Sexual Arousal: The Correspondence of Eyes and Genitals

Gerulf Rieger

University of Essex

Brian M. Cash, Sarah M. Merrill, James Jones-Rounds, Sanjay Dharmavaram,

and Ritch C. Savin-Williams

Cornell University

Author Note

Gerulf Rieger, Department of Psychology, University of Essex; Brian M. Cash, Sarah M. Merrill, James Jones-Rounds, Sanjay Dharmavaram, and Ritch C. Savin-Williams, Department of Human Development, Cornell University.

Correspondence concerning this article should be addressed to Gerulf Rieger, Department of Psychology, University of Essex, Colchester C04 3SQ, UK. Email: gerulf@essex.ac.uk

Word Count: 5690

Abstract

Men's, more than women's, sexual responses may include a coordination of several physiological indices in order to build their sexual arousal to relevant targets. Here, for the first time, genital arousal and pupil dilation to sexual stimuli were simultaneously assessed. These measures corresponded more strongly with each other, subjective sexual arousal, and self-reported sexual orientation in men than women. Bisexual arousal is more prevalent in women than men. We therefore predicted that if bisexual-identified men show bisexual arousal, the correspondence of their arousal indices would be more female-typical, thus weaker, than for other men. Homosexual women show more male-typical arousal than other women; hence, their correspondence of arousal indices should be stronger than for other women. Findings, albeit weak in effect, supported these predictions. Thus, if sex-specific patterns are reversed within one sex, they might affect more than one aspect of sexual arousal. Because pupillary responses reflected sexual orientation similar to genital responses, they offer a less invasive alternative for the measurement of sexual arousal.

Keywords: sexual orientation, sex differences, pupil dilation, genital arousal

Sexual Arousal: The Correspondence of Eyes and Genitals

Although most men are genitally aroused to one sex that is consistent with their reported sexual orientation, women's sexual orientation is weakly reflected in their genital response because they are sexually aroused to both sexes (Chivers, Rieger, Latty, & Bailey, 2004; Chivers, Seto, & Blanchard, 2007; Rieger, Chivers, & Bailey, 2005). Sex-specific selection pressures might explain this sex difference. The majority of men have evolved to be strongly sexually oriented towards women, facilitating prompt sexual responses required for reproduction. Women may have evolved to be sexually responsive in these situations to avoid genital injury; these pressures might have been so strong that they evolved to respond to any sexual cue, including sexual stimuli depicting either sex (Bailey, 2009; Suschinsky & Lalumière, 2011).

The congruence of various physiological reactions likely reflects the salience of orienting oneself to sexual stimuli (Safron et al., 2007). Thus, men's bodies might synchronize their genital responses with other psychological reactions to build sexual arousal to sexually desired targets. However, if women's, unlike men's, sexual responses have not evolved to orient to specific targets (Bailey, 2009), then their arousal system may not require a coordination of different physiological reactions towards these targets. Consistent with this hypothesis, genital response relates stronger in men than women to subjective sexual arousal to sexual stimuli (Chivers, Seto, Lalumiere, Laan, & Grimbos, 2010). If this sex difference in concordance is robust, other measures of sexual arousal should correspond more strongly in men than women with their genital and subjective responses.

Pupil dilation is one possible reaction to sexual stimulation. Pupils that dilate to stimuli indicate activation of the autonomic nervous system (Bradley, Miccoli, Escrig, & Lang, 2008; Lang & Bradley, 2010), which is associated with many automatic processes such as perspiration, digestion, blood pressure, and heart rate (ten Donkelaar, Němcová, Lammens, Overeem, & Keyser, 2011). Other research suggests that pupil dilation reflects attention that is likely not in the conscious control of participants (Heaver & Hutton, 2011). For these reasons, pupil dilation has been used as an indicator of automatic responses, including responses reflecting sexual arousal (Goldinger & Papesh, 2012; Laeng, Sirois, & Gredebäck, 2012).

Pupils dilate more to sexual stimuli depicting an individual's preferred sex than to stimuli of the other sex or to non-sexual stimuli (Hess & Polt, 1960; Hess, Seltzer, & Shlien, 1965; Rieger & Savin-Williams, 2012). In fact, dilation to sexually preferred stimuli appears to be the strongest pupillary response elicited by stimuli (Laeng et al., 2012). Moreover, sex and sexual orientation differences in pupil dilation are similar to those reported for genital arousal (Rieger & Savin-Williams, 2012). Yet, direct evidence regarding how these indices correspond with each other and with subjective arousal is missing. The present research is the first to simultaneously assess these indices within participants. We hypothesized a stronger correspondence of genital arousal, pupil dilation, subjective arousal, and self-reported sexual orientation in men than women.

This general sex difference in the congruence of arousal indices could, however, vary by sexual orientation. There is inconsistent evidence whether bisexual-identified men are sexually responsive to both men and women, both with respect to their genital arousal (Cerny & Janssen, 2011; Rieger et al., 2005; Rosenthal, Sylva, Safron, & Bailey,

2011) and pupil dilations (Rieger et al., 2013; Rieger & Savin-Williams, 2012). Yet, some bisexual-identified men are sexually aroused to both sexes. Hence, their arousal patterns are, compared to other men, more female-typical. We therefore hypothesized that the correspondence between bisexual men's genital arousal, pupillary response, and subjective arousal is weaker than for other men.

Contrarily, homosexual women have more male-typical sexual arousal patterns, compared to other women, because they respond somewhat stronger to their preferred sex than the other sex. Although this effect was weak in previous studies on genital arousal, it was detected in two independent samples (Chivers et al., 2004; Chivers et al., 2007). Correspondingly, homosexual women dilate more strongly to their preferred sex than the other sex, whereas heterosexual women dilate equally to the sexes (Rieger & Savin-Williams, 2012). Hence, homosexual women could be more male-typical than other women in other aspects of their sexual arousal. We thus hypothesized that compared to other women, the congruency of homosexual women' sexual arousal indices will be stronger.

Based on the reviewed literature, the following hypotheses were tested:

The correspondence of sexual orientation, genital response, pupil dilation, and subjective arousal to sexual stimuli is stronger in men than women.

If bisexual men show bisexual, and hence female-typical sexual arousal, the correspondence of their sexual arousal indices will be weaker than in other men.

If homosexual women show more male-typical sexual arousal than other women, the correspondence of their sexual arousal indices will be stronger than in other women.

Method

Participants

Participants were uniquely recruited in 2013 for the present study. Advertisements were placed on several websites at Cornell University in Ithaca, NY, including those for dormitories, fraternities, athletic teams, and associations for sexual minorities. We also recruited from websites where men sought both men and women for sexual reasons. The latter method was used to find bisexual-identified men, a group less prevalent than other men. The recruited sample consisted of 76 men and 72 women who indicated their sexual orientation identity on a 7-point scale. Distributions of age, ethnicity, and recruitment venue (sexual website or not) are shown in Table 1.

Measures

Sexual orientation. In addition to reporting their sexual orientation identity (Table 1), participants indicated their sexual attractions and fantasies towards men and women on Kinsey-type Scales (Kinsey, Pomeroy, & Martin, 1948). These three measures were correlated in men (all p's < .0001, .97 < r's < .98, .95 < CI's < .99) and women (p's < .0001, .80 < r's < .94, .70 < CI's < .96) and averaged within participants. For this composite, a score of 0 indicated an exclusively heterosexual orientation, a score of 3 a bisexual orientation with equal preferences, and a score of 6 an exclusively homosexual orientation.

In general, people report a diverse range of sexual orientations and attractions between heterosexual, and homosexual (Savin-Williams, Joyner, & Rieger, 2012). Hence, analyses treated the sexual orientation composite as a continuous variable with numeric scores. However, for simplicity of interpretation, we refer to participants with sexual

orientation composite scores from 0 to 1 as "heterosexual," between 1 and 5 as "bisexual," and from 5 to 6 as "homosexual."

Stimuli. Three-minute videos of 3 male stimuli and 3 female stimuli were used for the study. Videos had similar content (i.e., a naked person in a bedroom) and depicted either a male model or female model masturbating.

In a pilot study the most attractive models were selected from a pool of 200 videos drawn from the Internet, showing either a man or woman masturbating. Six male and 7 female research assistants independently evaluated which 10 male and 10 female stimuli they found the most sexually appealing. Next, the assistants independently re-rated all stimuli compiled from these initial evaluations. Using a 7-point Likert scale, they agreed on whom they found the most sexually appealing (*Cronbach's* $\alpha = .96$). The 12 male and 12 female stimuli that were rated as most appealing, on average, were further evaluated by a group of participants (other than those in the main study). These raters were 31 heterosexual men, 31 nonheterosexual men, 34 heterosexual women, and 23 nonheterosexual women.

Within each group, ratings of the model's attractiveness were reliable (all *Cronbach's* α's $\geq .94$). The average correlation of these ratings across the four groups were modest for male stimuli, $r = .48$, 95% CI [.33, .64], and female stimuli, $r = .44$, CI [.22, .67]. The strongest correlation of these ratings was between heterosexual men and homosexual men for female stimuli, $r = .74$, CI [.56, .92]; the weakest correlation was between heterosexual men and homosexual women for female stimuli, $r = .11$, CI [-.49, .65]. Although this latter correlation was weak, three of the female stimuli were

highly evaluated by each group. The top-three male and female stimuli that were rated highest across all groups were used for further analyses.

Six 2-minute videos were taken from a nature documentary for assessing baseline genital responses. Their engaging but nonsexual content facilitated participants' return to an unaroused baseline. However, because their engaging content could elicit pupillary responses for reasons other than sexual interest, for pupil data two 2-minute animations of clouds were used for assessing baseline (Rieger et al., 2013). All videos were of similar luminance; furthermore, luminance was set to equal upper and lower thresholds across stimuli by using the programs MPEG Streamclip and Final Cut Pro. Videos had a resolution of 768 by 536 pixels, and were presented full screen.

Genital data. A BIOPAC MP100 data acquisition unit and the program AcqKnowledge recorded genital responses every 5 milliseconds. An indium/gallium strain gauge measured changes in penile circumference while viewing stimuli. The signal was sampled at 200 Hz, low-pass filtered to 10 Hz and digitized with 16 bits resolution. Gauges were calibrated over six 5-mm steps before sessions and signals were transformed into millimeters of circumference.

Women's genital arousal was assessed via change in vaginal pulse amplitude (VPA), using a vaginal photoplethysmograph. The VPA signal was sampled at 200 Hz, and high-pass filtered at 0.5 Hz with 16 bits resolution. VPA was measured as peak-to-trough amplitude for each vaginal pulse. VPA signals exhibit both convergent and discriminant validity of female sexual response (Suschinsky, Lalumiere, & Chivers, 2009).

Pupil data. A SR Research Remote infrared gaze tracker recorded pupil data every millisecond with a 35 mm lens focused on participants' preferred eye. The program

EyeLink computed pupil area as the number of the tracker's camera pixels occluded by the infrared light reflected by pupil. If pupils dilated while viewing stimuli, more pixels were occluded.

The program Python was used for all data processing. Because raw pupil area data included "0's" that represented missing values, for example from blinks or head movements, these values were removed prior to further analyses. Across all participants and stimuli, the average amount of missing raw pupil data was 6.42%, CI [5.45-7.39%].

Subjective sexual arousal. Participants indicated, in random order, how sexually attractive, appealing, and arousing each sexual stimulus was. Questions were answered with 7-point scales ranging from "not at all" to "average," to "very much." Answers were reliable within stimuli, for each stimulus sex, and for both men and women (all *Cronbach's* α*'s* $\geq$ .92). Thus, for each participant and stimulus sex, an average was computed across ratings. Averages represented participants' subjective sexual arousal to stimuli of the same sex and the other sex.

Procedure. All participants were informed about the sexual content of some of the videos. Participants provided written informed consent and were seated in a dimly lit room facing a screen with resolution of 1024 by 768 pixels. Participants' heads rested on a mount 500 mm from the gaze tracker's lens. For calibration of their pupil data, participants fixated and re-fixated their gaze on 9 points that defined the outline of the screen. Next, in privacy, males placed the gauges midway around their penises and females inserted the photoplethysmograph. Eye movements were then remotely recalibrated from the control room.

Participants were instructed to watch all videos carefully, regardless of whether they liked the content. While viewing stimuli they were free to watch whatever part of the video, as long as they kept their eyes on the screen. First, participants watched an animation of clouds followed, in random order, by presentations of sexual stimuli alternating with nature scenes. Ratings of subjective arousal followed after watching sexual stimuli. The final video was the second animation of clouds. Finally, participants completed a questionnaire with demographic information and sexual orientation and received payment ($50 for males and $100 for females). Participants were informed that the sex difference in payment was due to the more invasive measurement of genital arousal in women. The procedure took 60 minutes.

Genital data for two men and one woman, and pupil data for one man were excluded due to technical issues. There is no consensus as to the most appropriate technique of analyzing pupil size data (Otero, Weekes, & Hutton, 2011). We decided on procedures that have previously yielded reliable pupil dilation data (Rieger & Savin-Williams, 2012), and that were identical to procedures used for analyzing genital arousal responses (Chivers et al., 2007). For each participant, both genital and pupil data were averaged for each stimulus. For genital data, average response to the 10 seconds preceding a stimulus (at which time baseline for sexual stimuli was established) was subtracted from the average response to this stimulus. For pupil data, average responses to the animations of clouds were subtracted from average responses to all other stimuli. Resulting change scores where standardized by computing *z*-scores within participants. We then computed, for each participant, average values reflecting genital response and pupil response, respectively, to same-sex stimuli and other-sex stimuli.

Initial analyses indicated that for each arousal measure, responses to individual female stimuli varied in how strongly they were related to male sexual orientation. These relations were all strong, however, and in general, responses to stimuli of the same type (same sex or other sex) were similarly associated with sexual orientation. We therefore considered averaging responses across stimuli of the same type as justifiable.

Results

The following results are, where possible, compared to the cumulative effects of related, previous studies.

Sex Differences

The first hypothesis states that the correspondence of sexual orientation with genital arousal, pupil dilation, and subjective arousal to sexual stimuli is stronger in men than women. Table 2 indicates this was the case. For systematic comparison of this difference, we calculated Fisher's *z* transformations of the absolute values of the coefficients shown in Table 2. The average absolute correlation (re-expressed as *r*) was stronger in men, $p < .0001$, $r = .68$, 95% CI [.62, .73], than women, $p < .0001$, $r = .26$ [.16, .35]. These average correlations resemble the associations of genital and subjective arousal reported in a meta-analysis, $p < .0001$, $r = .66$ [.57, .75], and $p < .01$, $r = .26$ [.21, .32], respectively (Chivers et al., 2010). We then computed the difference between men and women for each correlation (within pairs of variables) and tested the average of these difference scores against 0 by conducting a repeated-measures *t*-test. The sex difference was significant, $p < .0001$, $d = 3.50$ [3.29, 3.89].

Figures 1 and 2 illustrate that the responses towards same-sex and other-sex stimuli, depending on sexual orientation, were stronger in men than women. We

conducted three regression analyses (one for each arousal index) to compute whether these associations of sexual arousal and sexual orientation differed by participant sex, stimulus sex, and their interaction. These interactions were included to test whether the sex differences depicted in Figure 1 and 2 were substantial. These interactions were significant for physiological responses, all p's $\leq .0001$, $.20 < \beta$'s $< .27$, $.11 <$ CI's $< .35$. Hence, men showed more distinct physiological responses to the same sex and other sex, consistent with their sexual orientation, than did women. However, Figures 1 and 2 also show that men and women were similarly strong in the correspondence of their sexual orientation with their subjective responses towards the same sex and other sex. The interaction, testing for the sex difference in effect, was not significant, $p = .93$, $\beta = .01$, CI [-.07, .06].

To further illustrate the sex difference between sexual orientation and sexual arousal indices (genital, dilation, or subjective), we computed contrast scores of these indices. Positive numbers represented stronger responses to the same sex; zeros, equal responses; and negative numbers, stronger response to the other sex. We regressed these contrast scores against sexual orientation. Based on previous research (Rieger et al., 2005), we tested for curvilinear effects; however, these effects were close to zero, thus, reported standardized coefficients, β's, represent linear relationships.

For men, self-reported sexual orientation was strongly reflected in their genital arousal, $p < .0001$, $\beta = .84$ [.74, .95], and pupil dilation, $p < .0001$, $\beta = .74$ [.58, .90]. Heterosexual men were most strongly aroused to the other sex, homosexual men were most strongly aroused to the same sex, and bisexual men were in-between these other men in their arousal (Figures 3A & 3B). Effects compared to previously found effects of

male sexual orientation and genital arousal, $p < .0001$, $\beta = .81$ [.69, .89] (Chivers et al., 2007; Rieger et al., 2005; Savin-Williams, Rieger, & Rosenthal, 2013). Men's sexual orientation also related to subjective arousal to the same or other sex, $p < .0001$, $\beta = .97$ [.91, 1.00], and in a pattern similar to their physiological reactions (Figure 3C). However, this effect was stronger than in aforementioned previous research, $p < .0001$, $\beta = .84$ [.78, .89].

For women, genital arousal and pupil dilation were weakly related to self-reported sexual orientation, $p = .08$, $\beta = .21$[-.03, .44], and $p = .05$, $\beta = .23$[.00, .43], respectively. Heterosexual women responded equally to the sexes, whereas homosexual women responded somewhat more to the same than the other sex. Bisexual women were intermediate between these other women in their responses (Figures 4A & 4B). Effects resembled those of previous research on women's genital arousal, $p = .02$, $\beta = .24$ [.03, .43] (Chivers et al., 2004; Chivers et al., 2007). Women's subjective arousal reflected their sexual orientation more strongly than their physiological responses, $p < .0001$, $\beta = .86$ [.74, .99] (Figure 4C). This effect was more pronounced than in aforementioned previous research, $p = .0008$, $\beta = .43$ [.25, .59].

Patterns within Men

The second hypothesis states that if bisexual men show bisexual and hence female-typical sexual arousal, the correspondence of sexual arousal indices will be weaker than for other men. We first examined whether bisexual men were aroused to both sexes. We computed a set of variables including measured responses toward the more arousing sex (genitally, dilation-triggering, and subjectively) and another set that included responses to the less arousing sex. If bisexual men were bisexually aroused, they

should show greater responses to the less arousing sex (whichever that sex happens to be) than either heterosexual or homosexual men.

We calculated the curvilinear effects of men' sexual orientation on their responses to the less arousing sex. Bisexual men were subjectively more responsive to their less arousing sex than either heterosexual or homosexual men, $p < .0001$, $\beta = -.72$ [-1.00, -.51]. Corresponding effects were weak for genital response, $p = .26$, $\beta = -.14$ [-.56, .28], and pupillary response, $p = .30$, $\beta = -.12$ [-.46, .22] (Figures 5A to 5C). The literature on genital response suggests a weak to modest cumulative effect for the curvilinear relationship of sexual orientation and arousal, $p = .04$, $\beta = -.22$ [-40, -.01] (Cerny & Janssen, 2011; Rieger et al., 2005; Rosenthal et al., 2011; Tollison, Adams, & Tollison, 1979). The effects of the physiological measures in the present study fall within the range of this cumulative effect.

We note that bisexual men responded *less* than other men to their *more* arousing sex, both for genital arousal, $p = .003$, $\beta = .34$ [.12, .53], and to some degree for pupil dilation, $p = .09$, $\beta = .20$ [-.03, .41]. This effect was approximately zero for subjective arousal, $p = .91$, $\beta = .01$ [-.13, .32] (Figure 5).

A set of three regression analyses compared the association between sexual arousal indices of bisexual men to those of other men. In each analysis, one of the arousal indices was regressed against one other. Furthermore, a contrast was calculated to compare the strength of association between these arousal indices of bisexual men with those of heterosexual or homosexual men. That is, a curvilinear effect of sexual orientation and its interaction with the predicting arousal measure were computed. With this interaction, we tested whether bisexual men differed in their association of arousal indices from

heterosexual and homosexual men. Participants were treated as random to account for their repeated responses to both male and female sexual stimuli.

Across these analyses, and across all men and sexual stimuli, indices of sexual arousal were strongly related, all p's < .0001, .65 < β's < .87, .55 < CI's < .99. However, based on the computed interactions these correspondences were somewhat weaker for bisexual men than for other men; for these interactional effects ranges of statistical values were .02 < p's < .07, .23 < β's < .33, -.01 < CI's < .55. Following statistical guidelines (Aiken & West, 1991), we examined these interactions at an average or "bisexual" level of sexual orientation (the mean score of 3.01), compared to a lower or "heterosexual" level of sexual orientation (1 *SD* below the mean, a score of 0.62) and a higher or "homosexual" level of sexual orientation (1 *SD* above the mean, a score of 5.40). For bisexual men, there were modest correspondences between sexual arousal indices, .001 < p's < .02, .34 < β's < .47, .06 < CI's < .77. However, these correspondences were stronger in heterosexual men, all p's < .0001, .58 < β's < .66, .35 < CI's < .86, and homosexual men, all p's < .0001, .68 < β's < .86, .51 < CI's < .99.

Patterns within Women

The third hypothesis states if homosexual women have male-typical arousal patterns, the correspondence of their sexual arousal indices will be stronger than for other women. For physiological measures, homosexual women had somewhat stronger responses to the same sex than other sex, as compared to other women (Figures 2 & 4). However, this did not translate into homosexual women responding more than other women to their more arousing sex than to their less arousing sex, either for genital arousal, p = .70, β = .05 [-.20, .29], or pupil dilation, p = .81, β = .03 [-.26, .33]. Women of all sexual orientations

responded to both sexes, and more so to their more arousing sex than to their less arousing sex (Figures 6A & 6B). Patterns were different for their subjective arousal, with similar arousal to both sexes more common in bisexual women than other women, $p < .0001$, $\beta = .74$ [.66, .86] (Figure 6C).

A set of regression analyses tested whether the strength of the correspondence between sexual arousal indices was stronger for homosexual women, compared to other women. Across all women and sexual stimuli, indices of sexual arousal were somewhat related, $.001 < p\text{'s} < .25$, $.13 < \beta\text{'s} < .36$, $-.01 <$ CI's $< .57$. However, these agreements were slightly stronger for homosexual women than for other women; for this interactional effects $.03 < p\text{'s} < .09$, $.20 < \beta\text{'s} < .28$, $-.02 <$ CI's $< .36$. We examined these interactions at an average or "bisexual" level of sexual orientation (the mean score of 2.69), compared to a lower or "heterosexual" level of sexual orientation (1 *SD* below the mean, a score of 0.79) and a higher or more "homosexual" level of sexual orientation (1 *SD* above the mean, a score of 4.67). For homosexual women, there were modest to strong correspondences between sexual arousal indices, $.00006 < p\text{'s} < .02$, $.25 < \beta\text{'s} < .53$, $.05 <$ CI's $< .75$. These correspondences were weaker in heterosexual women, $.10 < p\text{'s} < .24$, $-.13 < \beta\text{'s} < .19$, $-.36 <$ CI's $< .42$, and bisexual women, $.38 < p\text{'s} < .42$, $-.13 < \beta\text{'s} < .10$, $-.44 <$ CI's $< .38$.

Discussion

This present study is the first to assess genital arousal and pupil dilation within the same population. Moreover, it is the first study to report that the correspondence of these indices with each other and subjective sexual arousal was substantially stronger in men than women. Within each sex, we have hypothesized that the association of these

associations will be gender-reversed for specific groups: they will be weaker for bisexual men than for other men, and stronger for homosexual women compared to other women. Present results support these hypotheses.

Sex Differences

For most men, regardless of their sexual orientation, the relationship between their sexual arousal indices was substantially stronger than for most women (Table 2). These findings were consistent with the literature on sex differences in the agreement of genital arousal with subjective arousal (Chivers et al., 2010). In addition, physiological sexual arousal and sexual orientation were more strongly linked in men than women (Figures 1 & 2), consistent with previous reports (Bailey, 2009). We hypothesized that males might have evolved to coordinate their sexual arousal and attraction indices more strongly than women because it aids them in building their sexual orientation towards relevant sexual targets. Perhaps, then, men's, more than women's, reactions are an integrated part of their sexual response system that involves the synchronization of other aspects of their sexual arousal. These factors could include, for example, the activation of the visual cortex or limbic system (Sylva et al., 2013), the time spent viewing relevant stimuli (Lippa, 2012), or their temperature regulation during sexual arousal (Kukkonen, Binik, Amsel, & Carrier, 2010).

Notably, the association of subjective arousal with sexual orientation was strong in both men and women, and stronger so than previously reported (Chivers et al., 2004; Chivers et al., 2007). This was possibly because we used more rigorous criteria for selecting the most appealing sexual stimuli for both sexes and a range of sexual orientations.

Patterns within Men

Heterosexual men were predominantly aroused to women, and homosexual men were predominantly aroused to men. Hence, heterosexual and homosexual men were comparable to each other with respect to their sexual arousal to their preferred sex. Furthermore, the correspondences of sexual arousal indices were similar for these men. These findings are in line with other research suggesting that some aspects of the neurological organization of male sexual arousal are independent of sexual orientation, and therefore expressed similarly in heterosexual and homosexual men (Sylva et al., 2013).

For bisexual men, however, the coordination of arousal indices was weaker, thus, more female-typical than for other men. Hence, present findings for bisexual men indicated that if the general sex differences in the correspondence of arousal indices are reversed within one sex, it affects more than one aspect of the expression of sexual arousal. Bisexual men were, however, in their physiological reactions not particularly responsive to their less arousing sex; yet, this finding fell within the expected range of previously reported effects. Hence, in general, bisexual men responded at least slightly stronger to their less arousing sex than other men.

Moreover, bisexual men were less responsive in their physiological reactions to their more arousing sex compared to other men. We had not hypothesized this pattern. However, Rieger and Savin-Williams (2012) previously reported a similar finding by measuring men's arousal via pupil dilation. They noted that this pattern had been anecdotally reported for bisexual men's genital arousal (Ray Blanchard, personal communication). Lowered physiological responses to the preferred (or more arousing)

sex are more prevalent in heterosexual women than heterosexual men, both for their genital arousal (Chivers et al., 2004; Chivers et al., 2007) and pupil dilations (Rieger & Savin-Williams, 2012). In the present data, this sex difference was observed for heterosexual men's and women's responses to the preferred sex (Figures 1 & 2) and to some degree for their responses to the more arousing sex (Figures 5 & 6).

Assuming this sex difference is reliable, we offer a novel interpretation of bisexual men's arousal patterns. Similar to heterosexual women, they have bisexual physiological responses in the sense that they are somewhat (but less) aroused to either sex. Consequently, they are less discriminative in their sexual arousal than either heterosexual or homosexual men. Women's variable sexual arousal, as compared to men's (Chivers et al., 2007; Rieger & Savin-Williams, 2012), could be due to the fact that female sexual attraction is more strongly affected by situational, cultural, and environmental circumstances (Baumeister, 2000; Diamond, 2008; Peplau, 2003). If bisexual men are more female-typical than other men, then, perhaps, they are more influenced by these external factors, resulting in a less specific arousal pattern. Such variability within bisexual men could in part explain inconsistent findings for their sexual arousal to men and women (Rieger et al., 2005; Rosenthal et al., 2011).

Notably, bisexual men's subjective responses were more consistent with their sexual orientation than were their physiological responses (Figures 5). Because subjective arousal and sexual orientation were assessed by self-report, it is possibly that participants matched their responses to these measures. Physiological sexual reactions, however, are likely less under participants control than are their subjective responses, and can therefore lead to stronger discrepancies with someone's self-identified sexual orientation.

Patterns within Women

On average, women of all sexual orientations were physiologically sexually aroused to both sexes (Figures 2 & 6), a finding consistent with the literature (Chivers et al., 2007; Rieger & Savin-Williams, 2012). Because these patterns were observed with both physiological measures, results for pupil dilation bolster those for genital response. Even though research has pointed to the validity of the photoplethysmograph (Suschinsky et al., 2009), the question of whether measures of male and female genital arousal are comparable has been raised (Dreger, 2014). Present findings on pupil dilation, which is assessed in the exact same way in both men and women, reflect sex differences in genital arousal. Hence, our findings support the view that male and female genital responses can be measured with different devices. Moreover, our findings suggest that women's unique sexual arousal patterns are robustly linked to their sex, and not measurement artifacts.

The correspondences of sexual arousal indices were weak across women. However, these findings depended to some degree on women's sexual orientation. Homosexual women were marginally more aroused to the same sex than the other sex, similar to men. In addition, the correspondence of their arousal indices were more male-typical, that is, stronger, than for other women. Male-typical sexual arousal in females may be due to elevated exposure to prenatal androgen that affects postnatal masculinized behaviours (Auyeung et al., 2009). These prenatal influences are possibly responsible for why homosexual women are more male-typical than heterosexual women in other ways, including their motor behaviours, voice patterns, physical appearance, and self-concepts (Freeman, Johnson, Ambady, & Rule, 2010; Lippa, 2008; Rieger, Linsenmeier, Gygax, & Bailey, 2008). The most masculine-behaving women may therefore have most male-

typical sexual responses. Precaution in interpretation is needed, however, because in the present data, gender reversions in sexual arousal for specific sexual orientation groups were weak and variable in effect.

In contrast to their physiological responses, women's subjective responses were more consistent with their sexual orientation (Figure 2). Unlike their physiological responses, women's subjective responses are more controlled (and less automatic) reactions to sexual stimuli. That is, unlike their physiological reactions, women's subjective sexual arousal could be more heavily influenced by other factors, including their reported sexual orientations.

Limitations and Future Directions

Certain limitations should be considered. It has been suggested that whether bisexual men are aroused to both sexes is linked to their previous sexual experiences with men and women (Rosenthal et al., 2012), and further research should consider this potential moderation of their arousal patterns. Furthermore, whether bisexual men are aroused to both sexes can depend on their personality: Those with high curiosity about a diverse range of sexual activities show bisexual physiological arousal, whereas those with low sexual curiosity are mostly aroused to men (Rieger et al., 2013). Present results could therefore be moderated by this trait. We have collected information on sexual curiosity and similar to previous research (Stief, Rieger, & Savin-Williams, 2014), bisexual men scored higher on sexual curiosity than other men, on average. However, there was no indication that differences in sexual curiosity moderated their sexual arousal. Thus, even though current results do not appear to be influenced by this particular personality

characteristic, we were also not able to replicate previous findings, questioning their full meaning.

We have chosen a combination of video and audio for sexual stimuli because these elicit stronger sexual responses than pure visual or audio stimuli (McConaghy, 1999). However, pupil dilation may have been affected by visual information that is other than sexual. For example, pupils could dilate to the background in the videos that participants consider interesting. Thus, statistical error may be increased in the pupillary responses, and true sexual orientation effects could be stronger than presently reported. Further research should investigate the correspondence of genital arousal and pupil dilation by using pure audio stimuli such as the International Affective Digitized Sounds (e.g., Henderson, Bradley, & Lang, 2014). Pupillary responses are also affected by emotions and cognitions (Bradley et al., 2008; Goldinger & Papesh, 2012); hence controlling for these reactions to stimuli in future research could increase the precision of results.

Future research should also investigate the relationship of arousal indices within stimuli. The correspondence of genital arousal and pupil dilation is likely weak at stimulus onset. Pupils dilate strongly to stimuli within seconds (Bradley et al., 2008), whereas strong sexual arousal may take over a minute to occur (Cerny & Janssen, 2011). However, as exposure to salient sexual stimuli progresses, these physiological reactions should become more coordinated.

Conclusion

The present research suggests that in men more than women, pupil dilation and genital arousal were strongly associated with each other and with self-reported sexual orientation. Importantly, in present findings sexual orientation effects based on pupil

dilation were similar to those derived from genital responses. Hence, either measure can be utilized in future research, even though which of them is more applicable will depend on a researcher's goals. A benefit of genital assessment is that for males, sexual orientation differences are, to this date, stronger than those found with pupil dilation. However, the assessment of sexual arousal via pupil dilation is less invasive than via genital response and likely attracts a larger and more diverse group of participants. Pupillometry should become more precise in the future and effects should increase with precision. Moreover, mobile units allow data collection outside the lab, offering a moveable assessment kit of sexual arousal, suitable, for example, for research on cross-cultural comparisons.

Acknowledgement

This research was supported by the American Institute of Bisexuality (1100.13) and the United States Department of Agriculture (NYC-321421).

References

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions.* Thousand Oaks, CA: Sage Publications.

Auyeung, B., Baron-Cohen, S., Ashwin, E., Knickmeyer, R., Taylor, K., Hackett, G., et al. (2009). Fetal Testosterone Predicts Sexually Differentiated Childhood Behavior in Girls and in Boys. *Psychological Science, 20*, 144-148. doi: 10.1111/j.1467-9280.2009.02279.x

Bailey, J. M. (2009). What is sexual orientation and do women have one? In D. A. Hope (Ed.), *Contemporary perspectives on lesbian, gay, and bisexual identities* (Vol. 54, pp. 43-63). New York, NY: Springer.

Baumeister, R. F. (2000). Gender differences in erotic plasticity: The female sex drive as socially flexible and responsive. *Psychological Bulletin, 126*, 347-374.

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

Cerny, J., & Janssen, E. (2011). Patterns of sexual arousal in homosexual, bisexual, and heterosexual men. *Archives of Sexual Behavior, 40*, 687-697-697. doi: 10.1007/s10508-011-9746-0

Chivers, M. L., Rieger, G., Latty, E. M., & Bailey, J. M. (2004). A sex difference in the specificity of sexual arousal. *Psychological Science, 15*, 736-744. doi: 10.1111/j.0956-7976.2004.00750.x

Chivers, M. L., Seto, M. C., & Blanchard, R. (2007). Gender and sexual orientation differences in sexual response to sexual activities versus gender of actors in

sexual films. *Journal of Personality and Social Psychology, 93*, 1108-1121. doi: 10.1037/0022-3514.93.6.1108

Chivers, M. L., Seto, M. C., Lalumiere, M. L., Laan, E., & Grimbos, T. (2010). Agreement of self-reported and genital measures of sexual arousal in men and women: A meta-analysis. *Archives of Sexual Behavior, 39*, 5-56. doi: 10.1007/s10508-009-9556-9

Diamond, L. M. (2008). *Sexual fluidity: Understanding women's love and desire* Cambridge, MA: Harvard University Press.

Dreger, A. (2014). The Problem With Sexual Arousal Studies, *Pacific Standard*. Retrieved from http://www.psmag.com/navigation/health-and-behavior/problem-sexual-arousal-studies-87383/

Freeman, J. B., Johnson, K. L., Ambady, N., & Rule, N. O. (2010). Sexual Orientation Perception Involves Gendered Facial Cues. *Personality and Social Psychology Bulletin, 36*, 1318-1331. doi: 10.1177/0146167210378755

Goldinger, S. D., & Papesh, M. H. (2012). Pupil dilation reflects the creation and retrieval of memories. *Current Directions in Psychological Science, 21*, 90-95. doi: 10.1177/0963721412436811

Heaver, B., & Hutton, S. B. (2011). Keeping an eye on the truth? Pupil size changes associated with recognition memory. *Memory, 19*, 398-405. doi: 10.1080/09658211.2011.575788

Henderson, R. R., Bradley, M. M., & Lang, P. J. (2014). Modulation of the initial light reflex during affective picture viewing. *Psychophysiology, 51*, 815-818. doi: 10.1111/psyp.12236

Hess, E. H., & Polt, J. M. (1960). Pupil size as related to interest value of visual stimuli. *Science, 132*, 349-350. doi: 10.2307/1706082

Hess, E. H., Seltzer, A. L., & Shlien, J. M. (1965). Pupil response of hetero- and homosexual males to pictures of men and women: A pilot study. *Journal of Abnormal Psychology, 70*, 165-168. doi: 10.1037/h0021978

Kinsey, A. C., Pomeroy, W. B., & Martin, C. E. (1948). *Sexual behavior in the human male*. Philadelphia: Saunders.

Kukkonen, T. M., Binik, Y. M., Amsel, R., & Carrier, S. (2010). An evaluation of the validity of thermography as a physiological measure of sexual arousal in a non-university adult sample. *Archives of Sexual Behavior, 39*, 861-873. doi: 10.1007/s10508-009-9496-4

Laeng, B., Sirois, S., & Gredebäck, G. (2012). Pupillometry. *Perspectives on Psychological Science, 7*, 18-27. doi: 10.1177/1745691611427305

Lang, P. J., & Bradley, M. M. (2010). Emotion and the motivational brain. *Biological Psychology, 84*, 437-450.

Lippa, R. A. (2008). Sex differences and sexual orientation differences in personality: Findings from the BBC Internet survey. *Archives of Sexual Behavior, 37*, 173-187. doi: 10.1007/s10508-007-9267-z

Lippa, R. A. (2012). Effects of sex and sexual orientation on self-reported attraction and viewing times to images of men and women: Testing for category specificity. *Archives of Sexual Behavior, 41*, 149-160. doi: 10.1007/s10508-011-9898-y

McConaghy, N. (1999). Unresolved issues in scientific sexology. *Archives of Sexual Behavior, 28*, 285-318. doi: 10.1023/A:1018744628161

Otero, S. C., Weekes, B. S., & Hutton, S. B. (2011). Pupil size changes during recognition memory. *Psychophysiology, 48*, 1346–1353. doi: 10.1111/j.1469-8986.2011.01217.x

Peplau, L. A. (2003). Human sexuality: How do men and women differ? *Current Directions in Psychological Science, 12*, 37-40.

Rieger, G., Chivers, M. L., & Bailey, J. M. (2005). Sexual arousal patterns of bisexual men. *Psychological Science, 16*, 579-584. doi: 10.1111/j.1467-9280.2005.01578.x

Rieger, G., Linsenmeier, J. A. W., Gygax, L., & Bailey, J. M. (2008). Sexual orientation and childhood gender nonconformity: evidence from home videos. *Developmental Psychology, 44*, 46-58. doi: 10.1037/0012-1649.44.1.46

Rieger, G., Rosenthal, A. M., Cash, B. M., Linsenmeier, J. A. W., Bailey, J. M., & Savin-Williams, R. C. (2013). Male bisexual arousal: A matter of curiosity? *Biological Psychology, 94*, 479-489. doi: 10.1016/j.biopsycho.2013.09.007

Rieger, G., & Savin-Williams, R. C. (2012). The eyes have it: Sex and sexual orientation differences in pupil dilation patterns. *PLoS ONE, 7*, e40256. doi: 10.1371/journal.pone.0040256

Rosenthal, A. M., Sylva, D., Safron, A., & Bailey, J. M. (2011). Sexual arousal patterns of bisexual men revisited. *Biological Psychology, 8*, 112–115. doi: 10.1016/j.biopsycho.2011.06.015

Safron, A., Barch, B., Bailey, J. M., Gitelman, D. R., Parrish, T. B., & Reber, P. J. (2007). Neural correlates of sexual arousal in homosexual and heterosexual men. *Behavioral Neuroscience, 121*, 237-248. doi: 10.1037/0735-7044.121.2.237

Savin-Williams, R., Rieger, G., & Rosenthal, A. M. (2013). Physiological Evidence for a Mostly Heterosexual Orientation Among Men. *Archives of Sexual Behavior, 42*, 697-699. doi: 10.1007/s10508-013-0093-1

Savin-Williams, R. C., Joyner, K., & Rieger, G. (2012). Prevalence and stability of self-reported sexual orientation identity during young adulthood. *Archives of Sexual Behavior, 41*, 103-110. doi: 10.1007/s10508-012-9913-y

Stief, M. C., Rieger, G., & Savin-Williams, R. C. (2014). Bisexuality is associated with elevated sexual sensation seeking, sexual curiosity, and sexual excitability. *Personality and Individual Differences, 66*, 193-198. doi: 10.1016/j.paid.2014.03.035

Suschinsky, K. D., & Lalumière, M. L. (2011). Prepared for anything?: An investigation of female genital arousal in response to rape cues. *Psychological Science, 22*, 159-165.

Suschinsky, K. D., Lalumiere, M. L., & Chivers, M. L. (2009). Sex differences in patterns of genital sexual arousal: Measurement artifacts or true phenomena? *Archives of Sexual Behavior, 38*, 559-573. doi: 10.1007/s10508-008-9339-8

Sylva, D., Safron, A., Rosenthal, A. M., Reber, P. J., Parrish, T. B., & Bailey, J. M. (2013). Neural correlates of sexual arousal in heterosexual and homosexual women and men. *Hormones and Behavior, 64*, 673-684. doi: 10.1016/j.yhbeh.2013.08.003

ten Donkelaar, H. J., Němcová, V., Lammens, M., Overeem, S., & Keyser, A. (2011). The Autonomic Nervous System. *Clinical Neuroanatomy*, doi: 10.1007/1978-1003-1642-19134-19133_19112.

Tollison, C. D., Adams, H. E., & Tollison, J. W. (1979). Cognitive and physiological indices of sexual arousal in homosexual, bisexual, and heterosexual males. *Journal of Behavioral Assessment, 1*, 305-314. doi: 10.1007/BF01321372

Table 1.

Distribution of Sexual Orientation Identities across Ages, Ethnicities, and Recruitment Venues.

Men (N = 76)	Exclusively Straight	Mostly Straight	Bisexual Leaning Straight	Bisexual	Bisexual Leaning Gay	Mostly Gay	Exclusively Gay
Number	18	10	8	3	5	16	16
Average Age	22.00	27.60	31.50	20.33	22.20	23.75	23.56
	[19.17, 24.83]	[23.81, 31.35]	[27.26, 35,74]	[13.41, 27.26]	[16.83,27.57]	[20.75, 26.75]	[20.56, 26.56]
Percentage Caucasian	72	80	75	0	40	56	63
	[49, 88]	[49, 94]	[41, 93]	[0, 56]	[12, 77]	[33, 77]	[39, 82]
Percentage Sexual Websites	0	20	63	0	20	13	0
	[0, 18]	[6, 51]	[31, 86]	[0, 56]	[4, 62]	[4, 36]	[39, 82]
Women (N = 72)	**Exclusively Straight**	**Mostly Straight**	**Bisexual Leaning Straight**	**Bisexual**	**Bisexual Leaning Lesbian**	**Mostly Lesbian**	**Exclusively Lesbian**
Number	13	16	8	5	12	10	8
Average Age	23.15	21.88	23.88	25.60	23.50	27.90	27.63
	[21.01, 25.30]	[20.40, 23.36]	[20.99, 26.75]	[17.47, 33.72]	[21.86, 25.13]	[22.06, 33.75]	[24.00, 31.25]
Percentage Caucasian	77	63	38	20	50	80	63
	[50, 92]	[39, 82]	[14, 69]	[4, 62]	[25, 75]	[49, 94]	[31, 86]

Note. Numbers in brackets represent 95% confidence intervals. Some sexual orientation identities differed, on average, in age, ethnicity (proportion of being Caucasian), or recruitment venue (sexual website or not). These differences had little influence on results: reported effects marginally changed by statistically controlling for these variables.

Table 2.

Correlations between Genital Response, Pupil Dilation, Subjective Arousal to Sexual Stimuli, and Reported Sexual Orientation across 76 men (above diagonal) and 72 women (below diagonal).

Measure	Genital Response To Same Sex	Genital Response To Other Sex	Pupil Dilation To Same Sex	Pupil Dilation To Other Sex	Subjective Arousal to Same Sex	Subjective Arousal to Other Sex	Sexual Orientation
Genital Response To Same Sex		-.63***	.60***	-.45***	.70***	-.71***	.78***
		[-.75, -.48]	[.42, .73]	[-.61, -.24]	[.55, .80]	[-.81, -.57]	[.67, .85]
Genital Response To Other Sex	-.28*		-.58***	.57***	-.72***	.67***	-.78***
	[-.48, -.05]		[-.72, -.41]	[.39, .71]	[-.81, -.57]	[.52, .78]	[-.85, -.66]
Pupil Dilation To Same Sex	.36*	-.16		-.64***	.61***	-.65***	.66***
	[.14, .55]	[-.38, .07]		[-.76, -.48}	[.45, .74]	[-.77, -.50]	[.51, .77]
Pupil Dilation To Other Sex	-.07	.19	-.24*		-.52***	.65***	-.65***
	[-.3, .17]	[-.04, .41]	[-.44, .00]		[-.67, -.33]	[.50, .76]	[-.77, -.50]
Subjective Arousal to Same Sex	.33*	-.21	.03	-.06		-.60***	.87***
	[.10, .52]	[-.43, .02]	[-.20, .26]	[-.29, .17]		[-.73, -.43]	[.81, .92]
Subjective Arousal to Other Sex	-.19	.23*	-.11	.11	-.37*		-.85***
	[-.41, .04]	[.00, .44]	[-.33, .13]	[-.12, .33]	[-.55, -.15]		[-.91, -.78}
Sexual Orientation[1]	.20	-.13	.19	-.17	.72***	-.72***	
	[-.04, .41]	[-.35, .10]	[-.04, .40]	[-.39, .06]	[.59, .82]	[-.81, -.58]	

Note. Numbers in brackets represent 95% confidence intervals. [1]Higher scores indicate stronger orientation to the same sex and less to the other sex. *$p < .05$. ***$p < .0001$.

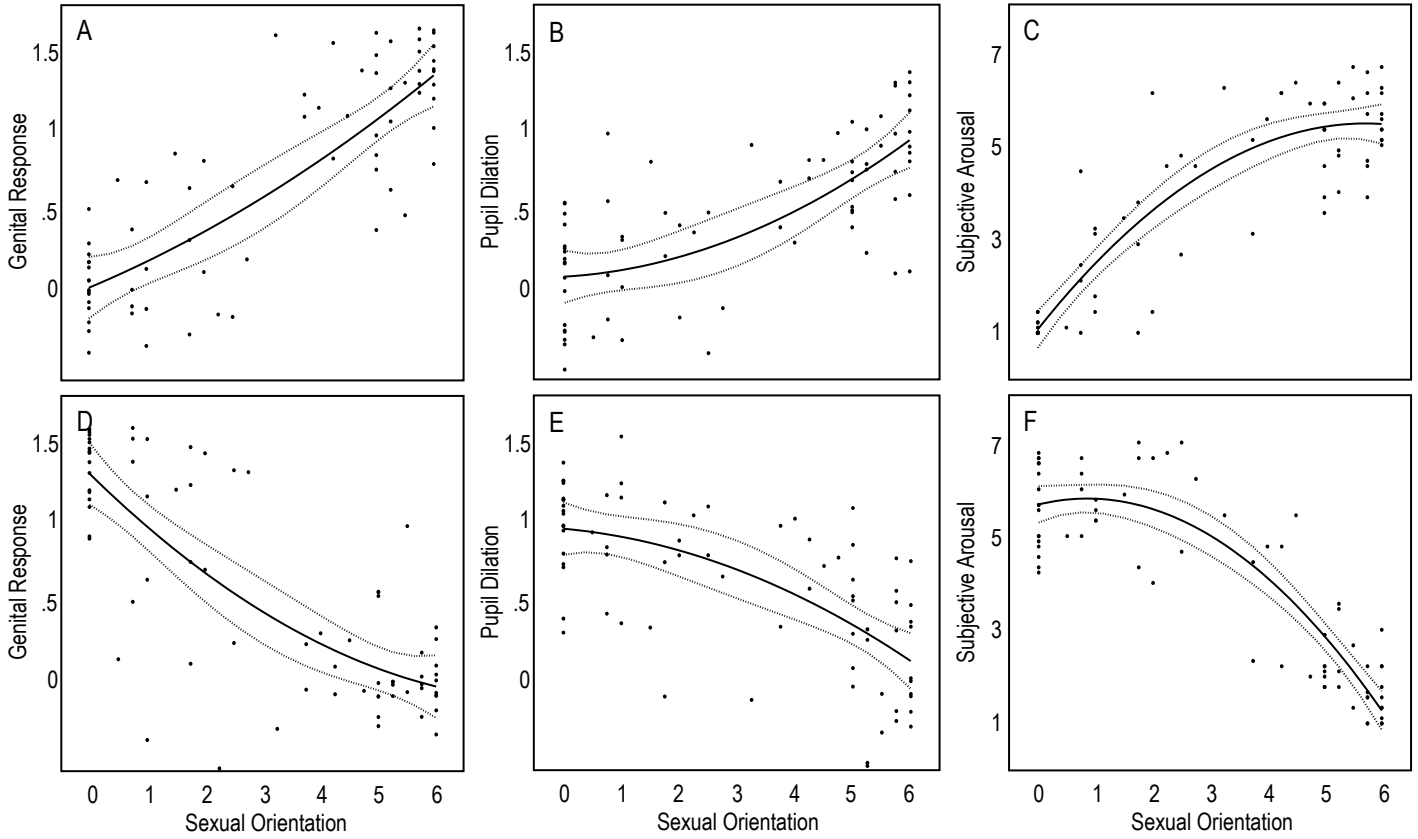

Figure 1. Men's responses to sexual stimuli. Reported sexual orientation of 76 men relates to genital response, pupil dilation, and subjective arousal to the same sex (A, B, C) and other sex (D, E, F). On the Y axes, genital response and pupil dilation scores reflect changes compared to baseline, *z*-scored within participants. On the X axes, 0 represents an exclusive heterosexual orientation, 3 a bisexual orientation, and 6 an exclusive homosexual orientation. Lines represent regression coefficients with 95% confidence intervals. Dots represent participants' average scores.

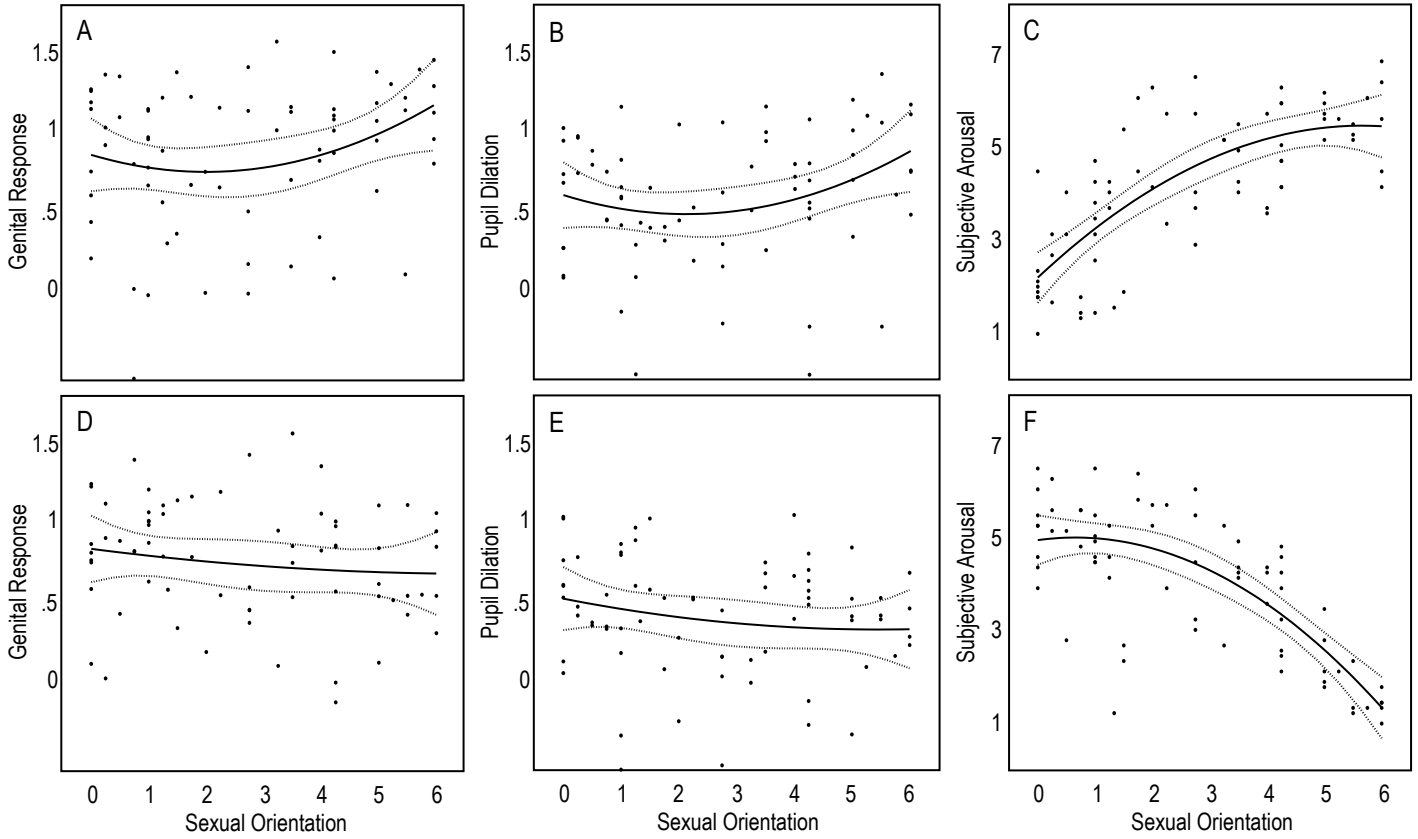

Figure 2. Women's responses to sexual stimuli. Reported sexual orientation of 72 women in relation to genital response, pupil dilation, and subjective arousal to the same sex (A, B, C) and other sex (D, E, F). On the Y axes, genital response and pupil dilation scores reflect changes compared to baseline, *z*-scored within participants. On the X axes, 0 represents an exclusive heterosexual orientation, 3 a bisexual orientation, and 6 an exclusive homosexual orientation. Lines represent regression coefficients with 95% confidence intervals. Dots represent participants' average scores.

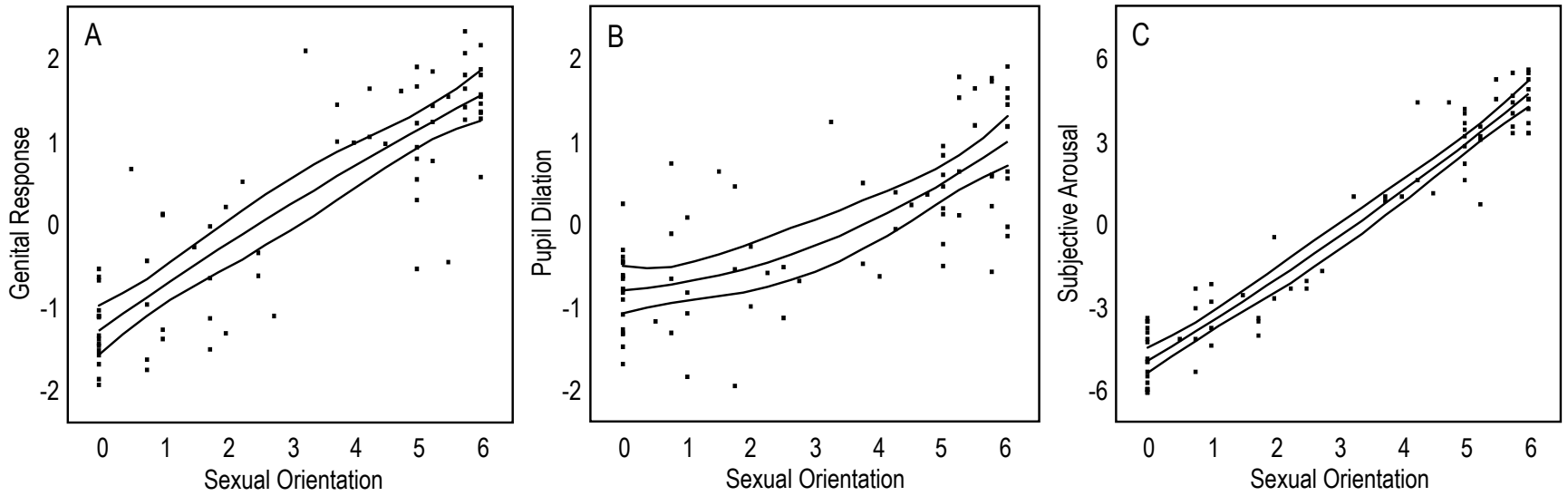

Figure 3. Men's responses to the same sex or the other sex. Reported sexual orientation of 76 men relates to genital response (A), pupil dilation (B), and subjective arousal (C). On the Y axes, positive numbers reflect stronger responses to the same sex, and negative numbers stronger responses to the other sex. Genital response and pupil dilation scores are *z*-scores within participants. On the X axes, 0 represents an exclusive heterosexual orientation, 3 a bisexual orientation, and 6 an exclusive homosexual orientation. Lines represent regression coefficients with 95% confidence intervals. Dots represent participants' average scores.

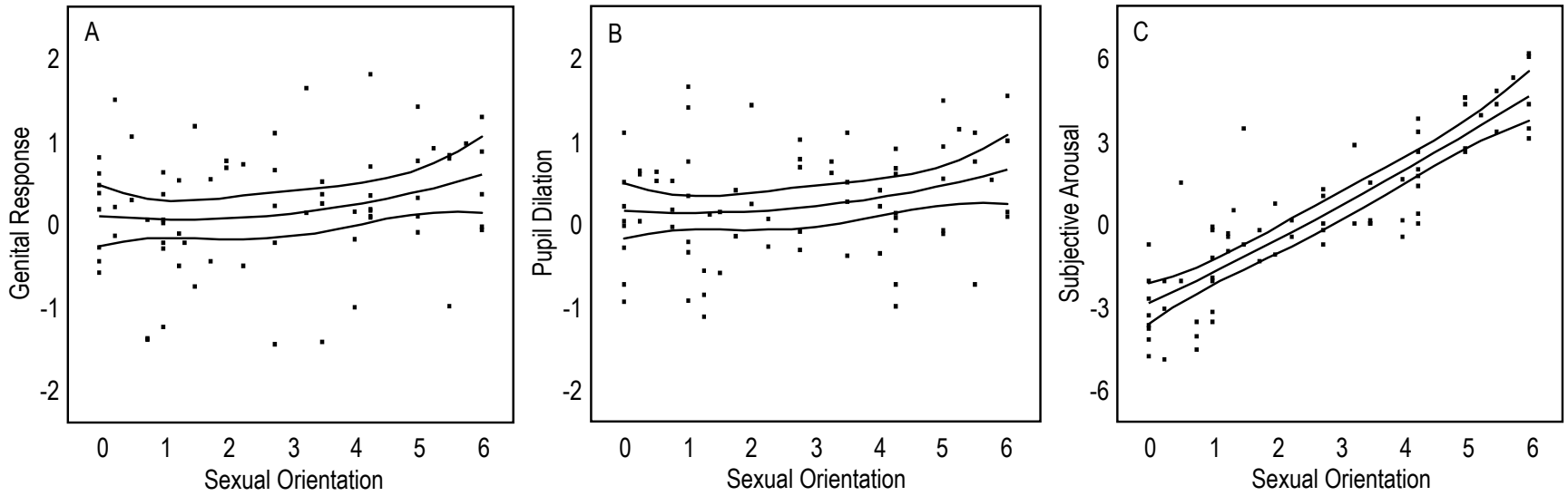

Figure 4. Women's responses to the same sex or the other sex. Reported sexual orientation of 72 women relates to genital response (A), pupil dilation (B), and subjective arousal (C). On the Y axes, positive numbers reflect stronger responses to the same sex, and negative numbers stronger responses to the other sex. Genital response and pupil dilation scores are *z*-scores within participants. On the X axes, 0 represents an exclusive heterosexual orientation, 3 a bisexual orientation, and 6 an exclusive homosexual orientation. Lines represent regression coefficients with 95% confidence intervals. Dots represent participants' average scores.

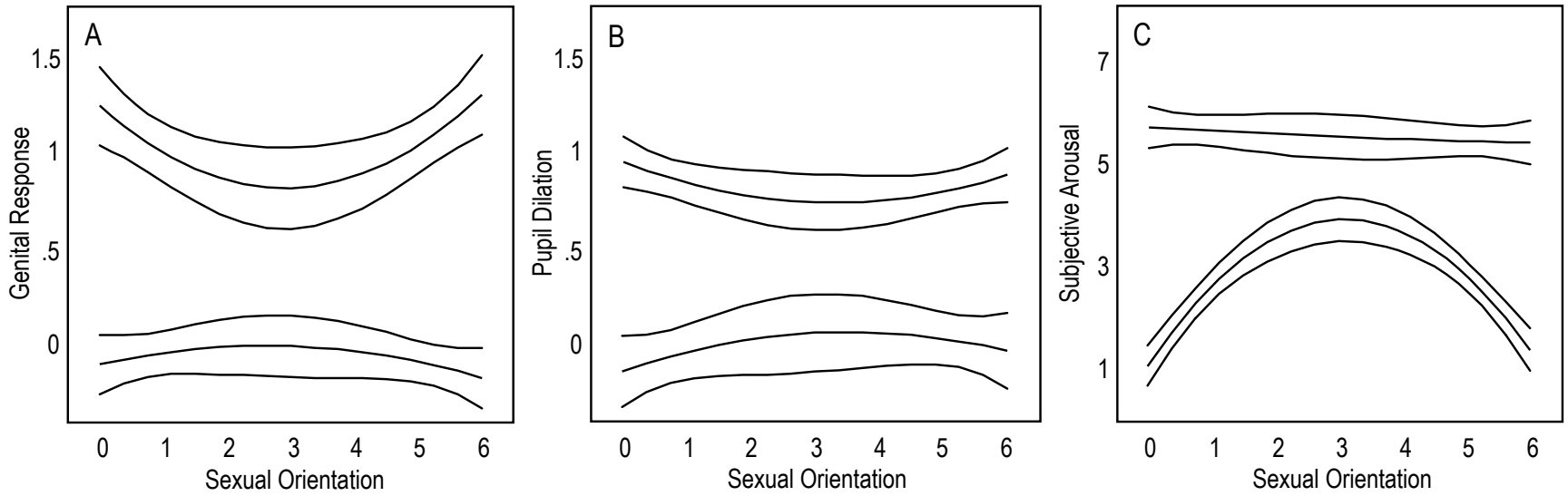

Figure 5. Men's responses to the more arousing sex (upper lines) and the less arousing sex (lower lines). Reported sexual orientation of 76 men relates to genital response (A), pupil dilation (B), and subjective arousal (C). On the Y axes, genital response and pupil dilation scores reflect changes compared to baseline, *z*-scored within participants. On the X axes, 0 represents an exclusive heterosexual orientation, 3 a bisexual orientation, and 6 an exclusive homosexual orientation. Lines represent regression coefficients with 95% confidence intervals.

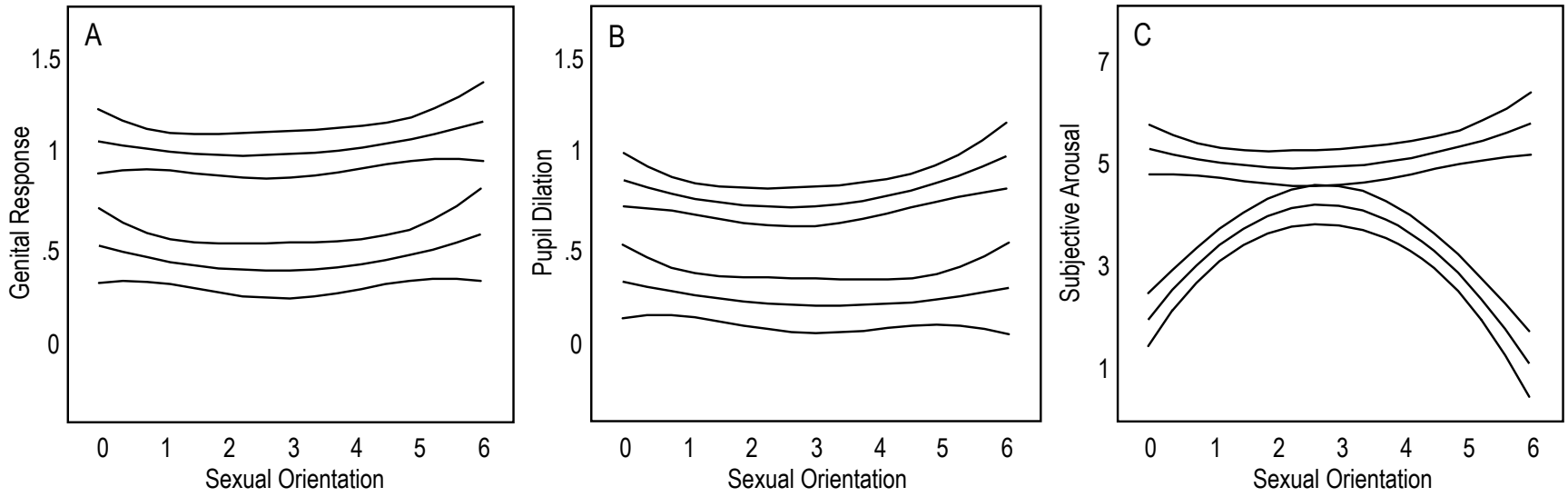

Figure 6. Women's responses to the more arousing sex (upper lines) and the less arousing sex (lower lines). Reported sexual orientation of 72 women relates to genital response (A), pupil dilation (B), and subjective arousal (C). On the Y axes, genital response and pupil dilation scores reflect changes compared to baseline, *z*-scored within participants. On the X axes, 0 represents an exclusive heterosexual orientation, 3 a bisexual orientation, and 6 an exclusive homosexual orientation. Lines represent regression coefficients with 95% confidence intervals.