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Visual spatial attention to sexual stimuli

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Abstract
Visual events of high salience are thought to automatically attract visual processing resources to their location. Hence, we should expect that stimuli with sexual content should trigger such a movement of visual resources. However, evidence for such an allocation of visual resources is sparse and rather contradictory. In two studies we tested this hypothesis. Using a dot-probe task, Experiment 1 showed that targets occurring at the location of a briefly presented and uninformative cue (hence engaging "exogenous" attention) with sexual content were responded to more rapidly than those that occurred at the location of the neutral cue - thus confirming that sexual stimuli can attract automatic attention to their location. However, the effect was small and had a low level of reliability. No consistent gender differences were found. In Experiment 2, we examined whether this cueing effect remained even for low-visibility cues. No cueing effects were found, but the task manipulation also abolished the cueing effect for high visibility cues. While the study supports the notion of spatial allocation of visual resources to sexual stimuli, it highlights that this effect is not robust or reliable, and discusses the implications of this.

Keywords Sexual images · Spatial attention · Sexual content induced delays (SCID) · Dot probe task · Reliability

Certain stimuli, such as those depicting an immediate threat to the person, have been claimed to have priority to processing resources within the visual system (Ohman et al., 2001). By the same token, it would seem that sexual stimuli might also claim prioritisation over more mundane stimuli due to the high appetitive potential of such stimuli (Strahler et al., 2019). In the present paper, we examine whether such sexual stimuli cause an automatic shift of visual attention to their location, and whether this shift can be induced by stimuli that are sufficiently brief that the person is unaware that a sexual stimulus was presented.

Humans have a limited capacity to process all of the currently available visual information. Therefore some objects, or spatial locations, are selected for deeper processing (Snowden et al., 2012). Posner and colleagues (Posner, 1980) demonstrated that visual targets appearing at a location that was cued are processed more rapidly and accurately than targets appearing at similar but not-cued location. This was attributed to attention being attracted to the location of the cue which allows for better processing of the target. Further work (e.g., Nakayama & Mackeben, 1989) has established that the allocation of visual spatial attention can be determined by automatic processes (exogenous movement of attention) or by consciously controlled processes (endogenous movement of attention). Some stimuli, such as the sudden onset of a cue, are thought to automatically attract attention to their location even though the cue is not predictive of the location of the target stimuli. When the cue is predictive of the target location, the person can deliberately move their attention to the likely location of the target. When it comes to attention to sexual cues it seems most likely that people would be able to deliberately move their attention to the location of a sexual object. However, in this paper we focus on whether such a sexual object automatically attracts attention via exogenous shifts.

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Exogenous shifts of attention have been investigated by presenting two cues (one containing sexual content and the other neutral content – see Fig. 1) either side of a fixation point, and then presenting a target at the location of one of these cues. If spatial attention is automatically moved to the location of the sexual cue, then reaction times (or errors) should be lower when targets appear at this location in comparison to targets appearing at the location of the neutral cue. This "dot-probe" experiment has been performed several times, however, the pattern of results is contradictory.

Prause et al. (2008) were the first to conduct such a test. They found that participants were actually faster when the target appeared at the location of the neutral cue rather than the sex cue, a result in direct opposition to that hypothesised by the idea that sexual stimuli attract attention. This result was then replicated in a sample of both normally sexually functioning women and a sample of women with hypoactive sexual desire disorder (Brauer et al., 2012). On the other hand, other studies (Doornwaard et al., 2014; Kagerer et al., 2014; Mechelmans et al., 2014; Nolet et al., 2021; Pekal et al., 2018) all report the hypothesised faster RTs for targets appearing at the location of the sexual cue, though it is notable that nearly all these effects were "small" (< 10 ms). Finally, there have also been a series of studies that have failed to find a significant effect of the sexual cues (Novák et al., 2020; Ziogas et al., 2022). Hence, every possible result has been found (and replicated!).

Strahler et al. (2019) attempted to meta-analyse results that used the dot probe task. They concluded that there was a significant effect of attention to the location of the sex cue ($g = 0.34$, 95%CI[0.17, 0.50]). However, the analysis appears to omit the findings from Prause et al. (2008), and presents the findings of Brauer et al. (2012) as positive when the actual results were negative.

Nearly all of the results noted above used a cue to target interval of 500 ms (and in some cases even longer). Research using "simple" cues (e.g. Nakayama & Mackeben, 1989) has shown that exogenous attention is quite short lived (< 300 ms) which raises the possibility that the effects of the exogenous shift of attention to the sexual cues might be missed at such long cue to target intervals (though it is seems most likely that it will take much longer for the sexual content of the image to attract attention in comparison to a simple flash of light). It has also been noted that long cue to target intervals, such as 500 ms, may allow time for overt movement of the eyes which may reduce the classic dot-probe effect (Petrova et al., 2013). To address this issue we chose to use two cue to target intervals. A cue to target duration of 500 ms was used so that the data could be compared to many previous studies that used this duration. In addition, we also chose a much shorter duration (200 ms) at which only a single shift of covert attention (and insufficient time for any eye movement – Sumner, 2011) and where a previous study has shown effects of sexual stimuli in such a task (Snowden et al., 2016).

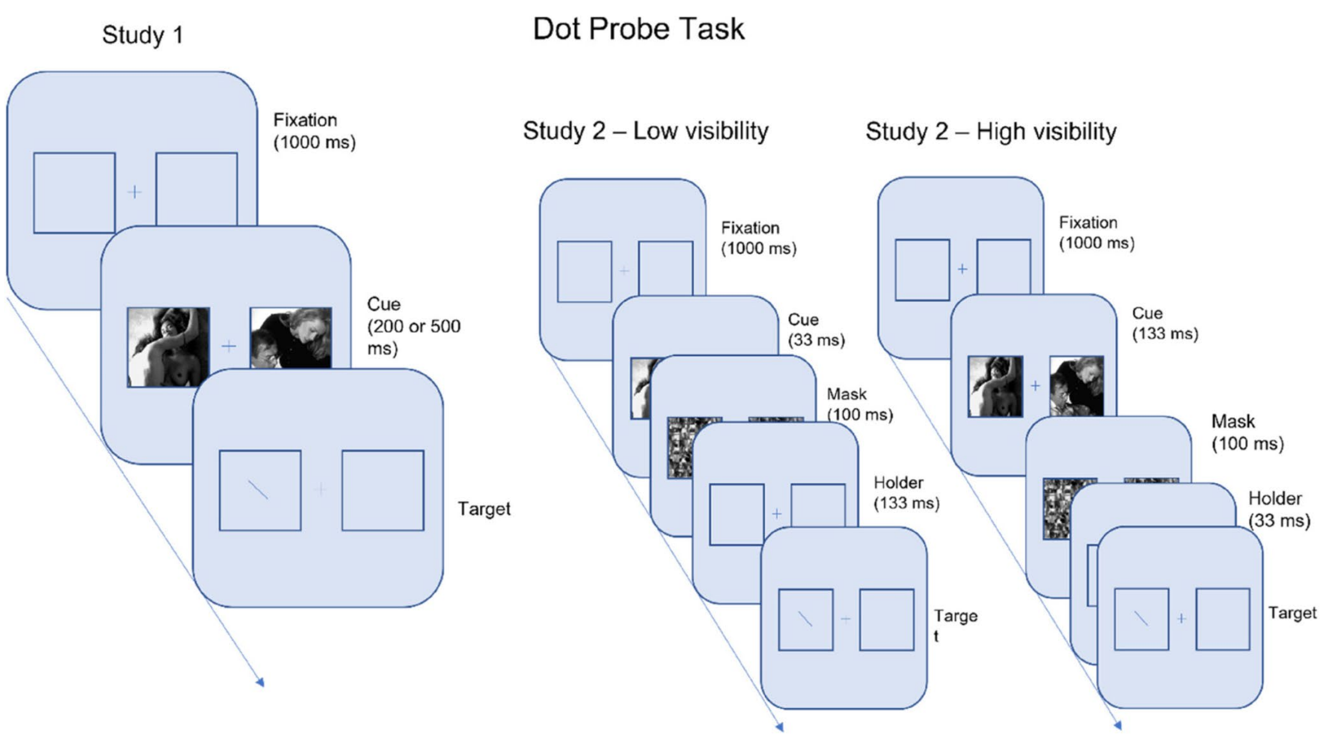

Fig. 1 Illustration of the tasks used

Sexual Content Induced Delay (SCID)

The study of Prause et al. (2008) also contained trials in which both cues were neutral. Under these conditions, RT to the targets were faster than under conditions where one of the locations was a sexual cue, indicating that the sexual images caused a slowing of RTs that was not related to its location. The finding that sexual images produce a general slowing of responses had been previously noted. For example, Geer and Bellard (1996) had participants make lexical decisions based on sexual and neutral words and found that decision time was slower for sexual words than for romantic or neutral words. This general slowing of RTs in the presence of sexual images was also noted in many other studies using the dot-probe task (Brauer et al., 2012; Doornwaard et al., 2014; Mechelmans et al., 2014; Nolet et al., 2021; Ziogas et al., 2022), though not all studies have shown this (Kagerer et al., 2014). The finding has also been found in variants of the Posner covert attentional paradigm where only a single cue is presented (Imhoff et al., 2020) and in paradigms where there is no obvious need for shifts in spatial attention (Codispoti et al., 2016; Kagerer et al., 2014).

Gender differences

In terms of gender differences in attention to sexual stimuli, it is intuitive to think that men would have a greater attention bias towards sexual stimuli because research has suggested that men tend to have a higher sex drive (Frankenbach et al., 2022) and are more motivated by sexual stimuli (Baumeister et al., 2001) compared to women. Men also tend to engage with sexual content more than women which could be indicative of sexual stimuli being more appealing to men and thus capturing their attention more (Carroll et al., 2017).

Both Kagerer et al. (2014) and Pekal et al. (2018) compared the size of the spatial attention bias to sexual stimuli between men and women in a healthy community samples but did not find any gender effects. Likewise, Novák et al. (2020) found no effect of gender, but this was in the context of neither gender showing an effect. In the meta-analysis of Strahler et al. (2019) reviewed above, gender was considered as a possible moderator of the effect of sex cues on the dot probe task. Only three studies were identified and no significant effect of gender emerged. Thus, the expected gender differences have not yet been supported by the empirical evidence. Experiment 1 therefore aimed to examine any effects of spatial attention to sexual stimuli or any non-spatial effects (e.g., SCID) as a function of gender.

Experiment 1

The first study attempted to gather more evidence in favour (or against) the notion that sexual stimuli automatically attract visual attention. It aimed to improve on the methodology used in (most) previous studies in several ways. First, the sample size was larger than most previous studies and included both men and women. It was powered to detect a "small" effect size ($d=0.3$) overall, and to detect a gender difference with a "medium" effect size ($d=0.5$). Second, most studies used a task in which the participant had to respond as to the location of the target. Unfortunately, such a task may reflect a response bias to this location or a "Simon" effect (Simon, 1969) rather than a perceptual enhancement of targets. To avoid this we used a choice reaction time paradigm where the response required was orthogonal to the location of the target (or cue). Third, great effort was made to match the sexual and neutral cues on physical characteristics: (a) previous studies appear to have used coloured images (though this information is absent in nearly all publications) which means that the sexual images almost certainly would have more "flesh" colours than the neutral cues. The present study used only grayscale images, (b) many studies used neutral cues that did not contain people, or used "scrambled" versions of the sexual cues (e.g., Ziogas et al., 2022). In the present study the neutral cues were matched in terms of composition (e.g., all contained two people, one male and one female), (c) efforts were made to match sexual and neutral images in terms of brightness and contrast. Fourth, careful consideration was given to the number of trials shown to each participant. While it is usually the "rule" that a greater number of trials leads to a more precise estimate of the measured effects, there may also be an habituation of the effect with repeated presentations. While we could not find literature directly relevant to the allocation of spatial attention for such sexual cues, Codispoti et al. (2016) show that the distracting effect of sexual cues diminishes with repeated presentations. Hence, we chose to use a relatively small number of trials/repetitions in order to reduce any effects of habituation. Fifth, no previous studies of the sex dot probe effect have reported on the reliability of the effect[1]. Unfortunately, the dot probe paradigm has been shown on several occasions to have poor reliability (Rodebaugh et al., 2016; Schmukle, 2005; Snowden et al., 2022; Staugaard, 2009). Given the importance of reliability

[1] Novák et al. (2020) present some data on reliability suggesting the task has a very high reliability. However, this analysis appears to have use the mean RT data for each condition (as they present reliability estimates for both sex target trials and for neutral target trials) rather than the difference scores (the difference in RTs between the sex and neutral trials). Hence, the reliability index they calculate is heavily influenced by individual differences in overall RTs rather than the effect of the sex cues per se.

to draw robust inferences from statistical analysis (for a review see Parsons et al., 2019) and for work involving individual differences (for a review see Hedge et al., 2018) this is a serious omission to our understanding of the field. We, therefore, report on the reliabilities of the effects obtained. Finally, we used two cue to target intervals (200 and 500 ms) in order to compare conditions where we thought only exogenous shifts of attention could be expected (200 ms) to those where other influences may also emerge (500 ms).

Hypotheses

We hypothesised that: (1) processing of targets at the location of the sexual cue would be more efficient than those occurring at the location of the neutral cue when a sex cue and a neutral cue were presented together. This should be manifest in shorter RTs to targets at the location of the sex cue. It might also be manifest in fewer errors. (2) processing of targets would be less efficient after the presentation of a sex cue (the SCID). This should be manifest in smaller RTs for the neutral-neutral targets compared to either the sex-neutral or neutral-sex conditions. It might also be manifest in fewer errors. We did not make specific hypotheses with respect to cue to target interval, or with respect to possible gender differences.

Method

The ethics of this study was approved by the psychology department of Cardiff University. The data used are available at https://doi.org/10.17632/tpx353nns6.1.

Participants

Participants were recruited from Cardiff University via advertisement on an online Experimental Management System (EMS) on a volunteer basis. Sample size was determined using a power analysis (G*Power: Faul et al., 2007). This showed that to detect a significant effect of sexual content with a small effect size ($d=0.3$) and standard alpha (0.05) and power (0.8) required 71 participants. To examine possible gender differences with a medium effect size (and a gender ratio of 2:1 as we suspected a greater number of females than males due to the distribution of gender in our recruitment sample) would require 114 participants. One-hundred and twenty-two participants volunteered and completed the study. After exclusion criteria were implemented (see Data Analysis), 117 participants (31 men, 86 women) were included in the analysis.

Eighty-eight (75.2%) reported their age as between 18 and 20 years and 29 (24.6%) as between 21 and 30. Twelve (10.3%) reported their ethnicity as Asian, 1 (0.9%) as Black, 101 (86.3%) as White, and 3 (2.7%) as other or prefer not to say. Seventy-eight (66.7%) reported being heterosexual, 6 (5.1%) as Gay/Lesbian, 24 (20.5%) as bisexual, and 9 (7.7%) did not report their sexual orientation.

Materials

Dot probe task

Eight sexual stimuli were chosen from established image databases (Nencki Affective Picture System (NAPS): Marchewka et al. (2014); International Affective Picture System (IAPS): Lang et al. (1997). Each image contained a heterosexual couple engaged in sexual activity. The neutral stimuli were chosen to match the sexual images in terms of pose and the background of the image. One was taken from the IAPs and the rest sourced from Google Images. These images featured heterosexual couples in a non-sexual context. For the neutral-neutral trials a further set of eight images were selected. These contained groups of people in a neutral, non-sexual context. All images featured people instead of some featuring objects to avoid finding a "people" effect because humans typically attend to faces more than objects (Frank et al., 2014). All stimuli were processed to be matched in contrast and luminance, and were presented in monochrome to avoid simple differences in "flesh" colors being used to guide attention. These images were then judged in a pilot study for sexual arousal. Thirty-seven participants (25 heterosexual, 4 homosexual, 5 bisexual, and 3 others), all were of white ethnicity and were aged between 18 and 25 years old) rated the stimuli of this study on an 11-point Likert scale to measure the perceived sexual arousal of each image (0 = low sexual arousal, 10 = high sexual arousal). The mean ratings are reported in Table 1 which shows that the sexual stimuli were rated as more sexually arousing than the neutral stimuli by both men and women. No gender differences were noted (all $ps > 0.1$).

The sex-neutral cues were constructed by placing one of the sexual images on one side of the image and its neutral foil on the other side to produce eight such cues. These cues were then duplicated but with the side of the sexual

Table 1 Ratings of perceived sexual arousal of the images used in studies 1 and 2

Gender	*N*	Stimulus Type	
		Neutral Mean (SD)	Sexual Mean (SD)
Men	18	0.7 (0.5)	5.2 (2.6)
Women	19	0.5 (0.4)	5.8 (3.1)
Total	37	0.6 (0.5)	5.5 (2.7)

and neutral images reversed to produce 16 cues in total. The neutral-neutral cues were produced in a similar manner by assigning the eight images into four pairs and having two versions of each pair where image X was on the right in one of them, and on the left in the other.

A typical trial is depicted in Fig. 1. Each trial commenced with a blank screen for 1000 ms, which was followed by a fixation screen that contained a fixation cross at the centre, with two placeholders either side (11.1 deg by 7.7 deg high with a gap of 5 deg between the boxes in the middle). The cue was then presented for 200 or 500 ms followed immediately by the target (a line 1.7 deg long at the centre of one of the placeholders). The target remained on the screen until the participant responded.

Participants were required to press the "A" key on the keyboard if the line was tilted anti-clockwise and the "L" key if it was tilted clockwise. A reminder appeared on the screen of this response requirement. Participants were asked to respond as quickly as possible while minimising errors. No feedback was given as to the correctness of response.

Three types of trial were presented (see above): sex-neutral (a sex cue and a neutral cue with the target appearing at the location of the sex cue), neutral-sex, and neutral-neutral). Each cue was presented for either 200 and 500 ms, and followed by a clockwise or anticlockwise target. This factorial combination (three cue types, two target types, two cue to target durations, eight exemplars) produced 96 trials that were presented in a new randomised order for each participants. The experiment was controlled via the DirectRT programme.

Procedure

Participants received an information sheet providing a brief description of the study, this forewarned participants that they would be exposed to sexual stimuli. Preliminary consent was then obtained for them to a preview of all the stimuli to be used. This was done via a single sheet with all of the images in "thumbnail" form. If participants were still happy to proceed they signed the consent form and then completed a demographic questionnaire. It was explained that their data will be held anonymously and participants were asked if they had any questions before starting the study.

Participants were then sat in front of the computer screen with their eyes approximately 57 cm from the screen. An instruction slide explained that they were required to look at the fixation cross when it appeared and to keep their gaze on this until the trial was complete. It stated that they should respond to the orientation of the target (and not the side it appeared on), which keys to press, and to use their left hand to press the "A" key and right hand to press the "L" key. These instructions were also placed on a sheet next to the screen in case the participant wanted a reminder of them. They then completed the dot-probe task. At the end, participants were thanked for their time and received a debrief sheet about the purpose of the study and credits were awarded.

Data analysis

For the dot-probe task, mean RT was calculated for trials on which the target was correctly classified in the range of 300–1500 ms. Error rates were also recorded. The primary analysis consisted of a three-way analysis of variance (ANOVA) of the RT data with main effects and interaction being followed-up by specific tests of the hypotheses. In addition, the error data were also analysed for any possible speed-accuracy trade-offs (where an increase in speed is accompanied by an increase in error rates).

Data for one participant was removed due to missing data points. Two participants were removed due to excessive errors ($>25\%$) and one was removed due to overall slow RTS (>3 SD from the mean). One person did not report on their gender and so was omitted. This left a final sample of 117 participants (86 women, 31 men).

Results

The reaction times were inspected for normality of distribution (Tabachnick & Fidell, 2007) and deemed to be close to a normal distribution with all conditions showing low levels of skew <1.0. As expected, the error data showed a skewed distribution so these data were transformed by the function $\sqrt{(1+X)}$ for statistical analysis. Untransformed scores are used for descriptive statistics.

Primary analysis

The mean RTs are depicted in Fig. 2. The RT means were analysed via a 3-way mixed ANOVA with within-subject factors of cue type (Neutral-neutral, Sex-neutral, Neutral-sex), and cue to target duration (200, 500 ms), and a between-subjects factor of gender. Mauchly's test indicated that the assumption of sphericity was not violated for the cue ($\chi^2(2)=4.90$, $p=.09$) or cue and cue to target duration interaction ($\chi^2(2)=2.37$, $p=.31$).

There was a main effect of cue type, $F(2, 230)=29.74$, $p<.001$, $\eta_p{}^2=0.21$. Analysis of this main effect showed the neutral-neutral cues to have the fastest RTs (596.8 ms) which were significantly faster than the sex-neutral cues (614.7 ms: Δ17.9ms: 95%CI[10.6, 25.2], $p<.001$) and the neutral-sex cues (623.6 ms: Δ26.8 ms: 95%CI[19.4, 34.1],

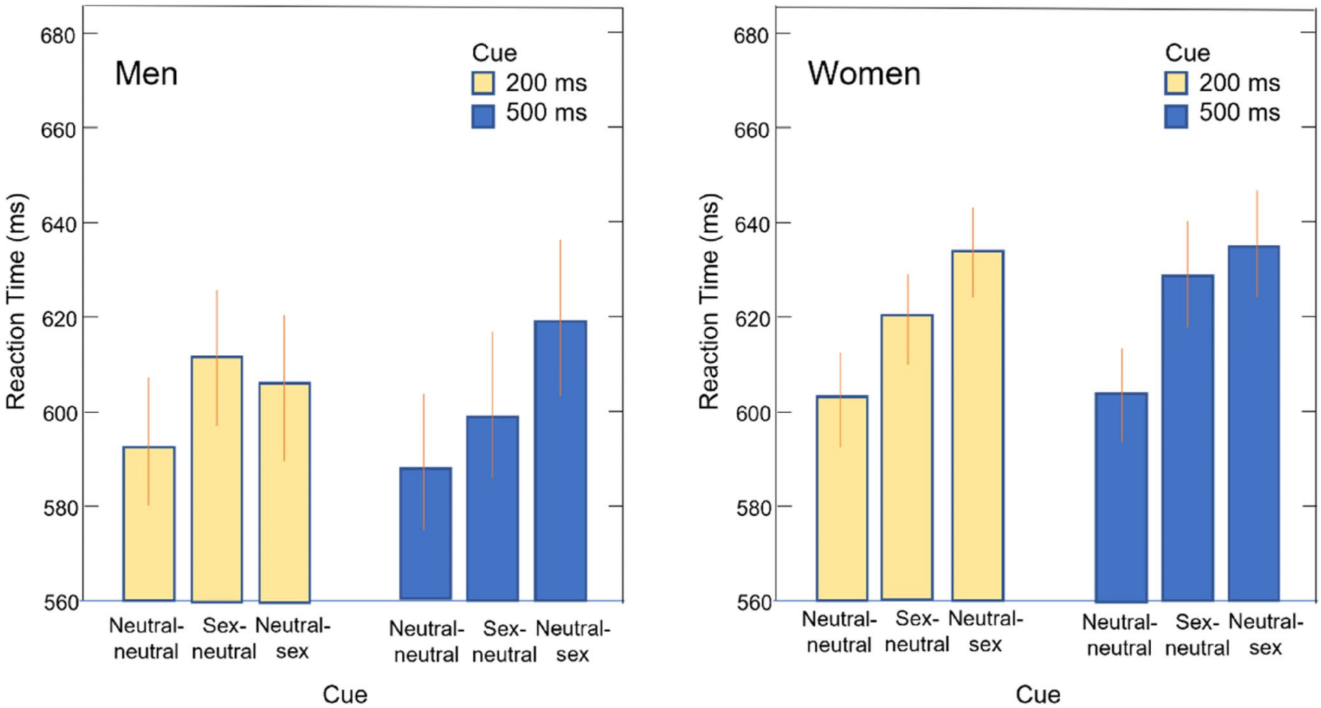

Fig. 2 Reaction Times to the target following the different types of cue in Experiment 1. The left panel is for the male participants and the right panel for female participants. Error bars represent ± 1 SEM

$p<.001$). The Sex-neutral cues produced faster RTs than the neutral-sex cues (Δ8.9ms: 95%CI[2.6, 15.1], $p=.006$).

There was no main effect of cue to target duration, or of gender (Fs < 1). There were no significant two-way interactions (Fs < 1). However, there was a significant three-way interaction, $F(2, 230)=3.27$, $p=.04$, $\eta_p^2=0.03$. This interaction is explored below.

Effect of location of the sex cue

Hypothesis 1 was that RTs would be faster when the target appeared at the location of the sex image compared to when it appeared at the location of the neutral image on trials that contained both a sexual and neutral image. To test this, the effect of the sexual cue was calculated via the formula $RT_{Neutral-sex}$ - $RT_{Sex-neutral}$, which would be positive if RTs were faster to targets at the location of the sex cue. For women, this cueing effect was significant at 200 ms (13.9 ms: $t(85)=3.32$, $p<.001$, $d=0.36$) but not at 500 ms (6.39 ms: $t(85)=1.16$, $p=.25$, $d=0.16$). However, the size of this effect was not significantly different between the two cue intervals ($t(85)=1.07$, $p=.29$, $d=0.12$). For men, the effect was not significant at 200 ms (-5.0 ms: $t(30)$ = -0.62, $p=.53$, d = -0.11), but was significant at 500 ms (20.1 ms: $t(30)=2.99$, $p=.006$, $d=0.54$). This difference in the effects at the two cue intervals was significant ($t(30)=2.16$, $p=.04$, $d=0.39$).

The reliability of the sex cue effect was also calculated via a split-half (odd vs. even trials) and the Spearman-Brown correction. Reliability was low at both 200 ms ($r<0$) and 500 ms ($r=.37$) cue to target intervals.

In summary, the sex cues produced smaller RTs at their location supporting Hypothesis 1. The effect was apparent at both cue to target intervals, and for both men and women, though not all effects in all conditions reached statistical significance. However, the reliability of the effect was poor.

Non-spatial effects of sex cue

Hypothesis 2 predicted that the sex-cues would produce a general slowing of responses to targets irrespective of their location. The slowing due to the sex cue was calculated via the formula $RT_{Sex-neutral}$ - $RT_{Neutral-neutral}$ which would be positive if RTs were faster to targets when no sex cue was present. The sex-neutral (rather than the neutral-sex) condition was chosen as this would produce a sterner test of the possible non-spatial effects of the sex cue. For women, this non-spatial effect of the sex cue was significant at 200 ms cue to target duration (16.5 ms: $t(85)=4.00$, $p<.001$, $d=0.43$) and at the 500 ms cue to target duration (24.5 ms: $t(85)=4.06$, $p<.001$, $d=0.44$). The size of this effect was not significantly different between the two cue intervals ($t(85)=1.18$, $p=.24$, $d=0.13$). For men, this non-spatial effect of the sex cue was significant at 200 ms cue to target duration (19.1 ms: $t(30)=3.08$, $p=.004$, $d=0.55$) but failed to reach significance at the 500 ms cue to target duration (11.5 ms: $t(30) = 1.48$, $p = .14$, $d = 0.27$). This difference in the effects at the two cue intervals was not significant ($t(30) = 0.96$, $p = .34$, $d = 0.17$).

The reliability of this generalised slowing was also calculated via a split-half (odd vs. even trials) and the Spearman-Brown correction. Reliability was low at both 200 ms ($r < 0$) and 500 ms ($r = .39$) cue to target intervals.

In summary, the sex cues produced a slowing of responses in comparison to when no sex cue was present (a SCID) and supporting Hypothesis 2. The effect was apparent at both cue to target intervals, and for both men and women, though not all effects in all conditions reached statistical significance. However, the reliability of the effect was poor.

Exploratory comparison of sexual orientation

Our sample included participants with a range of self-reported sexualities. It is possible that the sexual stimuli used may produce different effects of spatial attention as a function of sexual orientation. To examine this issue, we reanalysed the data using only participants that reported a heterosexual orientation. The pattern of results was highly similar to those reported in the whole sample with a significant overall effect of cue type ($F(2, 164) = 29.35$, $p < .001$, $\eta_p^2 = 0.21$), a significant difference when comparing the sex-neutral and neutral-sex conditions ($F(1, 82) = 7.44$, $p = .008$, $\eta_p^2 = 0.08$), and a significant non-spatial effect of the sexual cue ($F(1, 82) = 39.89$, $p < .001$, $\eta_p^2 = 0.33$).

We also performed an exploratory analysis using only participants who reported a bisexual orientation. This also produced a significant overall effect of cue type with an effect size similar to the heterosexual only group ($F(2, 44) = 9.55$, $p < .001$, $\eta_p^2 = 0.30$). However, the difference when comparing the sex-neutral and neutral-sex conditions was not significant ($F(1, 22) = 1.59$, $p = .22$, $\eta_p^2 = 0.07$) though the effect size was similar to the heterosexual group suggesting this was an issue of poor power. The non-spatial effect of a sexual cue was also significant in this group ($F(1, 22) = 15.58$, $p < .001$, $\eta_p^2 = 0.42$).

In summary, these analyses did not reveal any obvious differences in the pattern of results based on the self-reported sexual orientation of the participants.

Error data

The error data was also analysed via a three-way ANOVA. Mauchly's test indicated that the assumption of sphericity was not violated for the cue ($\chi^2(2) = 2.94$, $p = .23$) or cue and cue to target duration interaction ($\chi^2(2) = 3.39$, $p = .18$). The main effect of cue was significant ($F(2, 230) = 4.60$, $p = .01$, $\eta_p^2 = 0.04$). Pairwise comparisons showed that errors for the neutral-neutral cues (2.51%) were smaller than for the sex-neutral cues (3.75%) and for the neutral-sex cues (3.80%) (ps < 0.01). Errors for the sex-neutral and neutral-sex cues did not differ significantly ($p = .92$). No other effects were significant. In summary: (1) the SCID effect was also apparent in the error data, (2) the error data did not indicate any spatial shifts of attention to sexual stimuli, but neither did they suggest a speed-accuracy trade-off.

Discussion

Experiment 1 showed two main results. First, when a sex image and a neutral image were presented, RTs to targets at the location of the sex image were faster than those for the location of the neutral image. However, there were no differences in error rates. This supports Hypothesis 1, that sexual images attract spatial attention. Second, RTs were slowed when a sexual image was presented compared to when only neutral images were presented. Error rates also increased when a sexual image was presented. This supports Hypothesis 2, that there is a general decrease in processing targets in the presence of sexual images.

Experiment 2. Low-visibility sexual cues

While there are several aspects to the definition of "automatic" processing, one test of such processing is to reduce the visibility of the stimulus to the point where the nature of the stimulus is difficult or impossible to discern – so called "subliminal" presentations (Dixon, 1971). The exact definition of subliminal has been a cause for debate (Wiens, 2006) and different studies have used different definitions. It is not the purpose of this paper to enter this debate. We use the term "low-visibility" to refer to a stimulus that is presented very briefly and is masked so that its content is difficult to discern.

The evolutionary benefit of sexual stimuli capturing attention suggests that if sexual stimuli are exogenous cues for attentional processes, this effect might be present prior to conscious awareness of the stimuli. Previous research has highlighted that low visibility sexual stimuli, theoretically presented outside of someone's conscious awareness, influence genital response and neural activity (Gillath & Canterberry, 2012; Ponseti & Bosinski, 2010). Attention towards sexual stimuli has specifically been highlighted in theories of sexual dysfunction (Barlow, 1986). Further, attention towards sexual stimuli is thought to contribute towards sexual arousal (Janssen et al., 2000). Identifying if sexual stimuli are exogenous cues when the stimuli are of low visibility provides a focus for research investigating sexual dysfunction and a potential direction for treatment. Identifying the automatic allocation of attention towards low visibility sexual stimuli may also allow research to investigate theories of sexual attraction in younger populations, or in populations that might be motivated to hide sexual attraction to certain stimuli (Snowden et al., 2011).

There have been some attempts to use low-visibility cues in the classic dot-probe task, though not with sexual cues. For instance, Lee and Knight (2009) examined attention to facial expression in young and older adults using both low and high visibility cues. In the older adults they show that low visibility angry face cues show evidence of a "vigilance effect" (attention to the angry face) while the high visibility angry face cues show evidence of a "avoidance effect" (attention away from the angry face). Hence, not only could the low visibility stimuli produce attentional shifts, they were not simply "lesser" versions of the high visibility stimuli suggesting quite difference processes may be activated under these conditions (though in this particular study there was a strong confound due to the very different cue to target intervals in the two conditions).

The closest study to the dot-probe paradigm using low visibility sexual stimuli is that of Jiang et al. (2006). Here they used a single cue (either of a nude women or nude man) and examined the processing of a target that followed this cue. The paradigm therefore appears more like a "modified Posner cueing task" rather than a true dot probe task. The visibility of the cue was altered by using binocular suppression where a high contrast image in one eye rendered the cues presented to the other eye invisible. The results show strong effects of the nude images, that were modified by both the gender and sexual orientation of the participant. Despite these differences to the classical dot probe task, and not using masking to reduce the visibility of the cues, the study of Jiang et al. (2006) shows that spatial attention to low visibility images may be influenced by their sexual content.

Experiment 2 therefore examined if spatial attention could be guided by both high and by low visibility stimuli, and if the results were comparable in direction and magnitude. The study aimed to use the same stimuli and procedures as Experiment 1 where possible. The major difference is that for some trials the cue stimuli were made difficult to see by reducing their duration to 33 ms and masking them with a noise mask (see Fig. 1). In order to reduce the burden on the participants the trails from the neutral-neutral cues were removed.

Hypotheses

We hypothesised that: 1) processing of targets at the location of the sexual cue would be more efficient than those occurring at the location of the neutral cue in the high visibility condition. 2) We had conflicting hypotheses with respect to the effects of low-visibility cues. First, it is possible that such stimuli can also guide visual attention (e.g. Jiang et al., 2006) in which case this should be manifest in smaller RTs at the location of the sex cue under these low visibility conditions. Second, such low visibility cues may not be able automatically guide visual attention, in which case RTs at the location of the sex cue and at the location of the neutral cue would not differ. While this hypothesis predicts a "null" result, we hope to be able to contrast this lack of effect with the significant effect predicted in the high-visibility condition.

Methods

Participants

A total 132 participants were recruited through the same means as Experiment 1 save that 17 of these were recruited thought word of mouth and did not receive compensation for their participation. The experiment was granted ethical approval by Cardiff University School of Psychology Ethical Committee. After removing participants that did not meet the criteria for being analysed, the sample consisted of 117 participants (80 female, 37 male) with ages of 18–20 ($n = 90$, 76.9%) and 21–30 (27; 23.1%). Thirteen (11.1%) reported their ethnicity as Asian, 1 (0.9%) as Black, 101 (86.3%) as White, and 2 (1.8%) as other or prefer not to say. Seventy-nine (67.5%) reported being heterosexual, 5 (4.3%) as Gay/Lesbian, 24 (20.5%) as bisexual, and 9 (7.7%) did not report their sexual orientation.

Dot probe task

The dot probe task used the same stimuli as in Experiment 1 save that the neutral-neutral trials were removed. Trials on the low visibility condition presented the cue for just 33 ms and followed this with a mask for 100 ms that consisted of a random montage of small squares taken from the stimuli being used. The holding pattern was then presented for 133 ms and then the targets. Thus, the cue to target interval was 266 ms. The high visibility trials presented the cue for 133 ms, the mask for 100 ms, and the holder for 33 ms, and also had a cue to target interval of 266 ms.

Each of the 16 cues (8 sex-neutral, 8 neutral-sex) were presented with each of the target locations, and each of the target orientations for each of the cue visibility conditions to create 128 trials. The 128 trials were then presented in a new randomised order for each participants. The experiment was controlled via the DirectRT programme. Data analysis procedures were identical to Experiment 1.

Visibility task

A pilot study was conducted to assess the visibility of the sex cues. Trial construction and stimuli were identical to those of the main study (see Fig. 1) but, instead of the target stimuli, instructions appeared to ask on which side of the image (left or right) the sexual cue occurred. Ten participants (5 men, 5 women) took part from the same pool as the main experiment. For the low visibility trials the mean accuracy score was 51.3% (SE = 3.1) which did not differ significantly from chance levels, $t(9) = 0.41$, $p = .69$. For the high visibility condition performance was near perfect (98.6%, SE = 1.0). Therefore, the manipulations of cue visibility produced the desired effect of being very difficult to detect/locate for the low visibility condition but easy to detect/locate for the high visibility condition.

Results

Data for one participant were removed as they did not report their gender. Eleven further participants were removed due to making too many errors (> 25%) and three were removed due to slow RTS (> 3 SD from the mean), leaving a final sample of 117 participants.

The RT means are shown in Fig. 3 and were analysed via a 3-way mixed ANOVA with within-subject factors of cue condition (sex-neutral, neutral-sex), cue visibility (high, low), and a between-subjects factor of gender. There were no main effects of cue condition, $F(1, 115) = 1.77$, $p = .19$, $\eta_p^2 = 0.02$, or of gender, $F(1, 115) = 3.13$, $p = .08$, $\eta_p^2 = 0.03$. There was a main effect of cue visibility, $F(1, 115) = 341.63$, $p < .001$, $\eta_p^2 = 0.75$, with much slower RTs when the cues were of high compared to low visibility. None of the two-way and the three-way interaction terms were significant (Fs < 1.0). A similar analysis of errors showed no significant effects (Fs < 1.0).

These analyses showed no effects of sexual vs. neutral cues and do not replicate the results found in Experiment 1. In order to confirm this lack of effect for the high visibility cues, a paired t-test was performed. RTs for the targets at the location of the sex cue were actually slightly slower (629.3 ms) than at the location of the neutral cue (627.6 ms) though this difference was not significant, $t(116) = 0.46$, $p = .64$, $d = 0.04$). Hence, we conclude that Hypothesis 1

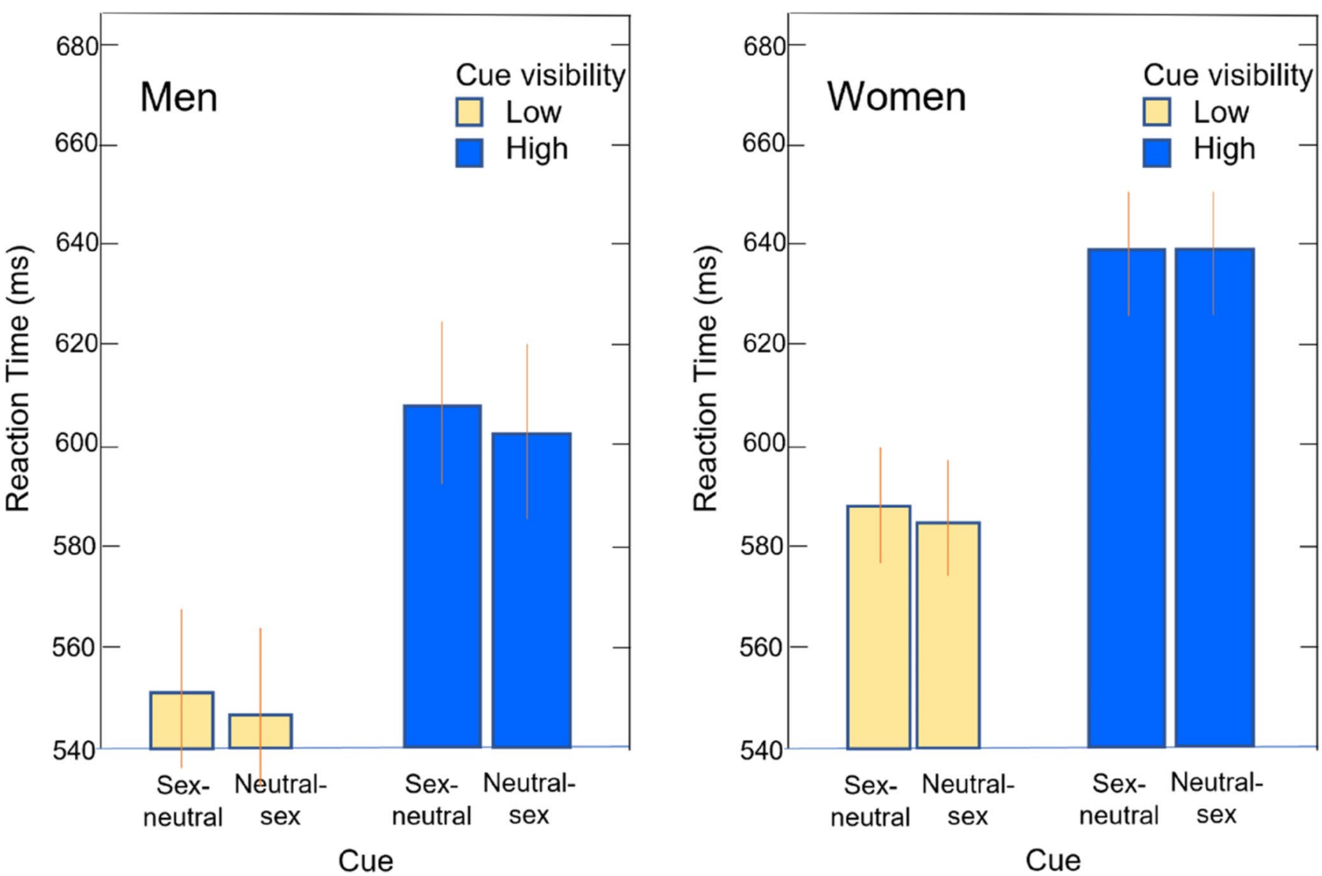

Fig. 3 Reaction Times to the target following the different types of cue in Experiment 2. The left panel is for the male participants and the right panel for female participants. Error bars represent ± 1 SEM

was not supported, and neither version of Hypothesis 2 was supported.

The reliability of the effects were once again calculated as in Experiment 1 and showed poor reliability for the both the high visibility cues ($r = .05$) and low visibility cues ($r < 0$).

General discussion

The present studies aimed to address the question of whether sexual stimuli produce an automatic shift in visual attention to their location in a healthy, young, community sample. Given the contradictory nature of previous studies of this issue, we attempted to refine and improve the methodology in order to produce a more definitive statement on the issue. Our results, however, are far from conclusive.

Experiment 1 did show the hypothesised faster RTs to targets at the location of sexual images compared to neutral images and supports the idea that sexual images can attract automatic spatial attention. However, the overall magnitude of this effect was small, with an absolute difference of only 8.9 ms (and a "small" effect size; $d = 0.26$). The effect was present both at 200 and 500 ms, and for men and women. However, it failed to reach significance for men in the 200 ms condition, or for women in the 500 ms condition. This complex pattern of results requires replication before any conclusions should be drawn or possible reasons for this pattern are speculated upon.

Against the "positive" results shown in Experiment 1 are the lack of any effect of sexual cues in Experiment 2. The aim of Experiment 2 was to see if the shift of spatial attention to the sexual cue could also be demonstrated under conditions where the person was not able to report the location of the sexual cue with any degree of accuracy. While the results support the notion that such low visibility cues do not produce a shift in attention, this conclusion is undermined by the lack of such an effect for the high visibility cue. Hence, at this stage it should not be concluded that the "subliminal" nature of the cues were responsible for the lack of any effect in this condition.

The difference in the pattern of results for the "high" visibility conditions between Experiments 1 and 2 are intriguing given the two studies used the same cues, task, and participants similar in demographics such as age, gender, etc. However, there appears to be two major differences that might account for the inconsistent results. The first is the detailed timing of the two tasks. In Experiment 1, the cues were presented for either 200 or 500 ms and were not masked. In Experiment 2, the cue was presented for either 33 or 133 ms and then masked. Therefore, the available information in even the "high" visibility condition of Experiment 2 was considerably less than in Experiment 1. Figure 1 shows that the differentiation of the sexual cue from the neutral cue is far from trivial, especially under the conditions of our study where the images were matched in terms of low-level physical properties of colour, etc. as well as higher level ones such as both containing two people, etc. Hence, it may take some time for the visual system to extract the sexual nature of such cues in order to trigger movements of attention. We note that others (Miller & Fillmore, 2010) have found that image complexity is important for shifts of spatial attention and were triggered only by "simple" images in their study of attention to alcohol-related cues. Hence, the conditions used in Experiment 2 may have not been sufficient for this differentiation between the neutral and sexual cues, whereas in Experiment 1 they were (we note that under the 200 ms condition, but not the 500 ms condition, there was no effect of the sexual cues for the male participants). Against this idea that the sexual information could not be extracted even in our high visibility conditions, was the finding of near perfect performance when participants were asked on which side the sexual cue occurred. However, this recognition test examines the conscious experience of the image rather than the automatic triggering of spatial attention. It could well be that these two processes are different (indeed, the whole point of Experiment 2, and many previous studies of "subliminal" stimuli, was to examine this dissociation in the low visibility condition).

The second possibility is that the masks themselves are responsible for the lack of effect. The masks occur at both locations, and would presumably work as exogenous cues for attention. Hence, presentation of the masks would drag attention to both locations even if there was an initial allocation of attention to the sexual image (or the neutral image for that matter) and so destroy any attentional effects that the sexual cue might have induced.

Clearly, further tests of these ideas are warranted. Future research may want further to explore the durations (whether masked or not) of the cues, and the relationship between the timings of the cue and the presentation of the target. For instance, there is some evidence that subliminal cues only act over a short time period as compared to supraliminal ones (Mulckhuyse & Theeuwes, 2010). Attempts might also be made to alter the "visibility" of the cues. The present study used cues that were presented to the near-peripheral retina and were of a small size (approx. 10 deg of visual angle). Images of a greater size or simplicity might be needed for fast recognition of the sexual content that could trigger spatial attention. To eliminate the possible driving of exogenous attention by the masking cue other methods of making the cues difficult to see might be used (e.g., low contrast cues, binocular suppression, etc.).

Sexual Content Induced Delay (SCID)

Experiment 1 was able to demonstrate that the presentation of any sexual cue, irrespective of its location, produced a general slowing of target recognition. This sexual content induced delay (SCID – Geer & Bellard, 1996) appears to be a robust finding across a range of paradigms (e.g. Imhoff et al., 2020; Most et al., 2007) and has previously been reported in studies similar to ours using the dot probe paradigm (Brauer et al., 2012; Doornwaard et al., 2014; Mechelmans et al., 2014; Nolet et al., 2021; Prause et al., 2008; Ziogas et al., 2022). Our study adds little to this literature other than in showing that the effect is present for both cue durations of 200 and 500 ms, and that there were no significant effects of gender related to this effect.

Experiment 2 did not include the neutral-neutral condition and therefore did not examine the SCID as a function of cue visibility. On reflection, this was a missed opportunity to test whether the non-spatial effects of a sexual cue are maintained under these low visibility conditions given there are few studies of this issue (Bloemers et al., 2010).

Effects of gender

The dot-probe task to sexual images has been used to examine group differences in sexual interest (Brauer et al., 2012; Doornwaard et al., 2014; Jiang et al., 2006; Kagerer et al., 2014; Mechelmans et al., 2014; Nolet et al., 2021; Pekal et al., 2018; Prause et al., 2008; Snowden et al., 2016, 2023). It would seem intuitive that men would show a greater dot-probe effect to sexual stimuli, given the many studies suggesting a greater interest in sexual stimuli (e.g., (Baumeister et al., 2001) in men. However, the present study did not find consistent evidence for such an effect. The present results are in line with previous studies of this issue (Kagerer et al., 2014; Pekal et al., 2018; Novák et al., 2020) including a meta-analysis of this issue (Strahler et al., 2019.

The present study also failed to find evidence for gender differences in the non-spatial slowing due to a sexual cue. Previous reports on this issue are highly contradictory. For instance, Geer and Bellard (1996) used a lexical decision task (where the participant had to state whether a string of letters is a real word or not) and found that the delay induced by sexual words was greater for women than for men. On the other hand, a recent study (Wiemer et al., 2023) used a go-nogo task superimposed on images that could be sexual. They found that sexual images caused greater commission errors (responding when they should not respond) for both male and female participants, but this effect was greater for men. Imhoff et al. (2020: Experiments 2 and 3) used a paradigm similar to the present studies. A dot-probe task was used and a non-spatial delay due to sexual content was obtained. Like the present findings, this effects was similar in magnitude for men and women. The reasons behind these contradictory results is far from clear. We note that in some cases the participants had to respond to the sexual stimuli itself (e.g. Geer & Bellard) whilst in others the sexual images was to be ignored (e.g. Wiemer et al.). Further work is needed to understand the nature of the sexual content induced delay, and why the different studies have produced different results.

Reliability

A further finding from this study was the very poor reliability of the results for both the spatial attention component and for the overall slowing due to sexual images. It should be emphasised that such estimates of reliability are not the same as whether the task is measuring something that is robust. As Hedge et al. (2018) note, a task can be robust in the sense of producing consistent effects over many studies, but if the individuals within the study all produce approximately the same result, then the task will have low reliability as indexed by such calculations as split-half reliability (as used here) or by test-retest reliability. Hence, the poor reliability in the present study did not render the task unable to show the effects of sexual cues at a group level, but would seriously affect the ability of the task to classify individuals into groups if this was the aim. For example, if the task were used to try and classify if some individual had a problem that was thought to be underpinned by dysfunction in sexual attention (e.g. Mechelmans et al., 2014), then the poor reliability of the task would render this a fruitless (and possibly misleading) endeavour.

It should be stressed that the lack of reliability of the dot probe task in the current studies is not specific to this study and appears to occur in many dot probe tasks (for a review see Parsons et al., 2019). Some researchers have attempted to examine alternate methods of statistical analysis, and with some success (e.g., Yang et al., 2022), but it seems unlikely that mere alterations in scoring procedures will produce a task that is reliable for use in research into individual differences or in clinical research.

Limitations

Most of the limitations of the study have been covered elsewhere in this Discussion (re: issues of reliability, issues related to the visibility of the sexual content of the cues). In addition, the study was limited to young, healthy individuals, and it would be of interest to look at a wider sample of people, including those with a lack of explicit sexual interest, those with sexually compulsive behaviors, etc. However, we suggest that such studies should be delayed until a better understanding of the task and the conditions in which a shift in spatial attention to sexual images occurs, as well as the issues of reliability, are resolved. We also note that our presentation of trials in each experiment was fully randomised. This means that there will have been occasional instances where the same cue was presented on successive trials which may produce possible priming effects. Whilst such instances should occur with the same overall frequency between all conditions, future studies may want to take steps to avoid such instances.

Conclusions

The study provides support for the notion that sexual images attract visual attention. However, to the authors' view at least, this effect is not the robust and large effect that might be imagined given the folklore that sexual images will attract strong automatic attention in most people. Much further work is needed to understand this "weak" effect and how it might be strengthened and made more reliable before the task can be used to explore the role of automatic attention in sexual processing.

Author contributions Robert Snowden: Conceptualization, Methodology, Software, Formal Analysis, Visualization, Supervision, Writing- Original draft preparation. Megan Kydd-Coutts: Software, Investigation, Writing- Reviewing and Editing, Ellie-May Varney: Investigation, Writing- Reviewing and Editing. Olivia Rosselli: Investigation, Writing- Reviewing and Editing. Nicola Gray: Conceptualisation, Writing- Reviewing and Editing.

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Data availability The data are available at: Mendeley Data, V2, https://doi.org/10.17632/tpx353nns6.1.

Code availability The studies were implemented using the DirectRT software package and the code is available from the corresponding author. The images used are subject to copyright restrictions and cannot be supplied by the authors.

Declarations

The authors have no relevant financial or non-financial interests to disclose. This study was performed in line with the principles of the Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study. Approval was granted by the Ethics Committee of the School of Psychology, Cardiff University (Date: 21.11.201: Ref:EC.12.10.09.3209GA5).

Conflicts of interest/Competing interests The authors report no conflicts of interest.

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