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Heterosexual, Homosexual, and Bisexual Men's Pupillary Responses to Persons at Different Stages of Sexual Development

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This study investigated whether pupil size during the viewing of images of adults and children reflects the sexual orientation of heterosexual, homosexual, and bisexual men (n = 100, M_{age} = 22). More specifically, we explored whether this measure corresponds with sexual age preferences for adults over children in nonpedophilic men. In general, results across three experiments, in which observers freely viewed or rated the sexual appeal of person images, suggest that pupil dilation to sexual stimuli is an indicator of sexual orientation toward adults. Heterosexual men's pupils dilated most strongly to adults of the other sex, homosexual men dilated most strongly to adults of the same sex, and bisexual men showed an intermediate pattern. Dilation to adults was substantially stronger than dilation to younger age groups. Sexual appeal ratings for images of adults and children also correlated with pupil responses, suggesting a direct link between pupil dilation and sexual interest. These findings provide support for pupil dilation as a measure of sex- and age-specific sexual preferences.

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Persistent sexual preferences for children are a primary predictive factor in the recidivism of child sex offenders (see Hanson & Bussière, 1998; Hanson & Morton-Bourgon, 2005). Reliable measures of sexual preference are therefore paramount in the assessment and management of these offenders (Seto, Harris, Rice, & Barbaree, 2004; Ward & Stewart, 2003), for example, to assess possible change following a treatment program (Gannon, Ward, & Polaschek, 2004; Laws & O'Donohue, 2008; Seto et al., 2004). The potential utility of a number of such measures has been examined with varying degrees of success (for reviews, see Akerman & Beech, 2012; Barker & Howell, 1992). This study explored a novel method for objectively measuring sexual interest: recording pupillary responses to images of male and female adults and children.

Self-report and phallometric approaches to the assessment of sexual interest have been applied widely to the study of sexual offending (Akerman & Beech, 2012). However, such methods suffer from social desirability responding; and in the case of measuring genital arousal, it is also possible to suppress such responses (e.g., Beck & Baldwin, 1994; Golde, Strassberg, & Turner, 2000; Mahoney & Strassberg, 1991). Researchers have therefore explored alternative measures of sexual interest that are less obtrusive and vulnerable to conscious manipulations, such as the implicit-association test, pictorial modified Stroop tasks, choice reaction time tasks, and viewing-time paradigms (Akerman & Beech, 2012; Harris, Rice, Quinsey, & Chaplin, 1996; Kalmus & Beech, 2005; Ó Ciardha & Gormley, 2009, 2012).

In these paradigms, response times are recorded as participants perform computer-based tasks. For example, in a viewing-time task, participants may be instructed to rate the sexual attractiveness of people depicted in a series of images while their response times are recorded. In this example, research shows that participants produce longer response times when rating their preferred sexual category (e.g., adult women) compared to other categories (for a review, see Laws & Gress, 2004). However, similar to subjective reporting, the reliability of these measures is uncertain. For example, in any task that requires manual responses (e.g., button presses), observers might be able to affect the task outcome by responding in a nonsensical pattern (e.g., by pressing buttons randomly or at variable intervals) or simply by failing to adhere to the task demands (i.e., to respond as quickly and as accurately as possible).

In light of these caveats, it is important to explore alternative measures that might be less susceptible to manipulation. One potential measure for this purpose that has received only limited consideration is pupillary response. This idea is appealing because the pupils are resistant to deliberate efforts to exert control over their size (Heaver &

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Hutton, 2011; Laeng, Sirois, & Gredebäck, 2012), which is an important characteristic when considering the use of such assessments with individuals who may attempt to conceal their sexual interests. The question remains, however, to what extent pupillary responses can be used to accurately assess sexual interest and whether it is a measure that can distinguish between such interest in adult and child targets.

Early studies in this field revealed pupil dilation in response to sexual content (Bernick, Kling, & Borowitz, 1971) that was specifically present for preferred sexual stimuli (see Hamel, 1974; Hess & Polt, 1960; Hess, Seltzer, & Shlien, 1965; Scott, Wells, Wood, & Morgan, 1967). However, these studies employed rather elementary techniques for measuring pupil size. Hess et al. (1965), for example, manually measured the pupil diameter of 10 adult males (five heterosexual and five homosexual) from video footage of their eyes, which was recorded while these participants viewed paintings and photographs of nude adult men and women. Despite this basic approach, a clear response pattern emerged whereby all of the heterosexual males displayed larger pupil sizes to pictures of women than to pictures of men, and four of the five homosexual men showed dilation to pictures of men compared to women (Hess et al., 1965).

While these early findings were compelling, it was not until recently that this effect was methodically reexamined using contemporary eye-tracking technology (Rieger & Savin-Williams, 2012). In this study, participants with diverse sexual orientations were shown sexually explicit video footage while their pupil sizes were recorded. The findings replicated Hess et al. (1965) closely; the pupils of homosexual men and women dilated to footage of the same sex, while pupils of bisexual men and women dilated to both sexes. The pupils of heterosexual men dilated to the opposite sex, but heterosexual women displayed equal pupil sizes to both sexes. A subsequent experiment strengthened these findings by demonstrating correspondence between pupil dilation and genital arousal, which supports the conclusion that pupillary responses reflect sexual interest (Rieger et al., 2015). In this study, participants viewed videos of a man or woman performing a sexual act while pupillary responses and genital arousal were measured. A high concordance between both measures was found in men and women. However, consistent with previous work, this relationship was weaker in heterosexual women (Rieger & Savin-Williams, 2012).

While these studies indicate a strong relationship between sexual preferences and pupil dilation, the possibility of using this method to assess age preferences has rarely been considered. An early study revealed reliable differences in pupillary responses between pedophilic and nonpedophilic participants to images of adults and children (Atwood & Howell, 1971). In this study, nine out of 10 pedophiles displayed larger pupils to pictures of dressed and nude young girls, compared to pictures of adults. By contrast, nine out of 10 nonpedophiles displayed greater dilation to images of adults. Once again, however, these data were obtained with a crude approach, which was based on manually measuring pupil size from video stills of observers' eyes.

A recent study therefore reexamined whether pupillary response can provide an age-specific measure of sexual interest using highly sensitive, contemporary eye-tracking equipment (Attard-Johnson, Bindemann, & Ó Ciardha, 2016). Consistent with previous research, heterosexual male observers displayed larger pupils during the viewing of adult women (Hess et al., 1965; Rieger et al., 2015; Rieger & Savin-Williams, 2012). These findings were accompanied by clear age effects for male and female observers, such that no pupil dilation was observed to images of children. Therefore, these findings suggest that pupil size, as measured with sensitive eye-tracking equipment, may not only provide an index of sexual interest that is sensitive to observers' sex preferences but also to sexual age preferences.

However, the study by Attard-Johnson et al. (2016) was also limited in some important respects. One caveat is that the pupils of heterosexual female observers also revealed dilation during the viewing of adult women. This pattern of female responding is not yet fully understood (Rieger et al., 2015; Rieger & Savin-Williams, 2012) but is common in the wider sex literature and has been obtained with a range of measures and paradigms, such as viewing and response times (Israel & Strassberg, 2009; Lippa, Patterson, & Marelich, 2010) and genital arousal (e.g., Chivers, Rieger, Latty, & Bailey, 2004; Chivers, Seto, Lalumière, Laan, & Grimbos, 2010; Suschinsky, Lalumière, & Chivers, 2009). However, in combination with the use of visual scenes, which were employed as a natural context for the presentation of the person stimuli and to provide alternative nonperson content to view, the possibility arises that these pupillary responses are driven by additional nonperson aspects of the stimuli, such as the distribution of luminance within scenes or image-based factors that cannot be easily identified (see Attard-Johnson et al., 2016; Bergamin & Kardon, 2003; Ellis, 1981).

The current study sought to address whether observers' pupil size during the viewing of people in natural scenes reflect their sexual orientation when these responses cannot be accounted for by person content and stimulus variation. This was done by comparing the pupil responses of nonpedophilic men with hetero-, homo-, and bisexual orientations. Only male participants were tested due to their high concordance between self-reported sexual orientation and phallometric measures of sexual interest (Chivers, 2005; Chivers et al., 2010; Rieger et al., 2015; Rieger & Savin-Williams, 2012). The inclusion of three male groups with different sexual orientations circumvents the issue of equating low-level aspects of the visual stimuli that might not be fully understood or cannot be easily identified. Thus, if the same pattern of pupillary responses is obtained across observers, irrespective of sexual orientation, then this pattern must arise from low-level visual attributes of the stimuli rather than their content (i.e., independent of whether male or female persons are depicted). In turn, if pupillary responses are consistent with observers' self-reported sexual orientation (e.g., larger to female targets in heterosexual observers, larger to male

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targets in homosexual observers), then this would confirm that these provide a measure of sexual interest.

An important second aim was to explore whether pupillary responses are sensitive to images of people at different stages of sexual maturity. While a small number of studies have compared pupil dilation for images of adults with very young children (see Attard-Johnson et al., 2016), there have been no documented attempts to explore this method with images of individuals of intermediate ages. However, this is an important step for forensic research and practice (Blanchard et al., 2009; Dombert et al., 2013). This study therefore also examined pupillary responses to images of people at five different stages of sexual development, ranging from infancy to adulthood. Previous research suggests that sexual arousal is not a fixed response but gradually increases with a target's similarity to a person of preferred age and sex (Blanchard et al., 2012). If pupillary response provides a sensitive measure of sexual interest, then the pupils should therefore also dilate increasingly to images of people as these more closely match the age and sex preferences of an observer.

Finally, we also examined whether pupillary responses correlate with observers' evaluations of the sexual appeal of the viewed target persons. Previous research shows that sexual appeal ratings in men link to other measurements of sexual interest, such as genital arousal and viewing time (Harris et al., 1996; Quinsey, Ketsetzis, Earls, & Karamanoukian, 1996; for a meta-analysis, see Chivers et al., 2010). If pupillary response provides a sensitive measure of sexual interest, then these measures should be linked here, too. These questions were investigated across three experiments.

Experiment 1: Free Viewing of People in Natural Scenes

The aim of this experiment was to investigate whether pupillary responses to people in natural scenes reflect their sexual orientation. For this purpose, hetero-, homo-, and bisexual nonpedophilic adult men viewed natural scenes depicting adults and prepubescent children, as well as control scenes without person content. If pupillary responses to these scenes are related to observers' sexual interests, then pupil size should be greatest during the viewing of targets that match self-reported sex and age preferences. Thus, in heterosexual men the pupils should be largest during the viewing of women compared to men, larger to men than women in homosexual observers, and comparable in size to men and women in bisexual observers. In addition, pupillary responses in all of these observers should be larger to their preferred adult targets than to images of children.

Method

Participants

One hundred male students with diverse sexual interests participated in return for a small payment or course credit. As all participants were recruited via the same advertisement and due to the uneven distribution of heterosexual, homosexual, and bisexual participants in our volunteer pool, this resulted in unequal sample sizes (59 heterosexual, 20 homosexual, 21 bisexual). The mean age was 21.6 years (SD = 5.6, range = 18 to 50 years) for heterosexual men, 24.5 years (SD = 7.6, range = 18 to 47 years) for homosexual men, and 21.1 years (SD = 2.5, range = 18 to 28 years) for bisexual men. All participants reported normal or corrected-to-normal vision, and all also completed Experiments 2 and 3.

Eye Tracking

The stimuli were displayed using SR-Research ExperimentBuilder software (VERSION 1.1.0) on a 21-inch (53.3-cm) color monitor, with a screen resolution of 1024 × 768 pixels. Eye movements were tracked using an SR-Research Eyelink 1000, which was running at 1000 Hz sampling rate, a spatial resolution of < 0.01°, a gaze position accuracy of < 0.5°, and a pupil size resolution of 0.1% of diameter. This infrared eye-tracking system computes the number of camera pixels that are occluded by participants' pupils and records pupil size as an integer between 400 and 16,000.

Materials

A total of 20 images that portrayed adult men and women, and prepubescent boys and girls (five scenes for each of these four categories) on beaches were used as stimuli (for examples, see online Supplementary Materials). In addition, a set of control beach scenes with no person content was included (five scenes). In previous research, the mean ages of the targets were estimated to be 26.4 years (SD = 2.1) for men, 22.8 years (SD = 2.6) for women, 5.7 years (SD = 1.1) for boys, and 4.7 years (SD = 1.4) for girls (Attard-Johnson et al., 2016). Individuals were portrayed in swimwear or leisurewear and depicted in similar non–sexually explicit poses. All stimuli were selected to be of similar composition. To confirm that the targets were of similar size in these scenes, their percentage occupancy area was calculated. This confirmed that all person categories occupied a similar amount of scene space (M = 7.1%, SD = 3.4, range across person categories = 6.6% to 7.7%; one-factor analysis of variance (ANOVA), F (3, 19) = 0.14, p = 0.93).

Two questionnaires relating to sexual interests were also included. The first instructed participants to select one or more of five applicable statements ("No sexual interest in adults"; "Strong sexual interest in female adults"; "Some sexual interest in female adults"; "Some sexual interest in male adults"; "Strong sexual interest in male adults"; see Attard-Johnson et al., 2016). The second questionnaire was an Interest in Child Molestation Scale, which participants completed to confirm that they were exclusively sexually interested in adults (Gannon & O'Connor, 2011). This scale

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consists of five short scenarios that describe incidents of child molestation. In response to these scenarios, participants rate their arousal, enjoyment, and behavioral propensity to child sexual abuse on 7-point Likert scales.

Procedure

This study was conducted following British Psychological Society (BPS) ethical guidelines and was approved by the ethics board of the School of Psychology at Kent. Participants provided informed consent prior to taking part. Participants were invited to an experiment that involved viewing photographs of adults and children but were kept naive to the full purpose until the end. Participants were seated at a distance of 23.2 inches (60 cm) from the display monitor, which was kept constant by a chinrest. Only participants' left eyes were tracked and calibrated using the standard nine-point fixation EyeLink procedure. For this experiment, a free-viewing paradigm was adopted so as not to constrain spontaneous eye movements, whereby participants were instructed to view the images as "naturally as they normally would" (for similar approaches, see, e.g., Attard-Johnson et al., 2016; Attard & Bindemann, 2013; Fromberger et al., 2012). Each trial began with a fixation dot, which allowed for drift correction. This was followed by a gray screen for 1 second, the stimulus display for 10 seconds, and another gray screen for 1 second. The gray screen presented before and after each image allowed pupil size to return to baseline (Rigato, Rieger, & Romei, 2016). Each participant viewed all 25 images once in a random order that was generated individually by the EyeLink software. Participants then completed the general information scale relating to their sexual interests and the Interest in Child Molestation Scale. Because participants took part in all three experiments, these scales were only completed once, on completion of the final eye-tracking task.

Data Analysis

None of the participants dropped out of the study, and there were no missing data. All analyses were conducted in SPSS Version 21 (IBM Software Group). Across all experiments, observers' pupillary responses for each stimulus category were calculated first, as a percentage change from their overall mean. The pattern of pupillary responses was then compared for the observer groups across the stimulus categories using 3 (sexual orientation: heterosexual, homosexual, bisexual) × 5 (category: men, women, boys, girls, no person) mixed-factor ANOVAs. To explore significant interactions, Bonferroni-adjusted pairwise comparisons were performed on observers' responses to each stimulus category. To gain further insight into these patterns, one-sample *t* tests were also applied to compare the change in pupil size for each stimulus category with a baseline of zero (with alpha corrected for multiple comparisons). This analysis was performed separately for observer groups. For Experiments 2 and 3, pupillary responses and mean sexual appeal ratings for each stimulus category were analyzed with 3 (sexual orientation: heterosexual, homosexual, bisexual) × 4 (category: men, women, boys, girls) mixed-factor ANOVAs and Bonferroni-adjusted pairwise comparisons. In addition, separate Spearman's correlations were performed for pupil size change and sexual appeal ratings for heterosexual, homosexual, and bisexual men.

Results

Sexual Orientation

To confirm sexual orientation, participants' responses on the sexual interest questionnaire were analyzed first. Of the 100 participants, 59 indicated *Some* (n = 6) or *Strong* (n = 53) sexual interest in females with no sexual interest in males and were categorized as heterosexual. A total of 20 individuals indicated *Some* (n = 1) or *Strong* (n = 19) sexual interest in males without any interest in females and were therefore categorized as homosexual. Of the remaining 21 participants, 14 selected both *Strong sexual interest in adult females* and *Some sexual interest in adult males*; five selected both *Some sexual interest in adult females* and *Some sexual interest in adult males*; and two participants selected *Strong sexual interest in adult females* and *Strong sexual interest in adult males*. These participants were therefore categorized as bisexual.

Responses on the Interest in Child Molestation Scale were analyzed to ensure that participants were not sexually interested in children. A total interest score was calculated by summing up responses across the five scenarios and three subscales (i.e., arousal, enjoyment, behavioral propensity; for similar analysis, see Gannon & O'Connor, 2011; Mitchell & Galupo, 2016). This produced scores that ranged from a minimum of 15 (low sexual interest in children) to a maximum of 105 (high sexual interest in children). A cutoff point for sexual interest in children does not currently exist. We adopted a simple metric by considering only individuals whose scores fell within the lowest third of the scale (i.e., scores between 15 and 45; see Attard-Johnson et al., 2016). The scores of four individuals fell above this range, which resulted in the exclusion of two heterosexual men (with scores of 51 and 52) and two bisexual men (with scores of 49 and 59). For the remaining participants, means of 20.4 (mode = 15, SD = 7.4, min = 15, max = 41) for heterosexual observers, 17.1 (mode = 15, SD = 4.4, min = 15, max = 32) for homosexual observers, and 18.4 (mode = 15, SD = 6.2, min = 15, max = 40) for bisexual observers were recorded.

Data Preparation

For brevity, observers' fixation behavior around the stimulus displays is reported as a supplement for all experiments (see online Supplementary Materials). Observers'

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pupillary responses to each stimulus category were calculated as a percentage change from their overall pupil mean. For this, pupillary responses were first computed by taking the mean pupil area at each fixation, averaged across the duration of a stimulus display. An overall mean, across all stimuli in all conditions, was then computed from these values for each participant. The percentage difference (i.e., an increase or decrease) in pupil size from the overall mean was then computed for each stimulus category using the following formula:

$$100 - (\text{mean pupil size for category} \times 100/\text{overall pupil mean}).$$

For the resulting scores, a value of zero indicates no change in pupil size and positive or negative scores reflect relatively larger (dilation) or smaller (constriction) pupil sizes for a stimulus category (for similar approaches, see Attard-Johnson et al., 2016; Dabbs, 1997; Laeng & Falkenberg, 2007).

Pupillary Responses

Pupillary responses were analyzed in two ways. First, pupillary responses were compared for heterosexual, homosexual, and bisexual observers across the stimulus categories. These data are illustrated in Figure 1. A 5 (category: men, women, boys, girls, no person) × 3 (sexual orientation: heterosexual, homosexual, and bisexual) mixed-factor ANOVA revealed an interaction between category and sexual orientation, F (8, 372) = 3.18, $p < 0.01$, partial $\eta^2 = 0.06$. To explore this interaction, Bonferroni-adjusted pairwise comparisons were conducted to compare the responses of observers for each stimulus category. This analysis revealed sexual orientation differences for images of adults, whereby the pupil sizes of homosexual males were larger than those of heterosexual males during the viewing of men, $p < 0.01$. By contrast, the pupils of heterosexual males were larger during the viewing of women than those of homosexual and bisexual observers, $p < 0.001$ and $p < 0.05$, respectively. Differences in sexual orientation were not observed for images of children, all ps ≥ 0.13.

These responses were also analyzed with one-sample t tests (with alpha corrected at $p < 0.01$ for multiple comparisons) by comparing the change in pupil size for each stimulus category with a baseline of zero (i.e., with the average dilation to all stimuli; see Data Preparation). For heterosexual males, this analysis revealed dilated pupils during the viewing of women, t (56) = 12.36, $p < 0.001$, d = 3.30, and constricted pupils during the viewing of boys, t (56) = −2.69, $p < 0.01$, d = 0.72, and girls t (56) = −6.46, $p < 0.001$, d = 1.70. No change in pupil size was observed for men and no-person scenes, both ts ≤ −0.57, ps ≥ 0.57, ds ≤ 0.15.

Homosexual males' pupils dilated during the viewing of men, t (19) = 3.33, $p < 0.01$, d = 1.53. Their pupils were also dilated during the viewing of women, t (19) = 2.52, p = 0.02, d = 1.16, but this was not reliably above zero (with alpha corrected at $p < 0.01$). In contrast, scenes depicting girls and boys, as well as no-person scenes, did not elicit a change in pupil size compared to baseline, all ts ≤ 2.24, ps ≥ 0.04, ds ≤ 1.03.

Finally, the pupils of bisexual males also dilated during the viewing of women, t (18) = 4.06, $p < 0.001$, d = 1.91, but constricted during the viewing of girls, t (18) = −4.88, $p < 0.001$, d = 2.30. Pictures of men, boys, and no-person scenes did not elicit a reliable change in pupil size, all ts ≤ 1.70, ps ≥ 0.11, ds ≤ 0.80.

Discussion

This experiment compared pupillary responses of heterosexual, homosexual, and bisexual men to pictures of adults and children. The results demonstrated dilation patterns that appear to be consistent with observers' self-reported sex and age preferences. Thus, pictures of women evoked the largest dilation response in heterosexual males, whereas men elicited the largest response in homosexual males. The data were somewhat less clear for bisexual males, who displayed dilation to pictures of men and women—but this was reliable only for the latter category. Importantly, however, no such dilation responses were observed for images of

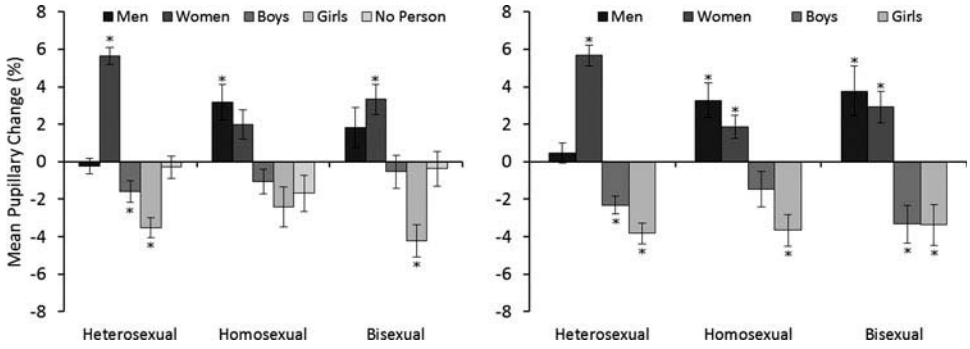

Figure 1. Mean pupillary change for heterosexual, homosexual, and bisexual observers by stimulus category in Experiment 1 (on left) and Experiment 2 (on right). Vertical lines represent the standard error of the means. *Note*. Asterisk represents $p < 0.01$ (for Experiment 1) and $p < 0.0125$ (for Experiment 2) in the one-sample t tests (alpha corrected for multiple comparisons).

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children in all three observer groups. These responses were therefore consistent with observers' scores on the Interest in Child Molestation Scale, which indicated a sexual preference for adults (Gannon & O'Connor, 2011).

Experiment 2: Sexual Appeal Ratings of People in Natural Scenes

Experiment 1 demonstrated that pupillary responses corresponded with observers' self-reported sexual orientation. However, as a free-viewing paradigm, which was designed to capture natural viewing interests, this task stopped short of relating these responses directly to the sexual interest value that those images hold for the observers. Therefore, the aim of Experiment 2 was to examine whether pupillary responses and sexual interest for the images are directly related. This was done by recording pupillary responses for the different person categories while observers rated the sexual appeal of these targets. If pupillary responses are strongly linked to sexual interest, then these ratings should correlate with the pupillary responses to the different categories.

Method

The same participants from Experiment 1 took part in Experiment 2. The eye-tracking setup and procedure were identical to Experiment 1, except for the following differences: The no-person beach scenes were excluded. For the remaining stimuli, participants were instructed to rate the sexual appeal of the person targets on a 7-point Likert scale. Responses were made via the number keys on a standard keyboard, where the number 1 key, for example, corresponded with *Not at all sexually appealing* and 7 with *Extremely sexually appealing*. Once a response was registered, the image was removed from view and the next trial began.

Results

Pupillary Responses

The pupillary data are illustrated in Figure 1. A 4 (category: men, women, boys, girls) × 3 (sexual orientation: heterosexual, homosexual, and bisexual) mixed-factor ANOVA revealed an interaction of category and sexual orientation, F (6, 279) = 3.95, $p < 0.001$, partial $\eta^2 = 0.08$. Bonferroni-adjusted pairwise comparisons showed that during the viewing of men homosexual and bisexual males showed larger pupils than heterosexual males, both ps < 0.05. When viewing women, heterosexual males showed larger pupils than homosexual, $p < 0.001$, and bisexual men, $p < 0.05$. No differences were found for images of children, all ps ≥ 0.41.

As in Experiment 1, these responses were also analyzed via a series of one-sample t tests (with alpha corrected at $p < 0.0125$ for multiple comparisons) to compare the change in pupil size with a baseline of zero. For heterosexual males, this analysis revealed dilated pupils during the viewing of women, t (56) = 10.33, $p < 0.001$, $d = 2.76$, and constricted pupils during the viewing of boys and girls, both ts ≥ −5.03, ps < 0.001, ds ≥ 1.34. No change in pupil size was recorded to images of men, t (56), $p = 0.38$, $d = 0.24$.

In homosexual observers, larger pupils were detected during the viewing of men, t (19) = 3.59, $p < 0.01$, $d = 1.65$, but also women, t (19) = 2.98, $p < 0.01$, $d = 1.37$. In contrast, the scenes depicting girls produced a decrease in pupil size, t (19) = −4.34, $p < 0.001$, $d = 1.99$, while no change in pupil size was detected for scenes depicting boys, t (19) = −1.56, $p = 0.14$, $d = 0.72$.

For bisexual males, an increase in pupil size was recorded during the viewing of both men and women, both ts ≥ 2.83, ps < 0.01, ds ≥ 1.33. In contrast, the pupils constricted during the viewing of boys and girls, both ts ≥ −3.10, ps < 0.01, ds ≥ 1.46.

Sexual Appeal Ratings

Observers' sexual appeal ratings are summarized in Table 1. Images depicting children scored the lowest ratings from all groups (with a range of 1.00 to 1.22) and the preferred adults for each observer group received the highest ratings (with a range of 3.86 to 5.67). The mean sexual appeal ratings were analyzed first with a 4 (category: men, women, boys, girls) × 3 (sexual orientation: heterosexual, homosexual, bisexual) mixed-factor ANOVA, which revealed an interaction, F (6, 279) = 97.99, $p < 0.001$, partial $\eta^2 = 0.68$. Bonferroni-adjusted pairwise comparisons showed that heterosexual and bisexual men recorded higher ratings for women than homosexual men, both ps < 0.01, and the ratings by heterosexual men were also higher than those of bisexual men for these images, $p < 0.001$. The opposite pattern was found for images of men, whereby homosexual and bisexual men recorded higher ratings than heterosexual men, ps < 0.05, and these ratings were also higher in homosexual compared to bisexual men, $p < 0.001$. No differences in sexual appeal ratings were found for images of boys and girls, all ps ≥ 0.79.

Table 1. *Heterosexual, Homosexual, and Bisexual Observers' Mean Sexual Appeal Ratings for Persons in Beach Scenes in Experiment 2*

Natural Scenes	Heterosexual	Homosexual	Bisexual
Men	1.81 (1.08)	5.11 (1.17)	3.86 (1.29)
Women	5.67 (0.70)	2.23 (1.35)	4.97 (1.19)
Boys	1.14 (0.60)	1.19 (0.63)	1.00 (0.00)
Girls	1.22 (0.61)	1.20 (0.81)	1.04 (0.11)

Note. Standard deviations are in parentheses.

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We next performed a correlation between change in pupil size and sexual appeal ratings. This analysis was performed separately for heterosexual, homosexual, and bisexual males, but the responses for the person categories (men, women, boys, girls) were combined and correlated with mean percentage pupillary change scores. The distribution of observers' responses for the sexual appeal ratings was skewed, and therefore nonparametric Spearman's correlations are reported. This analysis revealed positive correlations between pupil change and sexual appeal ratings for heterosexual, r_s (226) = 0.60, $p < 0.001$, homosexual, r_s (78) = 0.56, $p < 0.001$, and bisexual observers, r_s (74) = 0.53, $p < 0.001$.

Discussion

Pupillary responses during the evaluation of the sexual appeal of the target persons were similar to the free-viewing task of Experiment 1. Thus, the pupils of heterosexual males dilated to images of women but not men, and a reduction in pupil size to scenes with boys and girls was found. Surprisingly, however, homosexual males responded similarly to bisexual males such that dilation was recorded for both men and women. We return to these findings in the General Discussion. For both groups, pupil constriction or no change to scenes with boys and girls was recorded. In addition, these pupillary responses correlated positively with observers' sexual appeal ratings. These findings therefore provide further evidence that pupillary responses provide an index that reflects the age-specific sexual interests of heterosexual, homosexual, and bisexual men.

Experiment 3: Sexual Appeal Ratings to Tanner Stimuli

The preceding experiments found distinct pupillary response patterns when observers viewed photographs of people of different age groups, which consisted of children with a perceived age of about 5 years and adults of approximately 25 years of age (see Materials in Experiment 1). However, questions remain about the age sensitivity of these pupillary responses that cannot be addressed from such different age groups. Experiment 3 therefore explored whether pupillary responses are sensitive to images of people at different stages of sexual maturity. For this purpose, Experiment 3 depicted people at five developmental stages of sexual maturity, defined by Tanner's categorization (Tanner, 1978). If pupillary response provides a measure of sexual interest that is sensitive to different stages of sexual development, then observers' pupils should dilate increasingly as images of people more closely match their sex and age preferences. Similar to Experiment 2, participants were asked to rate these persons according to their sexual appeal, which should produce a graded response with higher appeal ratings with increasing age (among non-pedophilic participants). The primary aim was to determine whether pupil sizes during the rating of these persons produced a similar response pattern.

Method

The participants in this experiment were the same as in Experiments 1 and 2. This experiment also employed the same eye-tracking method and procedure as Experiment 2, except that the scene stimuli were replaced with images from the Not Real People (NRP) picture set (Pacific Psychological Assessment Corporation, 2004). These images depicted male and female persons at the five different Tanner stages of sexual development (see Tanner, 1978). Tanner stage I corresponds to prepubescent infants; II corresponds to onset of puberty; III represents intermediate pubertal stages; IV corresponds to postpubescent adolescence; and V represents early adulthood (Dombert et al., 2013). A total of 40 images were used, comprising four males and four females at each Tanner stage. The persons in these stimuli were depicted in undergarments similar to swimwear and poses that were not sexually explicit (for example stimuli, see online Supplementary Materials). Similar to Experiment 2, participants were instructed to rate the sexual appeal of these persons on a 7-point Likert scale.

Results

Pupillary Responses

Pupillary responses are illustrated in Figure 2. A 3 (sexual orientation: heterosexual, homosexual, and bisexual) × 2 (target sex: male, female) × 5 (Tanner stage: I, II, III, IV, V) mixed-factor ANOVA revealed a three-way interaction, F (8, 380) = 2.53, $p < 0.05$, partial $\eta^2 = 0.05$. To explore this interaction, Bonferroni-adjusted pairwise comparisons were performed comparing sexual orientation for all stimulus categories. This analysis showed that during the viewing of Tanner IV males, the pupils of bisexual males did not differ from those of homosexual, $p = 0.80$, and heterosexual males, $p = 0.18$. However, the pupils of homosexual males were larger than those of heterosexual males, $p < 0.01$. During the viewing of Tanner V males, the pupils of bisexual and homosexual males did not differ, $p = 0.20$, and were larger than those of heterosexual males, ps < 0.01. No differences were found for Tanner I, II, and III males, all ps ≥ 0.21.

In contrast, scenes depicting Tanner IV females elicited larger pupils in heterosexual compared to homosexual males, $p < 0.001$, but not bisexual males, $p = 0.07$. Pupil responses of homosexual and bisexual males to these images did not differ, $p = 0.45$. In addition, bisexual and heterosexual males' pupils did not differ during the viewing of Tanner V females, $p = 1.00$, and were larger than the pupils of homosexual males, $p < 0.05$. Overall, these results therefore appear to be consistent with observers'

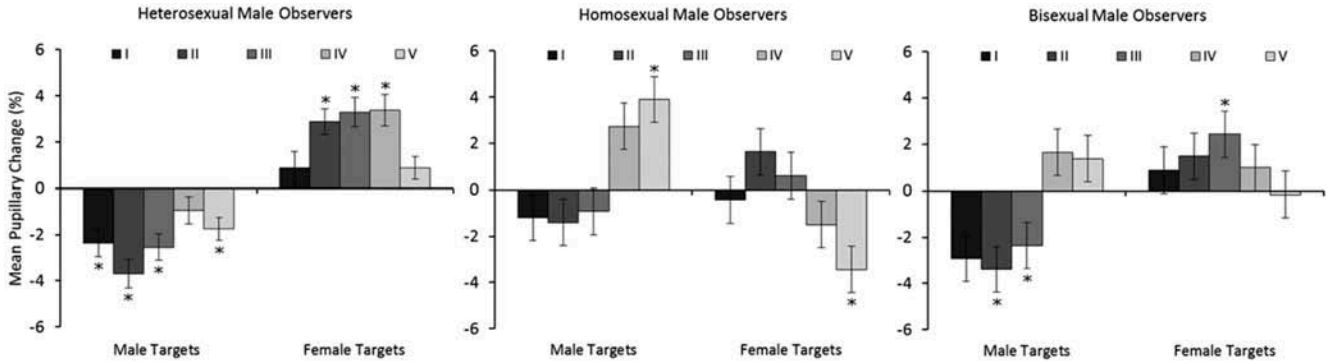

Figure 2. Mean pupillary change for heterosexual, homosexual, and bisexual observers in Experiment 3, as a function of Tanner category. Vertical lines represent standard errors of means. *Note*. Asterisk represents $p < 0.005$ in the one-sample t tests (alpha corrected for multiple comparisons).

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sexual orientation and preference for adults. No differences were observed for younger females, Tanner I, II, and III, all $ps \geq 0.07$.

Once again, the percentage change in pupil size to the different stimulus categories was also analyzed via a series of one-sample t tests (with an alpha of $p < 0.005$ applied to correct for multiple comparisons) to compare it with a baseline of zero. For heterosexual men, this revealed an increase in pupil size during the viewing of Tanner II, III, and IV females, all $ts \geq 5.15$, $ps < 0.001$, $ds \geq 1.33$, but no change for Tanner I, t (56) = 1.37, $d = 0.37$, and Tanner V females, t (56) = 1.71, $p = 0.09$, $d = 0.46$. In addition, a decrease in pupil size was detected for Tanner I, II, III, and V male figures, all $ts \geq 3.63$, $ps \leq 0.001$, $ds \geq 0.97$, whereas no change from baseline was found for Tanner IV males, t (56) = −1.53, $p = 0.13$, $d = 0.41$. Thus, the pupils of heterosexual men dilated to female targets but not male targets. Within the female category, dilation occurred for all female categories except the youngest and oldest of the Tanner stages (I and V).

The analysis for homosexual observers showed a decrease in pupil size during the viewing of Tanner V females, t (19) = −4.63, $p < 0.001$, $d = 2.13$, and no change from baseline was detected during the viewing of Tanner I, II, III, and IV females, all $ts \leq 2.06$, $ps \geq 0.05$, $ds \leq 0.95$. Furthermore, homosexual men recorded larger pupils during the viewing of Tanner V males, t (19) = 4.58, $p < 0.001$, $d = 2.10$. A similar effect was evident for Tanner IV males, t (19), $p = 0.006$, $d = 1.41$, but did not survive correction for multiple comparisons (i.e., alpha of 0.005). In addition, there was no reliable change in pupil size for Tanner I to III males, $ts \leq -1.70$, $ps \geq 0.11$, $ds \leq 0.76$. Overall, the pupils of homosexual males therefore dilated to images of adult males, whereas images of females and younger males elicited a reduction in pupil size or no change from baseline.

For bisexual observers, an increase in pupil size was revealed for Tanner III females, t (20) = 3.43, $p = 0.003$, $d = 1.53$, and no reliable change was recorded for all other female categories, all $ts \leq 2.58$, $ps \geq 0.02$, $ds \leq 1.15$. For male targets, the pupils constricted during the viewing of Tanner II and III males, both $ts \geq -3.28$, $ps \leq 0.004$, $ds \geq 1.47$, and also Tanner I males, t (20) = 2.91, $p = 0.009$, $d = 1.30$, but this change did not survive correction for multiple comparisons. No reliable change in pupil size was detected for Tanner IV and V males, t (20) = 1.24, $p = 0.23$, $d = 0.55$ and t (20) = 2.21, $p = 0.04$, $d = 0.99$, respectively. Overall, bisexual observers therefore did not show a strong dilation pattern for male or female adult categories but showed a constriction in pupil size for prepubescent and adolescent male figures.

Sexual Appeal Ratings

The sexual appeal ratings were consistent with observers' self-reported age and sex preferences (see Table 2). Heterosexual men, for example, rated female stimuli as most appealing and these ratings increased across the Tanner stages (i.e., from I to V). Homosexual men displayed the reverse pattern, and bisexual men found adults of both sexes most appealing. A 2 (category: males, females) × 3 (sexual orientation: heterosexual, homosexual, bisexual) × 5 (Tanner stage: I, II, III, IV, V) mixed-factor ANOVA of these ratings revealed a three-way interaction, F (8, 372) = 52.78, $p < 0.001$, partial $\eta^2 = 0.53$. Bonferroni-adjusted pairwise comparisons showed that ratings of heterosexual and bisexual men did not differ for Tanner IV and

Table 2. *Heterosexual, Homosexual, and Bisexual Observers' Mean Sexual Appeal Ratings for Persons in the Not Real People Scenes (Tanner Stages I–V) in Experiment 3*

Not Real People	Heterosexual	Homosexual	Bisexual
Male I	1.03 (0.11)	1.23 (0.53)	1.08 (0.24)
Male II	1.06 (0.24)	1.25 (0.60)	1.05 (0.10)
Male III	1.07 (0.20)	1.53 (0.74)	1.29 (0.49)
Male IV	1.17 (0.35)	2.41 (1.42)	2.09 (0.82)
Male V	1.28 (0.51)	2.91 (0.56)	2.76 (1.15)
Female I	1.18 (0.41)	1.15 (0.56)	1.07 (0.16)
Female II	1.30 (0.62)	1.16 (0.58)	1.16 (0.30)
Female III	1.50 (0.81)	1.14 (0.61)	1.36 (0.39)
Female IV	3.39 (1.20)	1.48 (0.76)	2.96 (1.04)
Female V	4.45 (1.19)	1.72 (1.04)	3.91 (1.09)

Note. Standard deviations are in parentheses.

V females, $ps \geq 0.22$, but were higher than those recorded by homosexual men, $ps < 0.001$. No differences were found for Tanner I, II, and III females, all $ps \geq 0.18$. For Tanner IV and V males, ratings of homosexual and bisexual men did not differ, all $ps \geq 0.43$, and were higher than those recorded by heterosexual men, $ps < 0.001$. Homosexual men also recorded higher ratings for Tanner I and III males than heterosexual men, both $ps < 0.05$, but not bisexual men, both $ps \geq 0.26$. No differences were found for Tanner II males, all $ps \geq 0.08$.

Finally, to examine the relationship between sexual appeal judgements and pupillary responses, these data were combined across Tanner categories. Spearman's correlational analyses revealed a positive relationship between these measures for heterosexual, r_s (568) = 0.24, $p < 0.001$, homosexual, r_s (198) = 0.26, $p < 0.001$, and bisexual men, r_s (188) = 0.27, $p < 0.001$.

Discussion

The pupils of homosexual men showed dilation responses that were most consistent with their sex preferences. In these observers, images of postpubescent adolescent and adult males (Tanner IV and V) provoked reliable dilation effects, whereas depictions of younger males evoked no change in pupil size. By contrast, a decrease in pupil size was obtained for female adults (Tanner V) and no change from baseline for the younger female categories (Tanner I to IV).

Heterosexual male observers also showed a pupil dilation pattern that corresponded to their sex preferences, such that their pupils dilated during the viewing of female models and constricted to males. Within the female category, the largest increase in pupil size was detected for images of postpubescent adolescents (Tanner IV). Surprisingly, however, images of pubescent females also dilated observers' pupils, but pictures of adult women (Tanner V) did not.

Finally, the bisexual group showed a constriction in pupil size to prepubescent males (Tanner I through III) and a dilation response emerged for adolescent and adult males (Tanner IV and V), which is generally consistent with these observers' interest in men. However, these dilation effects for adolescents and adults did not reach significance when compared to baseline. For female figures, the pattern was less clear, with only Tanner III eliciting a reliable change (dilation) from baseline.

Overall, the pupillary responses therefore show a clear pattern for homosexual men, whereas these responses suggest more interest in younger females than was expected in heterosexual and bisexual males, and are generally least clear for the latter group. Two aspects might underlie this pattern of effects. First, the pupillary responses of all observers indicate some interest in pubertal (Tanner III) or postpubescent (Tanner IV) targets. Considering the average age of this sample (mean ~22 years), it is possible that these adolescent targets were still within the age range that is of sexual interest to these observers (see Buunk, Dijkstra, Kenrick, & Warntjes, 2001). This explanation would converge with reports that male student participants favor the adolescent and adult females in this stimulus set (Mokros et al., 2011). In line with these observations, we also note that adults and adolescents were rated as most sexually appealing in the current study.

Second, although the pattern of pupillary responses in this experiment appears to correspond with self-reported sexual preferences for adults, adult females (Tanner V) did not elicit a specific dilation response in heterosexual and bisexual observers. The reason for this is unclear. We note, however, that sexual appeal ratings for adult females (and males) were somewhat low, which might reflect the age and composition of the stimulus set. Heterosexual males, for example, rated the sexual appeal of Tanner V females at 4.45/7 (with a range of 1.8 to 6.8), and these scores were lower still, at 3.91/7 (with a range of 1.8 to 5.5), in bisexual observers.

General Discussion

This study investigated whether pupillary responses to images of adults and children reflect the sexual interest and age preferences of heterosexual, homosexual, and bisexual males. Pupillary responses to pictures of adolescents and adults generally corresponded to observers' sexual orientation. In all experiments, the pupils of heterosexual men dilated during the viewing of women but not men. Similarly, homosexual observers consistently showed pupil dilation to images of men across all experiments. For bisexual men, pupil dilation was observed for pictures of women in Experiment 1, and a similar effect was observed for men, though this did not reach significance. In Experiment 2, dilation was observed for men and women. Generally, these results therefore converge with previous reports that pupillary responses provide an index of sexual interest that corresponds with self-reported sexual orientation (Hess et al., 1965; Rieger et al., 2015; Rieger & Savin-Williams, 2012).

However, for bisexual observers the pattern was less clear in Experiment 3, which revealed no clear dilation for male and female adults. In the sex research literature, there is conflicting evidence regarding the response patterns of bisexual males. Some viewing-time studies have revealed responses in bisexual men that were indistinguishable for images of adult men and women (Ebsworth & Lalumière, 2012; Lippa, 2013; Rosenthal, Sylva, Safron, & Bailey, 2011). Other studies, using measures of genital arousal, have recorded greater arousal for the same or the opposite sex but not both (Rieger, Chivers, & Bailey, 2005). The current experiments add to these data by showing that bisexual males produced pupillary responses that are generally consistent with their self-reported sexual interest in two of the experiments reported here. However, the same

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males can also produce a pattern that is more difficult to interpret, depending on the stimuli and the task demands (in Experiment 3).

Another key aim of the current study was to examine the extent to which these pupillary responses also provide an age-specific index of sexual interest. In Experiments 1 and 2, images of children produced either a constriction in pupil size or no change from baseline in all conditions. In the context of dilation effects for adults of sexual interest, this indicates that pupillary responses are age specific, in the sense that these can distinguish interest in adults and very young children (with a perceived age of about five years; see Materials for Experiment 1). This pattern is consistent with a study that compared pedophilic and nonpedophilic males when viewing images of young girls and adult women (Atwood & Howell, 1971). In that study, nonpedophilic males dilated only to images of women but not to images of girls. This is also in line with a more recent study that compared the responses of nonpedophilic heterosexual males and females to natural images of adults and children, and observed pupil dilation for pictures of adults but not of children (Attard-Johnson et al., 2016). These findings indicate that pupil dilation is not only sensitive to sex but also reflects broad age preferences.

In addition to these general age distinctions, we also assessed whether these responses are sensitive to a specific range of ages. For this purpose, participants were shown people at five different stages of sexual development in Experiment 3, which ranged from prepubescent infants to adults (Tanner, 1978). In this experiment, a pattern emerged for homosexual males in accordance with their sex and age preferences. For example, during the viewing of males, the pupils of these observers were smallest for prepubescent infants and pubescent boys (Tanner I, II, and III), and increased for images of postpubescent adolescents and adult males (Tanner IV and V). Furthermore, no dilation was detected when homosexual men viewed images of female children and adolescents, and images comprising adult women elicited a decrease in pupil size.

This pattern converges with the bipolar model of sexual arousal that places adult men and women on opposite ends of a continuum and pubescent children near the middle (see Blanchard et al., 2012). According to this model, nonpedophilic homosexual men show the highest sexual response to images of adult males, which gradually declines when viewing prepubescent males, followed by prepubescent females, and reaches the lowest arousal response when viewing adult females (Blanchard et al., 2012). The pupil responses for the homosexual males in the current study follow a similar pattern of sexual responding, whereby pupils were largest for adult men and smallest for adult women, with responses to pubescent and prepubescent stimuli intermediate between these two.

The responses of heterosexual and bisexual males in Experiment 3 were less clear. Pupil dilation was not elicited by the youngest stimuli, which comprised prepubescent infants (Tanner I), in any of the participant groups. These effects therefore converge with the results of Experiment 1 and 2, as well as previous research (Attard-Johnson et al., 2016). However, although heterosexual men's pupils dilated for the preferred sex category, the adult women did not elicit the strongest dilation. Instead, dilation was detected for images of pubescent and postpubescent adolescents (Tanner II, III, and IV). Similarly, bisexual men showed a pupil dilation effect for pubescent (Tanner III) but not older females. While the reason for this is unclear, we note that we tested a sample of relatively young adults with a mean age of 22 years. In a previous study, 20-year-old men reported being sexually interested in 18-year-old women (Buunk et al., 2001). It is therefore possible that the adolescent targets of Experiment 3 were also within an age range of sexual interest to these observers. Alternatively, these responses might reflect the age and composition of this stimulus set, which was not designed to provide sexually evocative content.

Despite the mixed effects in Experiment 3, we note that observers' sexual appeal ratings increased with the age of the depicted sexually preferred persons. Furthermore, these ratings correlated with pupil size in Experiment 2 and 3. This supports the conclusion that pupil dilation is an age-specific index of sexual interest (Attard-Johnson et al., 2016; Rieger et al., 2015; Rieger & Savin-Williams, 2012), albeit one that might be limited in its ability to distinguish between interest in pubescent and postpubescent adults in the Tanner stimuli.

In summary, the current findings confirm that pupillary responses can distinguish sexual interest in adult targets from those in young children. This was found with nonpedophilic male observers with diverse sexual orientations. The current experiments also show that this measure correlated well with the subjective sexual appeal that people of different ages held for an observer, which provides further evidence for a direct relationship between sexual interest, the age of an observed person, and pupil size. However, we note that the sensitivity of this method to distinguish specific age groups of adolescents and adults remains difficult to resolve.

In this context, some limitations need to be considered. The mixed pattern of Experiment 3 might reflect the artificial composition of the Tanner stimuli, which were constructed by combining features of three or more people to construct each identity (Laws & Gress, 2004). Therefore, replication of this experiment with more natural stimuli should be considered. In addition, the same participants contributed to all three experiments reported here. This approach controls for individual variability and facilitates comparison across tasks. However, it is also possible that this influenced pupillary responses across experiments. Further investigations are necessary to clarify these issues further.

More generally, it is also notable that pupil dilation as an index of age-specific sexual interests remains an underresearched area in eye-tracking and sex research. This is surprising considering the potential applied value of this measure. Pupillary responses are, for example, held to be

regulated by the autonomic nervous system, which could place this index beyond the conscious control of observers (Laeng et al., 2012; Laeng & Sulutvedt, 2014; but see Binda, Pereverzeva, & Murray, 2013). This could make it useful in forensic settings for assessing those with motivation to conceal their sexual interests. With further development, this could make it a potentially valuable tool for practitioners for the assessment of pedophilic interests, to measure behavioral change, and to estimate the risk of recidivism following a treatment program (see Gannon et al., 2004; Hanson & Bussière, 1998; Hanson & Morton-Bourgon, 2005).

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