additional participants (sample 2). We report results from the combined sample of 1207 respondents ($M = 42.5$ years, $SD = 13.01$; 45% males), all of whom reported current residence in the UK and were paid £0.15 for participating. After excluding eight participants who failed the attention check, the final sample consisted of 1199 participants.

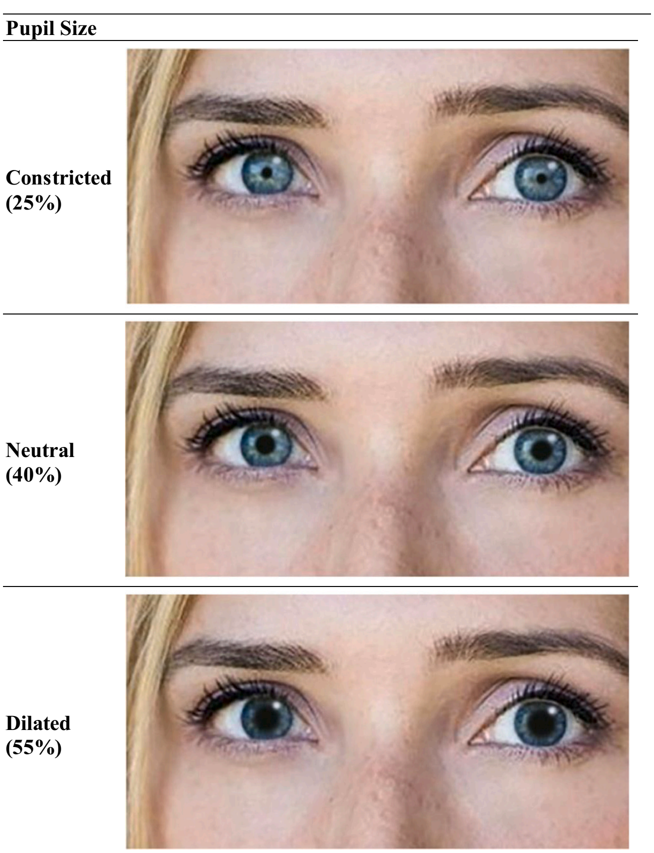

Fig. 5. Stimuli used in Experiment 3.

7.1.2. Stimuli

Stimuli consisted of three versions of an eyeshot of a female with blue eyes (see Fig. 5), sampled from Experiment 2. The constricted-pupil (25% of the iris diameter) and dilated-pupil (55%) stimuli were those used in Experiment 2. Those constricted-pupil ($M = 4.35$, $SD = 1.60$) and dilated-pupil ($M = 4.48$, $SD = 1.69$) versions of the stimulus did not differ in perceived naturalness of the image, $t(49) = -0.291$, $p = .772$ (as determined in the Editing Quality Pretest of Experiment 2). The neutral-pupil version was midway between them in pupil size (40%).

7.1.3. Procedure

Participants were randomly assigned to view either the constricted-, neutral-, or dilated-pupil version of the stimulus. After the face appeared on-screen for 5 s, participants evaluated attractiveness via one item, “How attractive is this face?”, on a slider scale from 0 (“very unattractive”) to 100 (“very attractive”).

7.2. Results and discussion

A 2 (sample: 1, 2) × 3 (pupil size: constricted, neutral, dilated) ANOVA revealed a significant main effect of pupil size, $F(2, 1193) = 5.16$, $p = .006$, $\eta^2 = 0.009$. As predicted, the face appeared more attractive with constricted pupils ($M = 76.01$, $SD = 15.02$) than with dilated pupils ($M = 72.54$, $SD = 15.61$), $t(799) = 3.20$, $p < .001$, $d = 0.23$. As shown in Fig. 6, neutral pupil size fell approximately midway between those two conditions ($M = 74.62$, $SD = 15.46$), and did not differ significantly from either the constricted ($t(798) = 1.29$, $p = .197$, $d = 0.09$) or dilated ($t(795) = 1.89$, $p = .059$, $d = 0.13$) condition. Neither the main effect of sample ($p = .445$) nor its interaction with pupil size ($p = .174$) was significant. Thus, pupil size had a linear effect on attractiveness.

8. Experiment 4

Experiments 1–3 reveal that constricted pupils are more attractive than dilated pupils. But why, exactly, is that so? Irises, by virtue of being colorful, are brighter than pupils, which are black. So under normal viewing conditions, as in Experiments 1–3, constricted pupils increase both the color and the brightness of the eyes. Consequently, it is unclear whether color or brightness underlies the effect. And indeed, both explanations are theoretically plausible. On one hand, people overwhelmingly cite iris color as the source of attractiveness in eyes (Gründl et al., 2012). On the other hand, bright sclerae are more attractive than dim sclerae (Provine et al., 2013; Russell et al., 2014), and the same may be true of irises. To discriminate between these explanations, in Experiment 4 we manipulated the chromaticity of the face images. That is, we presented a face either in color (as in Experiments 1–3) or in black-and-white, in a 2 (pupil size: constricted, dilated) × 2 (chromaticity: color, black-and-white) between-participants design (see Fig. 7). If the effect is due to increased brightness, then we should find a main effect of pupil size without interaction, such that constricted pupils increase attractiveness in both color and black-and-white. Alternatively, if the effect is due to increased color, then we should observe an interaction, such that constricted pupils increase attractiveness in color images but not in black-and-white images.

8.1. Method

8.1.1. Participants

We adhered to our general lab rules of (a) sampling 100 participants per condition and (b) doubling the N when testing for an interaction. Thus, given four between-participant conditions in this experiment, we recruited 800 respondents ($M = 40.74$ years, $SD = 14.37$; 49% males) from Prolific. All reported current residence in the UK or Ireland and

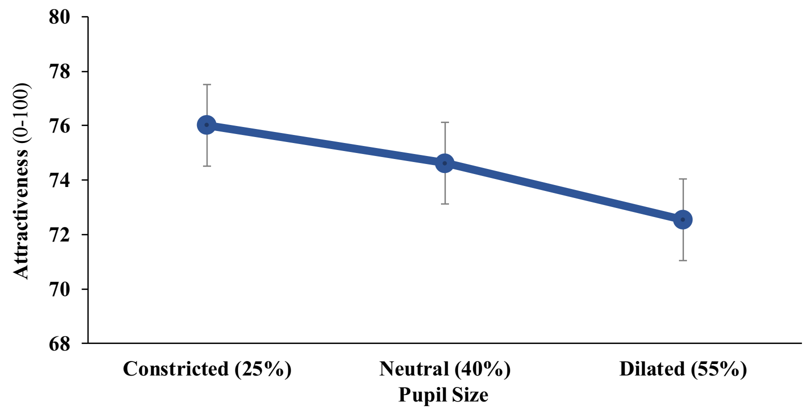

Fig. 6. Results ($M \pm CI_{95}$) of Experiment 3.

were paid £0.12 for participating. One participant failed the attention check, so as preregistered, they were excluded from the analysis, leaving 799 participants in our analyses.

8.1.2. Stimuli

We created four versions of a single headshot taken from a cosmetics ad. We chose a blue-eyed model because blue eyes are generally thought to be most attractive (Gründl et al., 2012), so blue eyes provide a strong test of whether color underlies the effect of pupil size on attractiveness. We first created constricted-pupil (25% of the iris diameter) and dilated-pupil (55%) versions of the headshot. As in the preceding studies, an Editing Quality Pretest ($N = 100$) indicated that the constricted ($M = 3.72$, $SD = 1.73$) and dilated pupil versions ($M = 4.12$, $SD = 1.85$) of the face were equal in editing quality, $t(98) = 1.12$, $p = .268$ (see the web appendix). We then created black-and-white versions of both images by converting them to grayscale. This produced four stimuli, shown in Fig. 7.

8.1.3. Procedure

Participants were randomly assigned to view only one of the four images, and the trial procedure was similar to that of Experiment 2. After the face appeared on-screen for 5 s, two questions appeared below it ("How [attractive / beautiful] is this model?"; $r = 0.88$). Participants responded on slider scales from 0 ("not at all") to 100 ("very much"), preset on 50. Finally, participants reported their own eye color, as in Experiment 2.

8.2. Results and discussion

Results are illustrated in Fig. 8.

We conducted a 2 (pupil size: constricted vs. dilated) × 2 (chromaticity: color vs. black-and-white) ANOVA. Overall, the model appeared more attractive with constricted pupils ($M = 78.89$, $SD = 17.75$) than with dilated pupils ($M = 69.50$, $SD = 17.76$), $F(1, 795) = 55.93$, $p < .001$, $d = 0.53$. Chromaticity had no effect ($p = .12$); the model was equally attractive in color and in black-and-white. And critically, there was no interaction ($p = .99$). As shown in Fig. 8, the model appeared more attractive with constricted pupils, regardless of whether the images were in color ($M_{constricted} = 77.90$, $SD = 16.67$ vs. $M_{dilated} = 68.51$, $SD = 18.76$, $t(396) = 5.28$, $p < .001$, $d = 0.53$) or black-and-white ($M_{constricted} = 79.87$, $SD = 14.93$ vs. $M_{dilated} = 70.50$, $SD = 20.57$, $t(399) = 5.30$, $p < .001$, $d = 0.53$). As preregistered, we interpret this pattern of results as indicating that the effect of pupil size on attractiveness is due to brightness, not color. Neither participants' sex ($p = .99$) nor participants' eye color ($p = .88$) interacted with pupil size, indicating that neither of those participant factors moderated the effect of the target's pupil size on attractiveness.

9. Experiment 5

Experiments 1–3 establish that people appear more attractive with constricted pupils than with dilated pupils. Experiment 4 suggests that this effect is due to eyes with constricted pupils appearing brighter. Experiment 5 more directly tests this explanation by examining whether perceived brightness mediates the effect of pupil size on attractiveness.

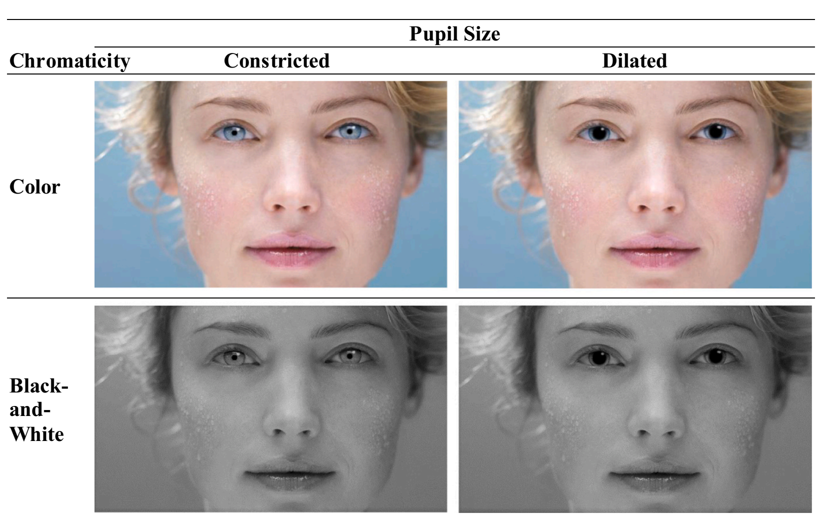

Fig. 7. Stimuli used in Experiment 4.

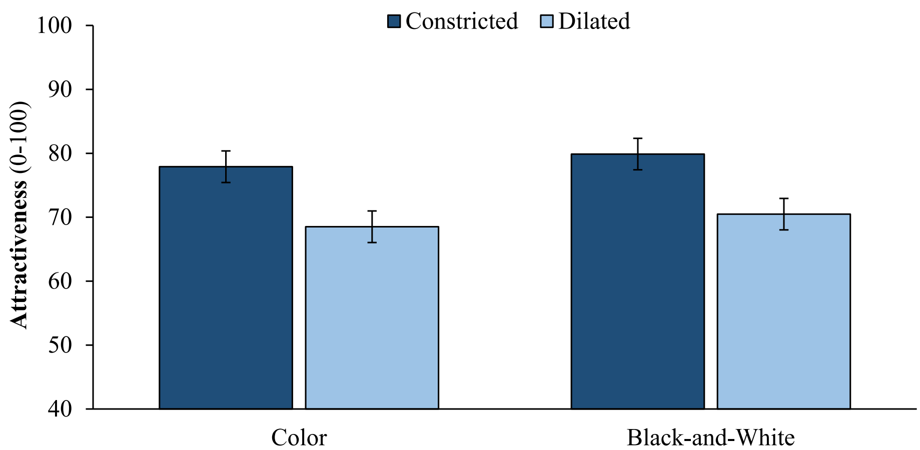

Fig. 8. Results ($M \pm CI_{95}$) of Experiment 4.

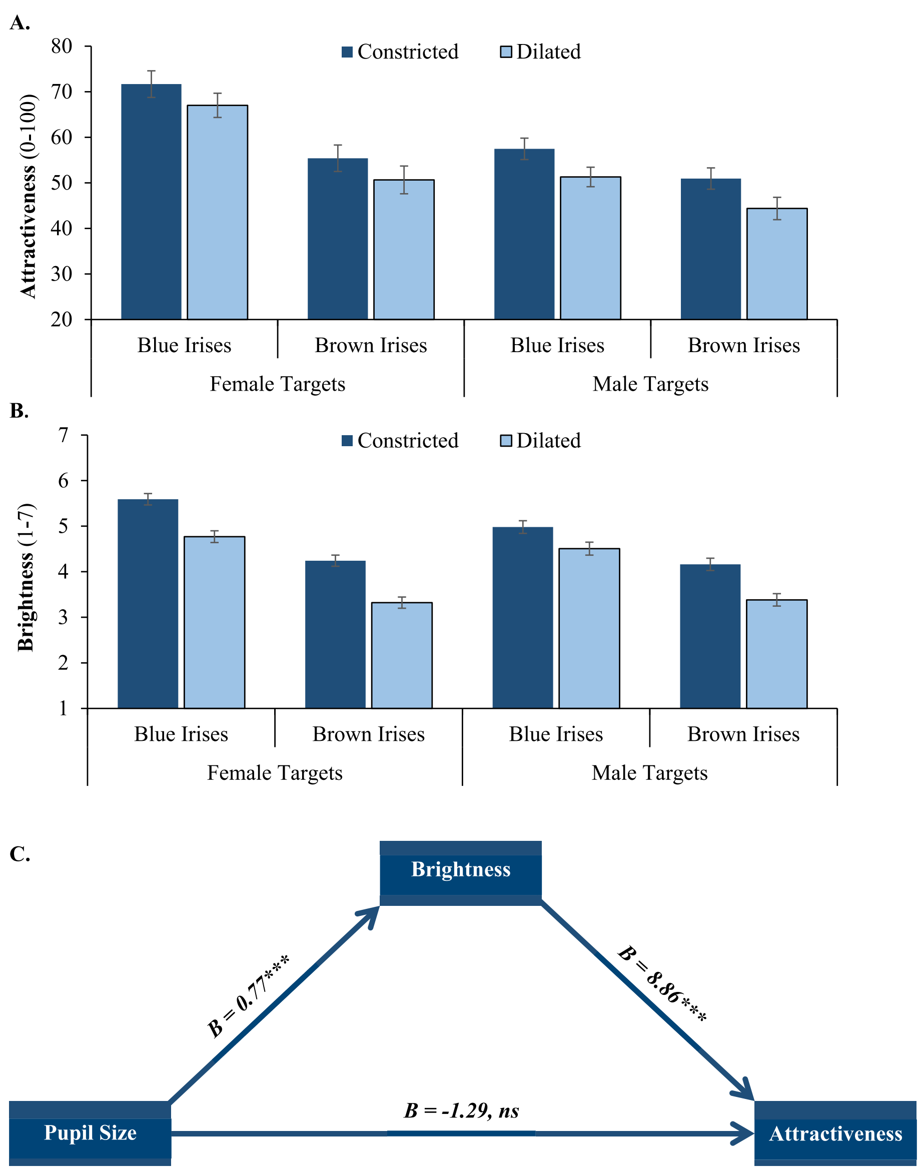

Fig. 9. Attractiveness (panel A; $M \pm CI_{95}$), brightness (panel B; $M \pm CI_{95}$), and mediation results (panel C; *** $p < .001$) of Experiment 5.

9.1. Method

9.1.1. Participants

As preregistered, we included our entire participant allocation for the semester in which the study was conducted. The study was conducted shortly after the Covid-19 pandemic had begun to abate (in March 2022), so although we anticipated approximately 400 students, we did not reach that target. Ultimately 307 students ($M = 20.53$ years, $SD = 1.59$; 55% males) chose to attend our in-person lab session. Based on the effect size in Experiment 2 ($d = 0.45$), which had the same basic design, power analysis (Faul et al., 2007) indicated that 67 participants would suffice to achieve power of 0.95.

9.1.2. Procedure

Experiment 4 replicated the design and procedure of Experiment 2 (i.e., participants evaluated 20 opposite-sex eyeshots), with two exceptions. First, here participants evaluated the attractiveness of the person's eyes on two 101-point sliding scales ("How [attractive/beautiful] are these eyes?"; from 0 = "not at all" to 100 = "very much"; $r > 0.79$). Second, we additionally included a measure of eye brightness. Participants rated the eyes' brightness on two 7-point scales ("This person's eyes are [bright/shiny]; from 1 = "strongly disagree" to 7 = "strongly agree"; $r > 0.65$). Using different scales for attractiveness (0–100) and brightness (1–7) prevented participants from providing the same rating on both measures; this could be important for discriminant validity between the presumed mediator (brightness) and dependent variable (attractiveness). We also counterbalanced the order of presentation of the two measures, so we could test whether the order affects participants' evaluations.

9.2. Results and discussion

Results are illustrated in Fig. 9.

9.2.1. Attractiveness

Replicating our prior findings, a 2 (target iris color: blue vs. brown; within) × 2 (pupil size: constricted vs. dilated; within) × 2 (target sex: male vs. female; between) mixed ANOVA on attractiveness revealed a significant main effect of pupil size, $F(1, 305) = 78.88$, $p < .001$, $d = 0.20$. As predicted, eyes appeared more attractive with constricted pupils ($M = 58.87$, $SD = 15.07$) than with dilated pupils ($M = 53.33$, $SD = 14.19$). The effect of pupil size did not interact with target iris color ($p = .80$) or target sex ($p = .18$), nor was the 3-way interaction significant ($p = .87$).

As in Experiment 2, the interaction between the target's sex and iris color was significant, $F(1, 305) = 42.57$, $p < .001$, $d = 0.53$. As evident in Fig. 9, male participants rated female targets with blue eyes more attractive ($M = 69.34$, $SD = 14.72$) than those with brown eyes ($M = 53.02$, $SD = 14.93$), $t(168) = 15.71$, $p < .001$, $d = 1.20$. Female participants also rated male targets with blue eyes more attractive ($M = 54.37$, $SD = 15.37$) than those with brown eyes ($M = 47.66$, $SD = 15.26$), though this effect was significantly attenuated, $t(137) = 6.61$, $p < .001$, $d = 0.56$.

Furthermore, a 2 (target iris color) × 2 (pupil size) × 2 (target sex) × 2 (participant iris color: blue/green vs. brown; between) mixed ANOVA revealed that pupil size did not interact with the participant's iris color ($p = .46$). The 3-way and 4-way interactions were also nonsignificant (all $p > .45$). Thus, faces appeared more attractive with constricted pupils, regardless of both the sex and iris color of both the participant and the target.

9.2.2. Brightness

Following a similar pattern, a 2 (target iris color) × 2 (pupil size) × 2 (target sex) mixed ANOVA on perceived brightness revealed a significant main effect of pupil size, $F(1, 305) = 320.09$, $p < .001$, $d = 0.66$. As predicted, participants perceived eyes as brighter with constricted pupils ($M = 4.74$, $SD = 0.67$) than with dilated pupils ($M = 3.99$, $SD = 0.68$).

Pupil size interacted with iris color, $F(1, 305) = 9.03$, $p = .003$, $d = 0.25$. Specifically, the effect of pupil size on perceived brightness was larger among brown irises ($M_{\text{constricted}} = 4.16$, $SD = 0.78$ vs. $M_{\text{dilated}} = 3.38$, $SD = 0.80$, $t(137) = 5.58$, $p < .001$, $d = 0.89$) than among blue irises ($M_{\text{constricted}} = 4.98$, $SD = 0.90$ vs. $M_{dilated} = 4.50$, $SD = 0.76$, $t(137) = 10.40$, $p < .001$, $d = 0.46$).

Pupil size also interacted with sex, $F(1, 305) = 8.52$, $p = .004$, $d = 0.26$, such that the effect of pupil size was larger among males evaluating female targets ($M_{\text{constricted}} = 4.92$, $SD = 0.64$ vs. $M_{dilated} = 4.04$, $SD = 0.71$, $t(168) = 15.97$, $p < .001$, $d = 1.23$) than among females evaluating male targets ($M_{\text{constricted}} = 4.57$, $SD = 0.70$ vs. $M_{dilated} = 3.95$, $SD = 0.64$, $t(168) = 9.76$, $p < .001$, $d = 0.83$). The 3-way interaction was nonsignificant ($p = .13$).

Moreover, a 2 (target iris color) × 2 (pupil size) × 2 (target sex) × 2 (participant iris color) mixed ANOVA revealed that pupil size did not interact with the participant's iris color ($p = .65$), and the 3-way and 4-way interactions were also nonsignificant (all $p > .16$). Thus, participants perceived eyes as brighter with constricted pupils, regardless of sex and iris color.

Finally, additional analyses revealed that the order of presentation of the two measures (i.e., brightness first vs. attractiveness first) did not interact with pupil size on either attractiveness ($p = .79$) or brightness ($p = .57$). Thus, the effects of pupil size on brightness and attractiveness were the same regardless of measurement order.

9.2.3. Mediation

The correlation between brightness ratings and attractiveness ratings was significant but not overly strong ($r = 0.52$, $p < .001$), suggesting sufficient discriminant validity between the presumed mediator (brightness) and the dependent variable (attractiveness). Indeed, this correlation is within the "sweetspot" for meaningful mediation (Pieters, 2017). We therefore conducted bootstrap mediation analysis (Montoya, 2019, model 1, 10 K samples), which revealed a significant indirect effect of pupil size on attractiveness via perceived brightness, $B = 6.74$, $CI_{95} = [5.48, 8.19]$. That is, as predicted, brightness mediated the effect of pupil size on attractiveness (see Fig. 9C). Constricted pupils increased attractiveness by increasing the perceived brightness of the eyes.

10. Experiment 6

Experiment 5 demonstrated that constricted pupils make eyes appear brighter, which in turn may make them more attractive. However, constricted pupils also reveal more *color* in the iris, and crucially, more colorful eyes are more attractive (Gründl et al., 2012). Thus, the results of Experiment 5 may be attributed to the perceived colorfulness of the eyes, rather than their perceived brightness. To provide a more stringent test of whether brightness underlies the effect of pupil size on attractiveness, Experiment 6 conceptually replicated Experiment 5, but additionally included a measure of how colorful the eyes are.

10.1. Method

10.1.1. Participants

We recruited 400 respondents ($M = 43.30$ years, $SD = 14.36$; 45% males) on Prolific. All reported current residence in the UK and were paid £0.15 for participating.

10.1.2. Stimuli

Stimuli were constricted-pupil (25% of iris diameter) and dilated-pupil (55%) versions of a single eyeshot, of a female with brown eyes, sampled from Experiments 2 and 5 (see Fig. 10). The constricted-pupil ($M = 4.42$, $SD = 1.68$) and dilated-pupil ($M = 3.96$, $SD = 1.70$) versions of the stimulus did not differ in perceived naturalness of the image, $t(49) = 0.98$, $p = .447$ (as determined in the Editing Quality Pretest of

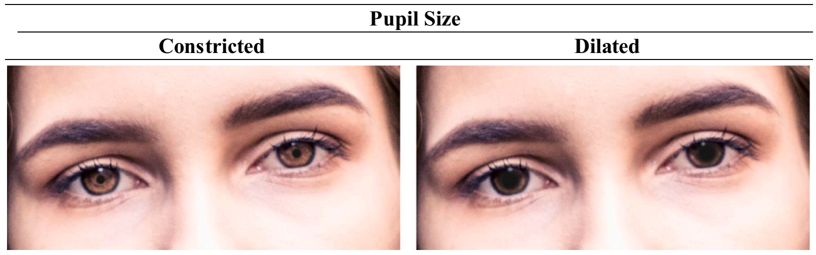

Fig. 10. Stimuli used in Experiment 6.

Experiment 2).

10.1.3. Procedure

Participants were randomly assigned to view either the constricted- or dilated-pupil version of the eyeshot. After it appeared on-screen for 5 s, participants evaluated the attractiveness (two items; $r = 0.90$) and brightness of the person's eyes (two items; $r = 0.63$). The procedure was identical to Experiment 5, except that we added a measure of how colorful the eyes are ("This person's eyes are colorful"; from 1 = "strongly disagree" to 7 = "strongly agree") in the block measuring brightness (order randomized).

10.2. Results and discussion

10.2.1. Attractiveness, brightness, and colorfulness

We conducted independent samples *t*-tests on attractiveness, brightness, and colorfulness. As predicted, the eyes appeared more attractive with constricted pupils ($M = 74.85$, $SD = 16.88$) than with dilated pupils ($M = 68.81$, $SD = 18.96$), $t(398) = 3.36$, $p < .001$, $d = 0.34$. Also as predicted, they appeared brighter with constricted pupils ($M = 4.90$, $SD = 1.10$) than with dilated pupils ($M = 3.61$, $SD = 1.34$), $t(398) = 10.56$, $p < .001$, $d = 1.06$. Finally, the eyes also appeared more colorful with constricted pupils ($M = 4.75$, $SD = 1.42$) than with dilated pupils ($M = 3.62$, $SD = 1.46$), $t(398) = 7.82$, $p < .001$, $d = 0.78$). That is, constricted pupils rendered the eyes not only brighter and more attractive, but also more colorful.

Separate 2 (pupil size: constricted vs. dilated) × 2 (order of the presentation: attractiveness first vs. brightness/colorfulness first) ANOVAs on attractiveness, brightness, and colorfulness revealed that the order of presentation of the measures did not interact with pupil size on any of the three measures (all $p > .55$). Thus, the effects of pupil size on attractiveness, brightness, and colorfulness were the same regardless of measurement order.

10.2.2. Mediation

The correlation between brightness ratings and attractiveness ratings was significant but not overly strong ($r = 0.51$, $p < .001$), suggesting sufficient discriminant validity between the presumed mediator (brightness) and the dependent variable (attractiveness). Indeed, this correlation is within the "sweetspot" for meaningful mediation (Pieters, 2017). However, colorfulness also correlated significantly with both brightness ($r = 0.64$, $p < .001$) and attractiveness ($r = 0.48$, $p < .001$). As preregistered, we therefore conducted bootstrap mediation analysis (Hayes & Preacher, 2014, PROCESS model 4, 10 K samples) with pupil size as independent variable (dilated = 0, constricted = 1), brightness as mediator, colorfulness as covariate, and attractiveness as dependent variable. As predicted, the indirect (mediation) effect of pupil size on attractiveness via brightness was significant, $B = 3.94$, $CI_{95} = [2.41, 5.76]$. We also conducted an exploratory analysis with brightness and colorfulness included as parallel mediators. Although both brightness ($B = 6.76$, $CI_{95} = [4.57, 9.20]$) and colorfulness ($B = 3.58$, $CI_{95} = [2.04, 5.43]$) significantly mediated the effect of pupil size on attractiveness, the effect through brightness was significantly larger than the effect through colorfulness, $B = 3.18$, $CI_{95} = [0.16, 6.33]$. Thus, constricted pupils increased attractiveness primarily by increasing the eyes' apparent brightness.

11. General discussion

Physical attractiveness profoundly affects a broad array of life experiences and outcomes, from mate selection (Walster, Aronson, Abrahams, & Rottman, 1966) to salary (Hamermesh & Biddle, 1994) and psychological well-being (Umberson & Hughes, 1987). The face is perhaps the most important determinant of physical attractiveness, and specific features such as a small nose and large eyes are particularly attractive (e.g., Cunningham, 1986; Lorenz, 1943). We investigated whether a particular feature of the eyes – the relative sizes of the pupil and iris – affects perceived attractiveness. Despite fourteen previous studies investigating this question, conducted across more than half a century, the prior research was wholly inconclusive on whether or how pupil size affects attractiveness (see Table 1).

We conducted a series of high-powered, preregistered experiments with a greater number and broader variety of faces than prior studies, and with better-controlled stimuli and more varied methods and measures. Across experiments, we included nearly 50 different faces. We used both female and male faces, of varying attractiveness, and with varying eye colors. We used both headshots (e.g., Hess, 1975) and eyeshots (e.g., Gründl et al., 2012), in both color and black-and-white. We varied the percentage of pupil constriction (20%–25%) and dilation (50–55%) within the normal range of pupil sizes (de Groot & Gebhard, 1952), and unlike prior studies, we controlled the perceived naturalness of the constricted- and dilated-pupil versions of each face, which likely confounded some of the prior results. We used choice-based (e.g., Hess, 1975), rating-based (e.g., Hicks et al., 1967), and slider-based measures, both within-participant and between-participant designs, and we tested participants' own eye color and sex as potential moderators. Results are summarized in Table 4.

In the remainder of this section we identify the theoretical contributions and the practical implications of this research, followed by consideration of some of its limitations.

11.1. Theoretical contributions

According to sexual selection theory, facial features such as a small

Table 4
Summary of results.

Experiment	*N*	Effect	Effect Size (*d*)	
1	252	Constricted more attractive	0.35	***
2	257	Constricted more attractive	0.45	***
3	801	Constricted more attractive	0.23	***
4	799	Constricted more attractive	0.53	***
5	307	Constricted more attractive	0.20	***
6	400	Constricted more attractive	0.34	***

Note. For Experiment 3 we include only the constricted and dilated conditions. *** $p < .001$.

nose and large eyes are attractive (e.g., Cunningham, 1986; Lorenz, 1943) because they are neotenous, and hence they signal youth, health, and fecundity (Cunningham et al., 1990; Jones, 1995; Russell et al., 2014). Large pupils are also neotenous (Birren et al., 1950), so one might expect more dilated pupils to appear more attractive. But critically, our findings reveal instead that faces appear less attractive with large (dilated) pupils than with small (constricted) pupils.

We also tested several potential moderators suggested in prior research. We consistently obtained effects of pupil size on attractiveness regardless of the target's attractiveness (contra Hicks et al., 1978), the target's and respondent's sex (contra Bull & Shead, 1979; Hicks et al., 1967; Tomlinson et al., 1978), and the target's and respondent's eye color (contra Hess, 1975; Laeng et al., 2007).

We conclude that faces are perceived as more attractive with constricted pupils than with dilated pupils, and we hope to have demonstrated this effect more generally and more conclusively than any prior research. Moreover, the effect of pupil size on attractiveness appears to be monotonic and approximately linear. Across studies, the effect size was small-to-medium (see Table 4), and although constricted pupils were significantly and reliably more attractive than dilated pupils, neither constricted nor dilated pupils differed significantly from neutral pupil size.

Pupil size and iris size are inversely proportional: As one increases, the other equally decreases. Yet, the prior studies (see Table 1) have focused theoretically on pupil size, effectively ignoring iris size as a theoretical explanation. We find this surprising, because when explicitly asked what is attractive about eyes, most people mention the iris (i.e., the color), not the pupil (Gründl et al., 2012). And critically, theoretically focusing on the iris (rather than the pupil) yields two parsimonious but novel explanations for our observed effect: Enlarged irises are both more colorful and brighter than small irises. That is, constricted pupils could be more attractive than dilated pupils either because they reveal more color, or because they reveal more brightness in the iris. Notice that, of these two factors, the laypeople in Gründl et al.'s survey claim that color makes eyes attractive. Contrary to that intuition, we demonstrated that pupil size affects attractiveness via brightness. First, we showed that the effect is equally large with black-and-white photos, indicating that color is not necessary for the effect. Then, we directly measured observers' perceptions of how bright and colorful the eyes are, and although constricted pupils were both brighter and more colorful than dilated pupils, the effect of pupil size on attractiveness was mediated primarily by brightness rather than colorfulness. Thus, we not only provide clarity on the effect itself, but we also provide a novel and nonobvious explanation of that effect.

11.2. Practical implications

Pupil size differs from other features of facial attractiveness in that it is more fleeting, or transient. Whereas the size of one's nose and the prominence of one's cheekbones remain constant across the course of a day, the size of one's pupils can vary dramatically from moment to moment. In other words, unlike other features of facial attractiveness, pupil size is more like a state than a trait. So, whereas one cannot moderate the size of their nose, one can moderate the size of their pupils, albeit via external manipulations. For instance, brighter lighting causes the pupils to constrict more. Our results suggest that bright lighting therefore can also render one's eyes more attractive, though of course any such positive effect of iris exposure may trade off against increased visibility of other facial features (e.g., skin).

Given that physically attractive people tend to have more friends (Feingold, 1992), earn more money (Hamermesh & Biddle, 1994), and live longer and happier lives (Umberson & Hughes, 1987), it is little surprise that many people actively seek to improve their physical appearance, such as by altering the appearance of their eyes. For example, colored contact lenses have become more common in recent years, presumably because they are physically attractive (Fact.MR, 2022). Interestingly, many of these lenses contain visibility or enhancement tints that not only alter the color of the iris, but also increase its brightness. Thus, our results suggest that brightness may underlie the popularity of such lenses.

Similarly, many people also edit their appearance with a beauty filter before posting photos on social media (Consumer Reports, 2021). Indeed, in addition to the filters available directly on social media platforms such as *Instagram*, separate beauty enhancement apps such as *FaceApp*, *Facetune*, and *Perfect365* collectively have hundreds of millions of users worldwide. These filters and apps allow users to easily edit images to enhance many of their facial features, such as their mouth, nose, hair, and eyes. In Western countries like the US, however, most popular apps (e.g., *FaceApp*) do not currently provide an option to modify one's pupil size. Interestingly though, in some Asian countries like China, some popular apps (e.g., *Meitu*) do allow users to modify pupil size. Whether through lighting conditions, contact lenses, social media filters, or beauty enhancement apps, our research reveals a small but impactful way in which people can modify their appearance to enhance their attractiveness and improve others' perceptions of them.

11.3. Limitations and future directions

This research has several limitations that, we believe, highlight potentially fruitful directions for further research. We focus on only a few of them here. One potentially important methodological limitation is our use of predominantly neutral emotional expressions. Other expressions, such as anger, may moderate the effect by activating different evaluative systems. Another methodological limitation is that our studies are focused exclusively on attractiveness. Recent research has shown effects of pupil dynamics on social perceptions such as perceived trustworthiness (Kret & De Dreu, 2019) and other uniquely human traits (Delgado, Mattavelli, Brambilla, Rodríguez-Gómez, & Harris, 2023). Given that static images are also prevalent in contemporary life (e.g., on social media), we consider it important to test for similar effects with static pupil sizes.

Yet another limitation is that our studies do not test whether the effect generalizes across cultures. In particular, the prevalence of dark irises within a culture may moderate the effect, because dark irises hinder viewers' ability to detect pupil size. Thus, the effect may be attenuated in cultures in which dark irises predominate, such as in some regions of Africa, Southeast Asia, and South America. On the other hand, previous studies have shown effects of eye cues on observers' perceptions using pictures of non-human animals (Wacewicz, Perea-García, Lewandowski, & Danel, 2022) and even with line drawings of eye-like pairs of circles (Fawcett, Wesevich, & Gredebäck, 2016), suggesting potential cross-cultural generalizability. Moreover, in our studies we did obtain the effect with brown irises, though they were relatively bright. Thus, as is often the case with novel effects, additional consequences and moderators remain to be revealed.

CRediT authorship contribution statement

Martina Cossu: Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Maria Giulia Trupia:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Zachary Estes:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization.

Data availability

All our data, code, and materials are available at ResearchBox (https://researchbox.org/1829&PEER_REVIEW_passcode=KTRKVN).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2024.105842.

References

Amemiya, S., & Ohtomo, K. (2012). Effect of the observed pupil size on the amygdala of the beholders. *Social Cognitive and Affective Neuroscience, 7*(3), 332–341.
Batres, C., & Shiramizu, V. (2022). Examining the "attractiveness halo effect" across cultures. *Current Psychology*, 1–5.
Birren, J. E., Casperson, R. C., & Botwinick, J. (1950). Age changes in pupil size. *Journal of Gerontology, 5*(3), 216–221.
van den Bosch, W. A., Leenders, I., & Mulder, P. (1999). Topographic anatomy of the eyelids, and the effects of sex and age. *British Journal of Ophthalmology, 83*(3), 347–352.
Brown, M., & Sacco, D. F. (2018). Put a (limbal) ring on it: Women perceive men's limbal rings as a health cue in short-term mating domains. *Personality and Social Psychology Bulletin, 44*(1), 80–91.
Bull, R., & Shead, G. (1979). Pupil dilation, sex of stimulus, and age and sex of observer. *Perceptual and Motor Skills, 49*(1), 27–30.
Consumer Reports. (2021). Social media: A nationally representative multi-mode survey. https://article.images.consumerreports.org/prod/content/dam/surveys/Consumer_Reports_Social_Media_August_2021.
Cunningham, M. R. (1986). Measuring the physical in physical attractiveness: Quasi-experiments on the sociobiology of female facial beauty. *Journal of Personality and Social Psychology, 50*(5), 925–935.
Cunningham, M. R., Barbee, A. P., & Pike, C. L. (1990). What do women want? Facialmetric assessment of multiple motives in the perception of male facial physical attractiveness. *Journal of Personality and Social Psychology, 59*(1), 61–72.
Delgado, N., Mattavelli, S., Brambilla, M., Rodríguez-Gómez, L., & Harris, L. T. (2023). Humanity at first sight: Exploring the relationship between others' pupil size and ascriptions of humanity. *Journal of Experimental Social Psychology, 106*, Article 104455.
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*(12), 2729–2734.
Dion, K., Berscheid, E., & Walster, E. (1972). What is beautiful is good. *Journal of Personality and Social Psychology, 24*(3), 285–290.
Fact.MR. (2022). Colored contact lenses market. https://www.factmr.com/report/1139.
Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191.
Fawcett, C., Wesevich, V., & Gredebäck, G. (2016). Pupillary contagion in infancy: Evidence for spontaneous transfer of arousal. *Psychological Science, 27*(7), 997–1003.
Feingold, A. (1992). Good-looking people are not what we think. *Psychological Bulletin, 111*(2), 304–341.
Glocker, M. L., Langleben, D. D., Ruparel, K., Loughead, J. W., Gur, R. C., & Sachser, N. (2009). Baby schema in infant faces induces cuteness perception and motivation for caretaking in adults. *Ethology, 115*(3), 257–263.
de Groot, S. G., & Gebhard, J. W. (1952). Pupil size as determined by adapting luminance. *Journal of the Optical Society of America, 42*(7), 492–495.
Gründl, M., Knoll, S., Eisenmann-Klein, M., & Prantl, L. (2012). The blue-eyes stereotype: Do eye color, pupil diameter, and scleral color affect attractiveness? *Aesthetic Plastic Surgery, 36*, 234–240.
Hamermesh, D. S. (2006). Changing looks and changing "discrimination": The beauty of economists. *Economics Letters, 93*(3), 405–412.
Hamermesh, D. S., & Biddle, J. (1994). Beauty and the labor market. *The American Economic Review, 84*(5), 1174–1194.
Harrison, N. A., Singer, T., Rotshtein, P., Dolan, R. J., & Critchley, H. D. (2006). Pupillary contagion: Central mechanisms engaged in sadness processing. *Social Cognitive and Affective Neuroscience, 1*(1), 5–17.
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.
Hayes, A. F., & Preacher, K. J. (2014). Statistical mediation analysis with a multicategorical independent variable. *British Journal of Mathematical and Statistical Psychology, 67*(3), 451–470.
Hess, E. H. (1965). Attitude and pupil size. *Scientific American, 212*(4), 46–55.
Hess, E. H. (1975). The role of pupil size in communication. *Scientific American, 233*(5), 110–119.
Hicks, R. A., Pellegrini, R. J., & Tomlinson, N. (1978). Attributions of female college students to male photographs as a function of attractiveness and pupil size. *Perceptual and Motor Skills, 47*(3), 1265–1266.
Hicks, R. A., Reaney, T., & Hill, L. (1967). Effects of pupil size and facial angle on preference for photographs of a young woman. *Perceptual and Motor Skills, 24*(2), 388–390.
Hollingsworth, K., Bowyer, K. W., & Flynn, P. J. (2009). Pupil dilation degrades iris biometric performance. *Computer Vision and Image Understanding, 113*(1), 150–157.
Janisse, M. P. (1973). Pupil size and affect: A critical review of the literature since 1960. *Canadian Psychologist/Psychologie canadienne, 14*(4), 311–329.
Jones, D. (1995). Sexual selection, physical attractiveness, and facial neoteny: Cross-cultural evidence and implications [and comments and reply]. *Current Anthropology, 36*(5), 723–748.
Kret, M. E., & De Dreu, C. K. (2019). The power of pupil size in establishing trust and reciprocity. *Journal of Experimental Psychology: General, 148*(8), 1299–1311.
Laeng, B., Mathisen, R., & Johnsen, J. A. (2007). Why do blue-eyed men prefer women with the same eye color? *Behavioral Ecology and Sociobiology, 61*, 371–384.
Lorenz, K. (1943). Die angeborenen formen möglicher erfahrung. *Zeitschrift für Tierpsychologie, 5*(2), 235–409.
McAfee, L. J., Fox, R. A., & Hicks, R. A. (1982). Attributions of male college students to variations in facial features in the line drawing of a woman's face. *Bulletin of the Psychonomic Society, 19*, 143–144.
Montoya, A. K. (2019). Moderation analysis in two-instance repeated measures designs: Probing methods and multiple moderator models. *Behavior Research Methods, 51*, 61–82.
Ohanian, R. (1990). Construction and validation of a scale to measure celebrity endorsers' perceived expertise, trustworthiness, and attractiveness. *Journal of Advertising, 19*(3), 39–52.
Pieters, R. (2017). Meaningful mediation analysis: Plausible causal inference and informative communication. *Journal of Consumer Research, 44*(3), 692–716.
Pollet, T., & Little, A. (2017). Baseline probabilities for two-alternative forced choice tasks when judging stimuli in evolutionary psychology: A methodological note. *Human Ethology Bulletin, 32*(1), 53–59.
Provine, R. R., Cabrera, M. O., & Nave-Blodgett, J. (2013). Red, yellow, and super-white sclera: Uniquely human cues for healthiness, attractiveness, and age. *Human Nature, 24*, 126–136.
Russell, R., Sweda, J. R., Porcheron, A., & Mauger, E. (2014). Sclera color changes with age and is a cue for perceiving age, health, and beauty. *Psychology and Aging, 29*(3), 626–635.
Seddon, J. M., Sahagian, C. R., Glynn, R. J., Sperduto, R. D., & Gragoudas, E. S. (1990). Evaluation of an iris color classification system. The eye disorders case-control study group. *Investigative Ophthalmology & Visual Science, 31*(8), 1592–1598.
Solomon, E., & Lyons, M. (2020). Not my protector—Women have an aversion to high dark triad faces irrespective of childhood or current environmental danger. *Evolutionary Psychological Science, 6*, 241–245.
Tombs, S., & Silverman, I. (2004). Pupillometry: A sexual selection approach. *Evolution and Human Behavior, 25*(4), 221–228.
Tomlinson, N., Hicks, R. A., & Pellegrini, R. J. (1978). Attributions of female college students to variations in pupil size. *Bulletin of the Psychonomic Society, 12*(6), 477–478.
Umberson, D., & Hughes, M. (1987). The impact of physical attractiveness on achievement and psychological well-being. *Social Psychology Quarterly, 50*(3), 227–236.
Wacewicz, S., Perea-García, J. O., Lewandowski, Z., & Danel, D. P. (2022). The adaptive significance of human scleral brightness: An experimental study. *Scientific Reports, 12*(1), 20261.
Walster, E., Aronson, V., Abrahams, D., & Rottman, L. (1966). Importance of physical attractiveness in dating behavior. *Journal of Personality and Social Psychology, 4*(5), 508–516.