Measuring Sexual Interests with Pupillary Responses

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Abstract

During the visual processing of sexual content, pupillary responses have been positively associated with observers' sexual orientation. The question of whether this measure also reflects age-specific sexual preferences, however, is rarely considered. This is remarkable given the potential applied value of pupillary responses for directly measuring unhealthy and inappropriate sexual desires in clinical and forensic settings. The experiments in this thesis addressed this question with a series of tasks whereby observers' viewed images of adults and children while their eye movements and pupil responses were recorded. These results were then compared with sexual appeal ratings for these images and self-report questionnaires relating to sexual interests and experiences. The main findings indicate that pupil dilation is a measure of sexual orientation that is particularly robust and consistent for male participants (Chapters 2 to 4). Furthermore, these experiments provide initial evidence that pupil dilation could also be used as an age-specific measure of sexual interest in males and females (Chapters 2 and 3). Additionally, this thesis explored the influence of low-level stimulus artefacts within the scenes on pupillary patterns (Chapter 2). Findings provide further evidence that the pupillary responses obtained in these experiments are driven by the person content in the scenes. These findings are discussed in relation to existing research on eye-tracking and other current measurements of sexual interest.

Acknowledgements

First and foremost, I would like to thank my supervisor Dr. Markus Bindemann, whose maddening attention to detail, blunt feedback, constant support, optimism, and enthusiasm, have pushed me to become a better researcher and writer than I could have imagined, and kept me sane(-*ish*) in the process. I am immensely grateful for the opportunity to work with and learn from him.

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Special thanks goes to my husband Steven for his patience, constant support (and willingness to move country to support my career!). I couldn't have done it without you. I would also like to thank my Mum and Dad for their constant encouragement and support, and my mother-in-law for helping out when I needed time! Also, my PhD colleagues and office mates throughout the last three years who have listened to my rants and provided humour (and caffeine) when I needed it most.

Finally, I dedicate this thesis to baby RJ, whose cuddles and giggles make all the hard work worth it.

Declaration

I declare that this thesis is my own work carried out under the normal terms of supervision.

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Janice Attard-Johnson

Publications

Within this thesis, Chapter 2 (Experiments 1 and 2) and Chapter 3 (Experiment 3, 4, and 5) have been published and Chapter 4 (Experiment 7) is under review for publication.

Chapter 2

Attard-Johnson, J., Bindemann, M., & Ó Ciardha, C. (2016). Pupillary response as an age-specific measure of sexual interest. *Archives of Sexual Behavior, 45,* 855 – 870.

Chapter 3

Attard-Johnson, J., Bindemann, M., & Ó Ciardha, C. (in press). Men's pupillary responses to persons at different stages of sexual development. *Journal of Sex Research.*

Chapter 4

Attard-Johnson, J., & Bindemann, M. (in press). Sexually Specific but not Sexually Explicit: Pupillary responses to portraits of nude and dressed adults. *Royal Society Open Science.*

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CAPTER1 General Introduction

1.1 Background

Child sex offenses have become a topic of increased interest and concern. Recent research shows that one in 20 children in the UK have experienced sexual abuse (Radford et al., 2011) which accounts for 35% of all sexual crimes recorded in 2013 in England and Wales (Office for National Statistics, 2013). Although not all child sex offenders are sexually interested in children (Quinsey, Chaplin, & Carrigan, 1979), those with such paedophilic interests commit around 10 times more sexual acts on children than non-paedophilic child molesters (Abel & Harlow, 2001). Furthermore, meta-analysis shows that sexual preferences for children is the primary predictive factor in the recidivism of child sexual offending (see Hanson & Bussière, 1998). This indicates a strong link between sexual interests in children and child sex offenses. Being able to measure such interests is central for assessing risk of reoffending following a treatment programme (Navathe, Ward, & Gannon, 2008). Such a measure is also valuable to Clinical and Forensic psychologists for distinguishing between paedophilic and non-paedophilic child sexual offenders, which is important for selecting the appropriate treatment programmes and for assessing possible change following treatment (e.g., Navathe et al., 2008; Seto, Harris, Rice, & Barbaree, 2004; Ward & Stewart, 2003).

A measure for the assessment of deviant sexual interests is therefore important for the research and management of child sex offenders (Gannon, Ward, & Polaschek, 2004; Laws & O'Donohue, 2008). However, measuring paedophilia is notoriously difficult considering the tendencies of this population to conceal their sexual interests (O'Donohue, Regev, & Hagstrom, 2000). This is particularly feasible for self-report based measurements, which are frequently used by Clinicians and often lead to a high false negative rates (Abel, Blanchard, & Barlow, 1981; O'Donohue & Letourneau, 1992). Since the late 1950's researchers have strived to develop a method for objectively assessing sexual interests (Freund, Diamant, & Pinkava, 1958; Freund, 1963). This research was largely focussed on the direct measurement of sexual arousal with genital responses. However, this approach has been met with much reservation due to its' invasive nature and high false negative responses (see Kalmus & Beech, 2009; Laws, 2009; Marshall & Fernandez, 2000).

The need for an objective measure has triggered a surge in attempts by experimental psychologists to find alternative measures of sexual interests (for reviews, see Akerman & Beech, 2012; Kalmus & Beech, 2009; Thornton & Laws, 2009). These measures include latency-based tasks, such as the Implicit Association Task (IAT), the Choice Reaction Time task (CRT), the Pictorial-Modified Stroop task (P-MST), and visual response time (VRT), that assess the response times of participants on a given task while viewing sexual content (Schmidt, Banse, & Imhoff, 2015; Thornton & Laws, 2009). Although these tasks perform well in laboratory settings, they require the full cooperation of the participant and may therefore suffer under natural settings. For example, the participant may attempt to manipulate results by not adhering to task instructions and pressing buttons in a random fashion.

Eye tracking technology is emerging as a promising alternative approach for the measurement of sexual interest. During the visual processing of sexual content, attention has been shown to reflect sexual motivations and preferences (Hewig, Trippe, Hecht, Starube, & Miltner, 2008; Krupp, 2008; Rupp & Wallen, 2007; Suschinsky, Elias, & Krupp, 2007). More recently, changes in pupil size recorded during the viewing of sexual content have been shown to indicate sexual orientation, whereby pupils increase in size (dilate) for stimuli depicting the person of the preferred sex (Rieger & Savin-Williams, 2012). Furthermore, pupillary responses have also been validated against measurements of genital arousal which revealed a strong concordance between these measures (Rieger et al., 2015). This indicates that pupil dilation may be a strong index of sexual interest. This is particularly appealing because changes in pupil size are an involuntary and instantaneous response to the activation of the autonomic nervous system (Zuckerman, 1971), and consequently are difficult to control (Laeng & Sulutvedt, 2014; Laeng, Sirois, & Gredebäck, 2012). This approach would therefore make a promising measure for paedophilic sexual interests. For this purpose, pupil dilation needs to distinguish not only sex preferences, but also sexual age- preferences.

The present thesis explores pupillary response for the measurement of sexual preferences for the same and opposite sex, *and* more importantly whether this paradigm can be applied to detect preferences for adults and children. This thesis presents seven eye-tracking experiments conducted with a *non-deviant population*. Chapter 2 explores whether small changes in pupil size reflect sex- and age- preferences when viewing children and adults in natural scenes. This chapter also examines the influence of low level image factors, such as luminance and colour information, on these pupil responses. Chapter 3 explores whether these pupillary changes are also sensitive to images of people representing more intermediate stages of sexual maturity, as opposed to distinct adults and children categories. Chapter 4 then investigates whether different levels of sexual explicitness affect pupillary responses, and which level of exposure provides the clearest index of sexual interest.

I begin this chapter by outlining the concept of normative and deviant sexual interests and provide a brief overview of two prominent models of sexual arousal. Next, I review some existing measures of sexual interests starting with the most widely researched method - genital arousal, followed by an evaluation of latency-based tasks – IAT, CRT, P-MST and VRT. I will then consider the ways in which eye tracking can contribute to this field with focus on both eye movements and pupillary response. I end this chapter by describing the general methodological approach of the current work.

1.2 Normative and deviant sexual interests

Sexual arousal is described as an emotional state that is comprised of an interplay of physiological changes, emotional expression and motivated behaviour (Chivers, 2005). Research suggests that sexual arousal to a specific preferred category (e.g., male or female) is the primary motivation that directs an individual to seek sexual activity with a partner (Bailey, 2009). This is evident from meta-analysis which have found strong correlations between men's subjective self-reports of sexual interests or behaviours and objective measurements of sexual arousal (for meta-analysis, see Chivers, Seto, Lalumière, Laan, & Grimbos, 2010). In women this association is less clear whereby sexual arousal is not strongly directional (Bailey, 2009; Chivers, 2005). Women's sexual arousal responses are less category-specific than men's (Chivers, Rieger, Latty, & Bailey, 2004), and greater variability exists in the relationship between the physiological, psychological and behavioural manifestations of sexual preferences (for review, see Chivers, 2005).

Sexual preferences can also be considered in terms of specific age groups (Seto, 2012). Normative sexual-age preferences relate to sexual arousal for individuals who have reached full sexual development and are considered to be adults. Research shows that adult men typically report desiring mates who have reached full sexual maturity and are either in their reproductive years or of similar age (Buunk, Dijkstra, Kenrick, & Warntjes, 2001). For example, 20 year old men report sexual interest in people aged 18 to 32 years (Buunk et al., 2001). In contrast, *paedophilia* refers to individuals (at least 16 years of age) who feel sexually attracted to, fantasizes about, or are sexually aroused by prepubescent children under 11 years of age (Hall & Hall, 2007; Seto et al., 2004). This is distinguished from *hebephilia* which denotes sexual preferences for pubescent children of ages 11-14 (Blanchard et al., 2009). Seto (2008) estimates that paedophilia is present in approximately 50% of those who have sexually offended against children, and is the leading predictor of sexual reoffending among those convicted (Hanson & Morton-Bourgon, 2004).

Paedophilia is found to be more prevalent in the male population and although such interests can be found in women, this is considerably lower (on average 4% in women compared to 10% in men; Fromuth & Conn, 1997; Wurtele, Simons, & Moreno, 2014). As a consequence, male paedophilic interests are more widely researched, and research on assessment measures of sexual deviancy is largely limited to the male population. Therefore, because of this distinction, for clarity any reference to paedophilic interests throughout this thesis will be referring to males.

1.3 Models of Sexual Arousal

1.3.1 SINGER'S MODEL OF SEXUAL AROUSAL

Singer (1984) proposes a trichotomoy of sexual arousal comprising of an aesthetic response, approach response and genital response. The aesthetic response refers to the hedonic feeling in response to sexual stimuli, whereby the viewer attempts to keep the target in view to continue to feel this positive emotion. The approach response refers to a movement of the body towards the sexual target, this may be both visual and physical. The final element is termed the genital response and in addition to genital arousal also includes a number of physiological responses (changes in heart rate, muscle tension, and respiration).

1.3.2 INFORMATION PROCESSING MODEL

Janssen, Everaerd, Spiering and Janssen (2000) suggested a model of sexual arousal that highlights the interaction between automatic and controlled cognitive processes (see Figure 1.1). Janssen et al. (2000) proposes two stages of information processing involved in sexual arousal: an appraisal stage which refers to a mechanism that gives meaning to a stimulus and a response generation stage, whereby integrating meaning with response may lead to experience of sexual arousal. These stages are thought to operate on an automatic or pre-attentive level, and are affected by attentional processes. Therefore, when a stimulus is perceived, this provokes an automatic search for sexual meaning, triggering an automatic arousal response and attentional processing. Attention will be directed towards the sexual cue which will once again provoke sexual meaning and so on.

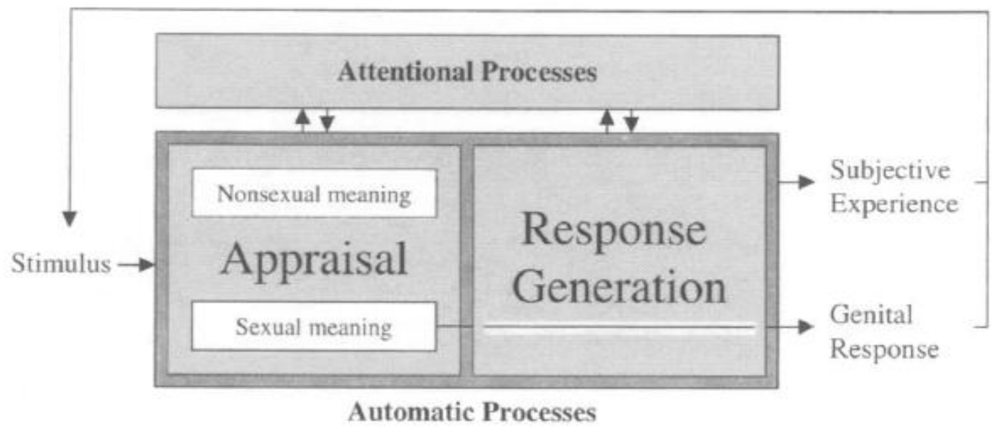

Figure 1.1 Information Processing Model of Sexual Arousal (taken from Janssen et al., 2000)

1.4 An evaluation of current measurements of sexual interest

1.4.1 GENITAL AROUSAL

According to Singer's (1984) model of sexual arousal it is possible gain insight into the sexual preferences of an individual by measuring their genital responses to specific stimuli. To date many reviews have been published concerning the measurement of genital arousal for the assessment of appropriate and deviant sexual interests (see for example, Barker & Howell, 1992; Laws, 2009; Marshall & Fernandez, 2000, 2001; Marshall, 2014; O' Donohue & Letourneau, 1992). These techniques generally work by measuring changes in penile volume (Freund, 1963) or circumference (Barlow, Becker, Leitenberg, & Agras, 1970) for male sexual responding and changes in vaginal blood volume (Geer, Morokoff, & Greenwood, 1974) or pulse amplitude (Heiman, 1977) for females.

When assessing sexual orientation, many studies have shown high levels of congruency between measures of genital arousal and subjective arousal in men (for meta-analysis, see Chivers et al., 2010). In women however, this association is less clear whereby sexual arousal is not strongly directional (Bailey, 2009; Chivers, 2005). Research shows that women's sexual arousal responses are less category-specific than men's (Chivers et al., 2004), and greater variability exists in the relationship between the physiological, psychological and behavioural manifestations of sexual preferences (for review, see Chivers, 2005). For example, females who identify as heterosexual typically report greater attraction and arousal towards male targets in self-report scales, but often show heightened physiological responses and visual attention towards both male and female targets, or sometimes more to female targets (Basson, 2002; Chivers et al., 2010; Rieger et al., 2015; Suschinsky & Lalumière, 2012). There exists a long standing debate on the reasons underlying these inconsistencies, but proposed explanations include measurement or stimuli artefacts, subject characteristics, self-report bias and sex differences in biological mechanisms underlying sexual responding (Baumeister, 2000; Chivers et al., 2004; Chivers, 2005; Suschinsky et al., 2010; Suschinsky, Lalumière, & Chivers, 2009; Suschinsky & Lalumière, 2012).

This approach is also a well-known method for the assessment of deviant sexual interests in men. However, reported levels of accuracy with this approach vary across studies (Laws, Hanson, Osborn, & Greenbaum, 2000). Some studies have recorded a *sensitivity* (i.e., percentage of men correctly identified as having paedophilic interests) of up to 86% during assessment of admitting child sex offenders (Laws et al., 2000) but sensitivity levels lower than 61% have also been reported (Blanchard, Klassen, Dickey, Kuban & Black, 2001; Freund &

Blanchard, 1989). The *specificity* (i.e., percentage of men correctly identified has non-paedophilic) is estimated to be around 96% (Blanchard et al., 2001).

A main concern with these methods relates to non-responding and response suppression during recording (Laws, 2009; Looman, Abracen, Maillet, & DiFazio, 1998; Marshall & Fernandez, 2000). Bailey (2009) reports that men are capable of feeling sexual arousal without a penile erection, and is the case under many laboratory assessments. Furthermore, numerous studies demonstrate that participants - particularly those who had experience with the procedure - were able to *suppress* arousal responses to sexual stimuli with relative ease (Beck & Baldwin, 1994; Card & Farrall, 1990; Golde, Strassberg, & Turner, 2000; Laws & Holmen, 1978; Mahnoney & Strassberg, 1991; Wilson, 1998). This is problematic because offenders often need to be assessed multiple times during the course of their treatment programme, meaning that any decrease in arousal response due to voluntary suppression may be misinterpreted as decreased sexual interest to the inappropriate stimuli.

Another caveat concerns stimulus variation among studies measuring genital arousal. Stimulus choice is likely to have a substantial effect on the results obtained in these experiments and may account for some of the variation in sensitivity across studies. For example, some studies have used audio-only clips whereby participants listen to narratives describing sexual interactions (Golde et al., 2000; Letourneau, 2002; Looman et al., 1998). While others employed images of nude figures (Malcolm, Andrews, & Quinsey, 1993; Kuban, Barbaree, & Blanchard, 1999), static representations of a sexual act or audio-visual tapes of people performing a sexual activity (Quinsey et al., 1979), or a combination of materials (Blanchard & Barbaree, 2005; Kuban et al., 1999; Looman et al., 1998).

These experiments also vary in the degree of sexual aggressiveness that these materials portray (Chaplin, Rice, & Harris, 1995; Miner, West, & Day, 1995).

Of the few studies that have directly compared the effects of different stimulus sets, the strongest arousal responses were achieved with videotapes (Abel, Blanchard, & Barlow, 1981). However, videotapes depicting highly sexually explicit materials reduced the classification accuracy for offenders and non-offenders, as both groups often responded to these stimuli (Marshall, 2006). Furthermore, such sexually explicit images also raise ethical and legal concerns (Merdian & Jones, 2011) and therefore restrict the use of this measure for assessing paedophilic interests. To address this, alternative forms of stimuli have been developed whereby 'fake' identities are constructed from images of two or more people (see Figure 1.2) (Laws & Gress, 2004; Pacific Psychological Association Corporation, 2004). However, the realism of these images is undetermined and it is unclear what effect this factor has on responses to these stimuli.

The lack of a universally standardized method for administration is therefore one of the issues with phallometric measurements of sexual interest expressed by researchers in the field among other reservations surrounding this method, including low test-retest reliability and legal challenges (see Kalmus & Beech, 2009; Laws, 2009). These characteristics, along with the measure's vulnerability to response suppression, restricts the applicability of genital arousal for the measurement of sexual interest in clinical settings (see Merdian & Jones, 2011).

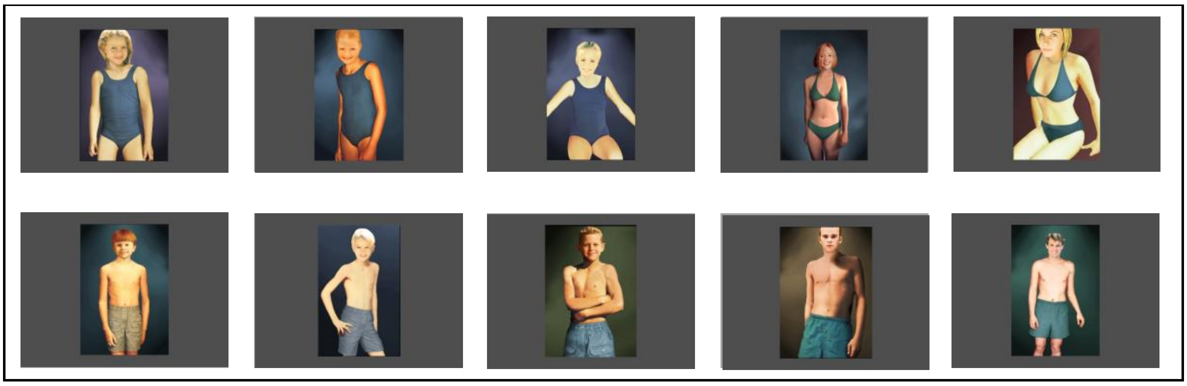

Figure 1.2 Illustration of computer generated representations of people depicting the Tanner stages I to V (left to right).

1.4.2 LATENCY-BASED MEASURES OF SEXUAL INTEREST

Latency-based measures hinge on the concept that response times on a task can indicate an individual's sexual preference when presented with stimuli that may be related to their sexual interests. For some of these tasks, such as the CRT, a slowing-down of responses could indicate a distraction from the task when viewing preferred sexual content– a mechanism coined as sexual-content induced delay (Geer & Bellard, 1996). In contrast, in other tasks, such as the IAT, it is the speeding-up of responses that indicates sexual preferences. These tasks are discussed in detail in the following sections.

Implicit Association Test (IAT)

The Implicit Association Task (IAT) is centred on the idea that certain associations are stronger and more readily available in a person's memory (such as flower and pleasant) (Banse, Schmidt, & Clarbour, 2010; Gray, Brown, MacCulloch, Smith, & Snowden, 2005; Greenwald, McGhee, & Schwartz, 1998; Snowden, Craig, & Gray, 2011). The IAT measures the strength of these associations by comparing reaction times to these word pairings. Consequently, faster response times are recorded for concepts that are strong in an individual's memory than newly paired concepts. In an IAT task, participants are presented with a series of words or photographs in the centre of the screen. They are asked to classify the target into either concept or attribute categories, for example adult versus child or sexy versus not sexy, respectively (see Figure 1.3) (Gray et al., 2005; Nunes, Firestone, & Baldwin, 2007).

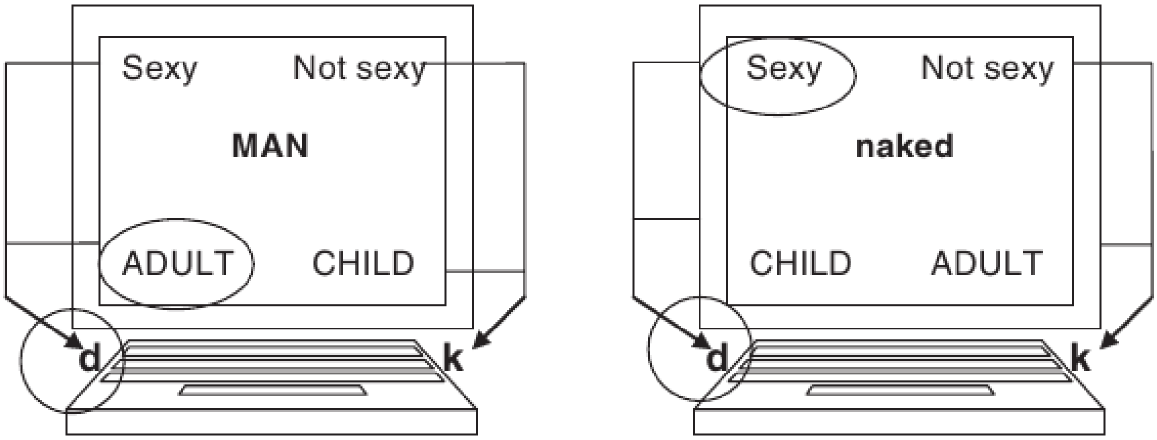

Figure 1.3 Illustration of the IAT procedure (taken from Nunes et al., 2007).

The IAT has shown an ability to accurately dissociate between different sexual orientations (Ó Ciardha & Gormley, 2013) and also age-specific sexual preferences (Hempel, Buck, Goethals, & van Marle, 2013; Nunes et al., 2007). According to this notion, individuals who are sexually interested in children will be quicker to respond when presented with a child-sex pair than an adult-sex pair. This has been demonstrated in studies, whereby child sex offenders viewed children as more sexually attractive on the sexy-child IAT compared to non-sex offenders (Nunes et al., 2007). Therefore, child sex offenders recorded faster responses for child-sexy associations, while non-sex offenders' responses were faster for adult-sexy associations. Overall, the child-sexy IAT has been shown to distinguish between child sex offenders and non-offenders by correctly classifying 78% of paedophiles (Gray et al., 2005; Hempel et al., 2013; Nunes et al., 2007).

However, high false positive rates have also been reported. On an individual level these tests have incorrectly misidentified 42% of controls as having paedophilic interests (Gray et al., 2005). One reason for this is that it may be possible to hold child-sex associations for reasons other than sexual interest and arousal (Gray et al., 2005). For example, it is easy to imagine that the association between sex and child can develop in witnesses or victims of child abuse, or perhaps even through multiple assessments on the IAT. However, limited research exists exploring the mechanisms underlying this approach (Babchishin, Nunes, & Hermann, 2013; Snowden, et al., 2011).

Measuring Sexual Content Induced Delay with CRT and a Stroop Task

Other approaches for implicitly measuring sexual interests are based on the notion that individuals are drawn to images that they consider sexually attractive and consequently are distracted from the task at hand thus resulting in slower responding (Kalmus & Beech, 2005). This systematic delay is referred to as Sexual Content Induced Delay (SCID) (Geer & Bellard, 1996) and is captured by covertly measuring response times with a range of tasks. Two of the most widely researched methods for this purpose are the Modified Stroop Task (Price & Hanson, 2007) and Choice Reaction Time task (Geer & Bellard, 1996).

Research suggests that cognitive processes underlying deviant sexual interests can be assessed using a version of the Stroop colour-naming task (Price & Hanson, 2007; Smith & Waterman, 2004). In this task participants are presented with words from six categories (neutral, aggression, positive, negative, sexual and colour). These words are shown in four different colours (red, green, blue and yellow), and participants are instructed to name the colour in which the word was presented. When this experiment was conducted with child molesters and a community sample, response times for child molesters were reliably slower than community sample for sexual words (Price & Hanson, 2007, Experiment 1; Smith & Waterman, 2004). However, the sexual words included in these experiments were non-specific to child molestation and could simply indicate a general higher sexual response in this group. In a subsequent experiment, a child molestation word category (including words such as, incest, fondle, naked, kiss and child) was also included (Price & Hanson, 2007, Experiment 2). Although a similar pattern also emerged for this word category, responses did not differentiate reliably from those recorded by the community sample. However, some of the words included in the child molestation category were still non-specific to children (such as kiss and naked) and may have been perceived as sexual to non-offender groups.

A variation of this approach is the Pictorial- Modified Stroop Task (P-MST), this method eliminates the issue of word choice by using images of adults and children (Laws & Gress, 2004; Ó Ciardha & Gormley, 2012). In this task, images from the Not Real People stimulus set (NRP) (Tanner stimuli) are presented in one of four colours (red, green, blue and yellow), and participants are instructed to rapidly indicate the colour of these images (see Figure 1.4).

With non-deviant heterosexual and homosexual males, these studies demonstrate longer response times when viewing adult figures of the preferred sex (Ó Ciardha & Gormley, 2012). When the same experiment was performed with child sex offenders, response patterns consistent with subject's orientation emerged. However, age-specific responses were not recorded whereby response times were still slower for the images of adults than children (Ó Ciardha & Gormley, 2012). Therefore, although P-MST may be useful for discerning sexual orientation, it was not able to differentiate between paedophiles and non-paedophiles.

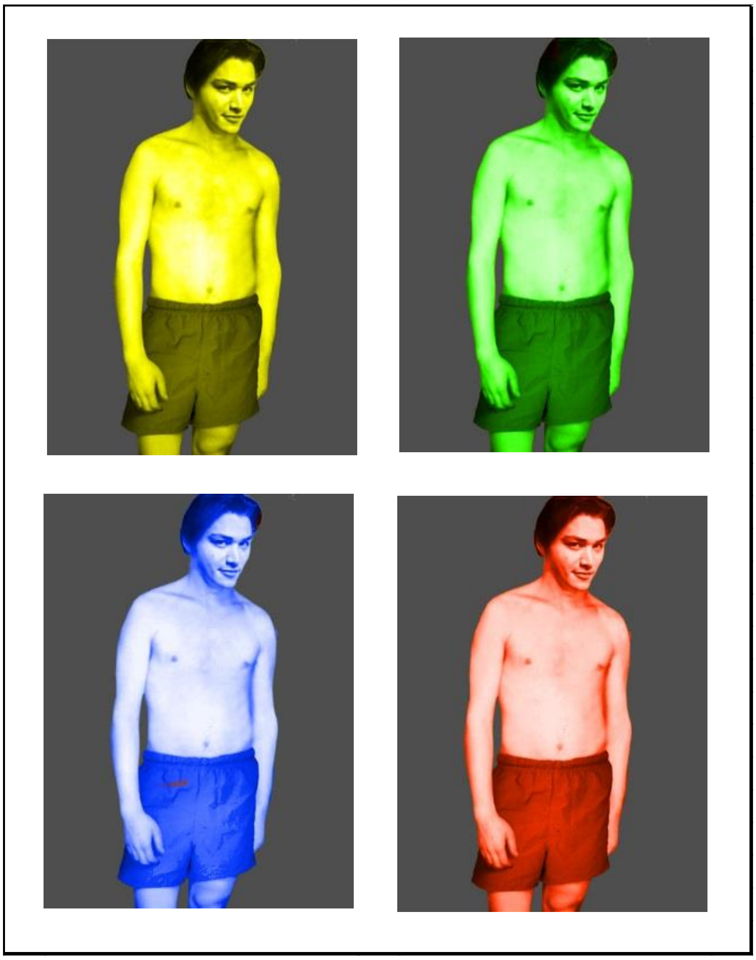

Figure 1.4 An example of stimuli from the Pictorial Modified Stroop task (Ó Ciardha & Gormley, 2012).

Another approach is the Choice Reaction Time task (CRT), which is also based on the premise that sexually relevant stimuli can cause detectable delays (Geer & Bellard, 1996). For this method, individuals are presented with a series of pictures of people and are instructed to indicate the location of a dot superimposed on the image (see Figure 1.5). Participants use a response pad to indicate whether the dot is located on the top left, top right, bottom left, bottom right, or in the middle (see Mokros, Dombert, Osterheider, Zappalà, & Santtila, 2010; Ó Ciardha & Gormley, 2013; Wright & Adams, 1994). This task has been shown to differentiate between different sexual orientations in men and women when presented with sexually explicit stimuli. For example, heterosexual men and homosexual women record longer response times when viewing images of nude women compared to nude men (Wright & Adams, 1994, 1999; Santtila et al., 2009).

Figure 1.5 An example of stimuli employed for the CRT

This approach has also been adapted to measure sexual age preferences (Mokros et al., 2010). Known child molesters are shown images from the Not Real People (NRP) stimulus set comprising both nude and partially dressed images of people at various stages of sexual development. In this task, child molesters take longer to respond to images of infants compared to adults, whereas non-sex offenders record the opposite patterns (Mokros et al., 2010). However, this task detects less differentiation between sexually explicit and non-explicit stimuli set following repeated measuring (Santtila et al., 2009). Consequently, although CRT provides a promising measure of sexual interest there are concerns surrounding habituation during multiple testing (Akerman & Beech, 2012).

Visual Response Time (VRT)

Since Rosenzweig's (1942) first observation that viewing times of sexual materials correlate well with sexual interest, many studies have demonstrated that observers view sexually preferred materials for longer than non-preferred content (Ebsworth & Lalumiére, 2012; Israel & Strassberg, 2009; Lippa, 2012). Various theories surrounding the mechanisms underlying the viewing time effect suggest that this is related to the first stage of Singer's (1984) model of sexual arousal, the *aesthetic* response (Kalmus & Beech, 2005). According to this theory, viewers attempt to keep the target in view for longer to continue to feel the positive emotion that the image elicits. However, the exact mechanisms underpinning this theory are poorly understood. This measure is usually combined with a subjective rating task, in which participants are instructed to rate the sexual attractiveness or appeal of the persons depicted in the images. In this way subjects are unaware that that their response times are being recorded.

Visual response time has been shown to accurately discern gender-specific sexual preferences (e.g., Israel & Strassberg, 2009, Lippa, 2012) and age-specific sexual preferences (Abel et al., 2004; Ebsworth & Lalumiére, 2012; Quinsey, Keytsetzis, Earls, & Karamanoukian, 1996). For example, Israel and Strassberg (2009) presented heterosexual men and women with magazine and catalogue pictures of partially dressed adults, as well as neutral stimuli, and asked them to rate their sexual appeal, while their response times were recorded. Both male and female observers viewed opposite sex images longer than same sex images, but this difference was smaller for female viewers. This pattern was also observed for sexual appeal ratings whereby men rated female images higher on sexual appeal than male images, and women rated *both* sexes more similarly.

Similar patterns were recorded when observers were shown images from the Not Real People (NRP) picture set which comprised partially dressed and nude males and females at five different stages of sexual development (Tanner, 1978) (Ebsworth & Lalumiére, 2012). Viewing time was recorded while subjects rated the sexual appeal of the targets. Viewing responses of men matched their reported sexual interests, such that the dressed and nude adolescent and adults (Tanner stages IV and V) consistent with observers' sexual orientation were viewed for longer and received the highest subjective ratings. Heterosexual women did not show category specific responses, but viewing patterns and subjective ratings were comparable for both adult sex categories (Ebsworth & Lalumiére, 2012).

Compelling patterns also emerge when this paradigm compares responses of child molesters and non-child molesters (Abel et al., 2004). In one experiment, participants viewed slides of partially nude individuals of varying ages (age groups 2-4, 8-10, 14-17 and adults over 21 years old) and rated their sexual arousal for these images (Abel et al., 2004). A clear difference in viewing time was found, whereby individuals who looked for longer at the child stimuli were more likely to have molested a child. Furthermore, within the sex offender groups, viewing time was also positively correlated with number of child victims and sexual acts committed (Abel et al., 2004).

These are promising findings for VRT as a measure of sexual age preferences. However, there is limited research concerning how this measure compares with other more direct measures (Abel, Huffman, Warberg, & Holland, 1998; Harris, Rice, Quinsey, & Chaplin, 1996). A study directly compared paedophilic and non-paedophilic visual response time (VRT) with plethysmography responses while they viewed images of nude males and females of ages 4, 8, 12, 16 and 22 (Abel et al., 1998). In this study, VRT was able to correctly classify between 39% and 67% of individuals interest to children and adolescents, while the accuracy for plethysmography ranged from 38% to 62% However, Harris et al. (1996) demonstrated that measurements of genital arousal showed greater discrimination for offenders versus non-offenders than viewing time.

Whether these two measures are directly comparable is debatable and it is possible that they are measuring two different aspects of sexual appraisal. For example, viewing time paradigms include a 'secondary task' of providing subjective sexual appeal or attractiveness ratings which may be capturing an evaluation process that is not necessarily reflecting sexual interest. Only a small set of studies, however, have attempted to tease apart the specific mechanisms underlying viewing response time (Imhoff, Schmidt, Nodsiek, Luzar, Young, & Banse, 2010; Imhoff, Schmidt, Weib, Young, & Banse, 2012).

Imhoff et al. (2010) found evidence against the theory that the VRT effect is part of the aesthetic response to sexual stimuli, whereby prolonged viewing is related to a desire to keep the preferred sexual stimuli in view for longer. Instead, the study suggests that the effects could be a result of cognitive processes arising from the structural demand of the rating task rather than a specific sexual interest. It is possible that individuals find it easier and quicker to dismiss a target as an unsuitable potential mate (e.g., male versus female), but must engage in a slower evaluation process (assessing attractiveness, fertility etc.) for judging a target that fits the category they consider suitable (Imhoff et al., 2010; 2012). For example, in a sexual appeal ratings task prolonged latencies for sexually preferred stimuli emerge even when the stimuli are removed from display *before* participants give their attractiveness ratings. This suggests that longer viewing time cannot be explained by a deliberate delay in responding to keep the preferred image in view but is more likely to be reflecting an evaluation process.

Consequently, this approach can be vulnerable to faking (Kalmus & Beech, 2005), such that individuals may simply dismiss all categories as potential targets or simulate an evaluation process for the targets considered appropriate. One way to reduce this possibility is to remove the 'secondary' task and directly record attention to these images with eye tracking methodologies.

1.5 Measuring sexual interests with eye-tracking

1.5.1 EYE MOVEMENTS: THE ROLE OF ATTENTION IN SEXUAL APPRAISAL

Eye tracking provides a method for directly assessing visual attention to complex stimuli. In the context of sexual interest, the distribution of fixations in an image depicting same and opposite sex people can reflect an attentional bias for specific targets which can indicate sexual orientation (Hall, Hogue, & Guo, 2011, 2014a, 2014b; Hewig et al., 2008; Krupp, 2008; Rupp & Wallen, 2007; Suschinsky et al., 2007). For example, heterosexual males view women for longer than men (Lykins, Meanna, & Strauss, 2008) and eye gaze patterns correlate strongly with self-reported attraction ratings (Dawson & Chivers, 2016).

Additionally, research demonstrates that these eye gaze patterns reveal differences in visual attention to *specific* body regions of these figures that are also indicative of sexual preferences (Hall et al., 2011; Hewig et al., 2008; Krupp, 2008). For example, when men evaluated a woman as a potential mate, more fixations were directed to specific regions of the female body, such as the face, chest and waist regions (Nummenmaa, Hietanen, Santtila, & Hyönä, 2012; Suschinsky et al., 2007). This is consistent with the idea that certain body regions are more useful than others at providing information relating to the suitability of an individual as a potential mate. For instance, the face provides cues about health, genetic relatedness and personality traits (Kramer, Gottwald, Dixon, & Ward, 2012; Scheib, Gangstad, & Thornhill, 1999; Stephen, Smith, Stirrat & Perrett, 2009), while the distribution of body fat inchest and waist regions provides information about age, health, fertility and sexual behaviour (Cloud & Perilloux, 2014; Stephen & Perera, 2014). In Suschinsky et al.'s (2007) study men directed more fixations towards these body regions (head, chest, and waist and hips) compared to less reproductively relevant regions, such as the legs.

Although this is strongly the case for male observers, men display more specific differences in their viewing patterns than women (Lykins et al., 2008). For example, when shown erotic and non-erotic stimuli of men and women, female viewers do not show a distinct preference for the same or opposite sex, but men view the opposite sex for longer and this difference is enhanced for erotic stimuli (Lykins et al., 2008). These non-specific response patterns in women are not uncommon in the sex literature and are in line with findings using other measures of sexual interest, such as genital arousal (Bailey, 2009; Chivers et al., 2004, Chivers, 2005; Suschinsky et al., 2009).

A small set of studies have also shown that this approach can be extended to differentiate between sexual preferences for people of different age groups (Fromberger et al., 2012, 2013; Hall et al., 2011). When heterosexual men are presented with images of males and females with age groups ranging from babies to 60-year olds, these viewers directed more fixations to the 20-year old female category than any of the other categories. The two categories furthest away from the subjects age (babies and the 60-year olds) received the least number of fixations from both groups (Hall et al., 2011).

However, when this approach is extended for the assessment of paedophilic interests in child sex offenders, differences in viewing behaviour were not always distinguishable (Hall et al., 2014b). For example, a comparison of viewing behavior of paedophilic and control observers to images of males and females at 10, 20 and 40-years of age, revealed no difference in the average number of fixations between the two observer groups (Hall et al., 2014b). When broken down by body region, the face received the most attention across all conditions, equating to approximately 50% in both groups. Contrary to previous studies, however, the limbs also received a large percentage of fixations (on average 22%) compared to the upper body (14%) and waist-hip region (7%) (Hall et al., 2014b). This is surprising considering the limbs are considered to be the least informative areas for mate selection (Suschinsky et al., 2007). One possibility for this discrepancy is that observers were displaying an avoidance viewing pattern by consciously directing more fixations to the regions that may be considered more appropriate and 'safe'. It is a well-known strategy of offenders to manipulate their responses and behaviour in a socially desirable manner (O'Donohue et al., 2000), and it is possible that this was also occurring in this study (Hall et al., 2014b).

Consequently, researchers have explored more automatic visual behaviours to sexual stimuli (Dawson & Chivers, 2016; Fromberger et al., 2012b, 2013; Rupp & Wallen, 2007). According to Spiering and Everaerd (2007), sexual features are pre-attentively processed and physiological arousal to sexually relevant stimuli occurs before and independent of conscious evaluation. These pre-attentive processes can be captured by recording fixation latencies (i.e., time taken for the first fixation to land on a ROI) (Fromberger et al., 2012b, 2013), and by calculating the probability of first fixation to a ROI (Fromberger et al., 2012a) and the duration of the first fixation (Hewig et al., 2008). In these experiments observers are presented with an image of a child and adult simultaneously and are instructed to rate the attractiveness of these people (see Figure 1.6). Paedophiles demonstrate shorter fixation latencies for child stimuli compared to non-paedophilic observers (Fromberger et al., 2012b). Response latency is able to classify 86% of paedophiles with a 10% false positive rate compared to the mean fixation time which accurately identifies 80% of paedophiles with a 20% error rate (Fromberger et al., 2012b).

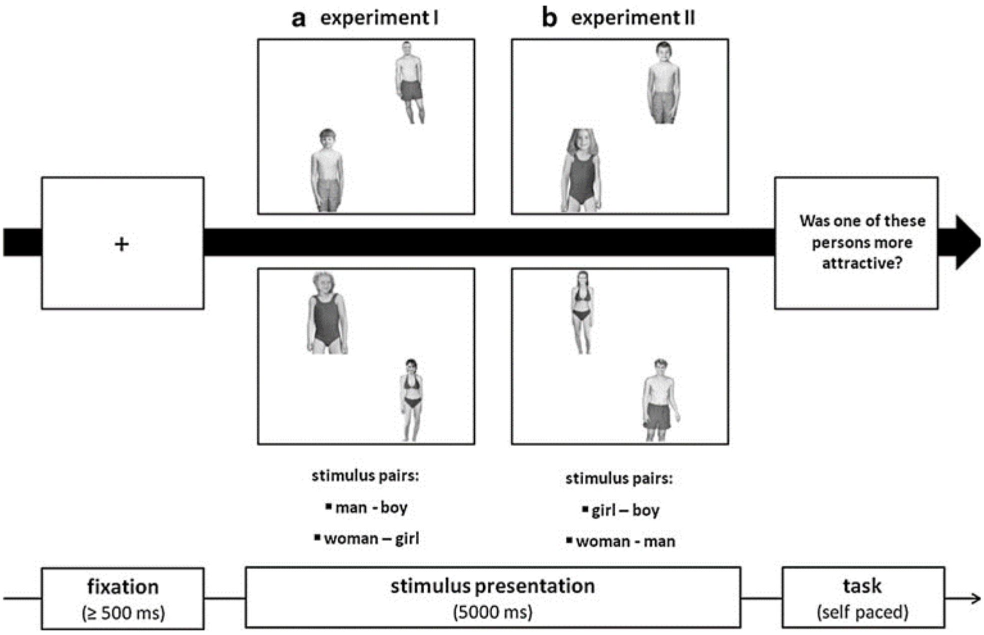

Figure 1.6 Illustration of experimental procedure employed in Fromberger et al., 2012

In other studies, non-paedophilic males direct more first fixations to adults (M = 17.04) than to children (M = 11.21) when presented with these targets simultaneously (Fromberger et al., 2012a). When comparing the duration of first fixation in heterosexual male and female observers, men fixated for longer the female targets compared to male targets (M_{female} = 352ms vs. M_{male} = 297ms) and women showed the opposite pattern (M_{female} = 281ms vs. M_{male} = 270ms) (Hewig et al., 2008). However, these studies only tested observers with a sexual interest in adults and do not address whether paedophiles show the opposite pattern or whether this approach is robust under circumstances were observers may knowingly attempt to conceal sexual interests.

1.5.2 PUPILLARY RESPONSE: AN ALTERNATIVE MEASURE OF SEXUAL INTERESTS?

With eye-tracking it is also possible to measure minute changes in the size of the pupil as a response to visual stimuli. The pupils in our eyes increase (dilate) and decrease (constrict) in size to regulate the amount of light reaching the retina to optimize vision. This is known as the pupillary light reflex (Sirois & Brisson, 2014). However, light is not the only factor that causes these changes. For the last 50 years researchers have been interested in how these minor changes can also be an index of cognitive functioning, including language processing, memory and decision making, emotional arousal (Steinhauer, Siegle, Condray, & Pless, 2004; for review, see Laeng et al., 2012) and sexual arousal (Bernick, Kling, & Borowitz, 1971; Dabbs, 1997; Hess & Polt, 1960; Hess, Seltzer & Shlien, 1965). This is particularly compelling because changes in pupil size are automatic and instantaneous responses to the activation of the autonomic nervous system (Zuckerman, 1971), which makes suppression or inhibition of a dilation response difficult (Laeng & Sulutvedt, 2014). For example, subjects are unable to voluntarily constrict or dilate their pupils when instructed to do so whilst viewing an empty grey screen or a simple outline of a shape (Laeng & Sulutvedt, 2014). This is an important feature for the assessment of deviant sexual interests in forensic settings, as observers may attempt to conceal inappropriate sexual interests (O'Donohue et al., 2000).

Early researchers explored the possibility that these subtle changes may be physiological responses that occur during the processing of sexual content (Bernick et al., 1971; Dabbs, 1997; Hess & Polt, 1960; Hess et al., 1965). For example, Dabbs (1997) measured pupillary responses to auditory stimuli comprising 30s of an aggressive stimulus, sexual stimuli and two control stimuli. The aggressive stimulus involved a heated argument between a couple in a relationship, the sexual stimulus was a vocal episode of sexual intercourse, and the control stimuli were 'rambling' conversations between people. A 6% increase in pupil size occurred during the presentation of the sexual stimuli and a 3% increase in the other three conditions. The dilation that occurred to sexual stimuli also lasted longer (15s) than the other conditions (5s). This indicates that pupil dilation may be an arousal response that is particularly strong for sexual content. However, this study does address whether these responses are sensitive to sexual content of specific persons (e.g., male versus female targets).

Hess et al. (1965; Hess & Polt, 1960) was the first to examine, with elementary eye-tracking methods, whether these pupil changes in response to sexual arousal are *specific* to preferred categories of pictorial sexual stimuli, which would therefore indicate subjects' sexual preferences. The pupils of heterosexual and homosexual men were measured with a camera recording at a rate of two frames per second whilst they viewed paintings and photographs of nude men and women. Twenty measurements were obtained for each stimulus by manually measuring the pupil diameter at each frame of video footage. The pupils of all five heterosexual men dilated to the female pictures, while four of the five homosexual dilated more to the males. In a subsequent study, the pupil responses of men and women to images of semi-nude people were measured

(Scott, Wells, Wood, & Morgan, 1967). Male observers dilated more to women while female observers showed the opposite pattern. These differences were not reliable in females. However, there is also evidence to suggest that heterosexual females' pupils dilate more to images of men than women, and that this effect is stronger for nude compared to dressed and partially dressed images of men (Hamel, 1974).

It was not until recently that these findings were re-examined with highly sensitive contemporary eye-tracking equipment involving millisecond precision of eye movements and pupil size recording (Rieger & Savin-Williams, 2012; Rieger et al., 2015). In these studies, hetero-, homo- and bisexual men and women were shown sexually explicit video footage comprising either a male or female model engaging in a sexual act. In men the results showed a clear dilation pattern that corresponded to subjects' self-reported sexual interest. In a subsequent experiment, these responses were compared directly to genital arousal which revealed a high concordance between these two measures in men (Rieger et al., 2015). This provides strong evidence for pupil size as a physiological response that is directly linked to sexual arousal. However, similar to Scott et al. (1967), pupillary responses in heterosexual female observers were similar to footage of men and women.

In light of this research, the question arises of whether this paradigm can be extended to indicate sexual interest for specific age groups. If changes in pupil sizes reflect arousal responses to specific sex categories when viewing adult stimuli, then it may also be possible to distinguish sexual preferences to specific *age* groups (i.e., adults and children). To date, only one study has considered this question. This was conducted over 40 years ago and employed elementary eye tracking methodology. In this study, the pupillary responses of ten paedophilic and ten non-paedophilic males to images depicting nude adults and children were recorded using a similar method to Hess et al. (1965) (Atwood & Howell, 1971). In this experiment, 90% of paedophiles recorded dilation during the viewing of young girls and 80% showed a constriction when viewing women. In contrast, 90% of non-paedophiles produced dilation during the viewing of mature women and half produced a constriction or no change for children. These findings suggest that pupil size could provide an alternative direct and implicit measure of sexual preferences that might also be specific to sexual age preferences. Surprisingly however, no further attempts have been made to replicate these findings.

In addition pupillary responses for measuring sexual interests is also an under researched area, and existing studies have used a variety of stimuli, ranging from static photographs of nudes (Hess & Polt, 1960; Hess, Seltzer, & Shlien, 1965) to sexually explicit video footage (Rieger, Chivers, & Bailey, 2005; Rieger & Savin-Williams, 2012). Consequently, it is unclear how different levels of sexual explicitness in stimuli effects pupillary responses, for example whether naked stimuli elicit clearer pupillary response patterns of sexual interest than dressed stimuli. Yet, this has important implications for evaluating the usability of this measure in clinical assessments.

A small set of studies have attempted to address this question by directly comparing responses to explicit and non-explicit images, but with inconsistent results. An early investigation indicated that nude images enhance pupillary responses to people of sexual interest in heterosexual females (Hamel, 1974). However, in another study naked images elicited a generalized pupillary response in heterosexual men and women that did not differentiate target sex (Aboyoun & Dabbs, 1998). A more recent investigation recorded observers' pupillary responses to video footage of nude persons performing a sexual act and dressed persons discussing weather (Watts, Holmes, Savin-Williams, & Rieger, in press). This study found a moderate correspondence of pupil dilation with sexual orientation for nude and dressed stimuli in female observers. In male observers, on the other hand, pupillary responses were enhanced for nude stimuli.

A number of reasons could account for these discrepancies, such as the use of different eye-tracking methods for measuring pupil size, which range from elementary pupillometry systems that record the pupil size every minute (Hamel, 1974), or every 0.5s (Aboyoun & Dabbs, 1998) to contemporary equipment with millisecond precision (Watts et al., in press). Furthermore, it is unclear whether other stimulus factors, such as variations in identity and pose, interacted with pupillary responses. In these investigations, for example, the stimuli used in Watts et al. (in press) compared responses to pornographic video footage with people discussing weather and did not control for scene content and person identity. Similarly, Aboyoun and Dabbs (1998), employed different identities of varying ethnicities across conditions. Consequently, variations in colour tone arising from mixture of race and identities could also have interfered with pupillary responses to these images. These factors leave open the possibility that results might reflect methodological differences. Therefore, the question remains as to whether sexual explicitness influences pupillary responses and which level of exposure provides clearest response patterns.

In summary, the measurement of pupillary responses for assessing sexual orientation and age-specific sexual interests remains under-researched.

As such questions remain about whether pupillary responses can be an index of sexual age preferences and the effect of stimulus nudity on these responses. The purpose of this thesis is to explore these questions.

1.6 Structure of this thesis

The purpose of this thesis is to examine whether changes in the size of the pupil in response to visual stimuli are reflective of sexual orientation, and more importantly whether this can be extended to indicate sexual preferences for specific age groups (i.e., young versus adult). The first experimental chapter examines these responses in heterosexual observers who are exclusively sexually interested in adults. While recent research has measured the pupil responses of adults to other adults of the same or opposite sex (Rieger et al., 2012, 2015), little has been done with regards to exploring these responses when viewing different age groups (Atwood & Howell, 1971). Furthermore, this chapter also assesses the influence of low level factors, luminance and colour, on pupil responses. This is achieved by equating the mean luminance values across image categories (Experiment 1) and by randomizing the image pixels to create an even distribution of luminance and colour (Experiment 2). Responses to these images are then compared to the pupil responses obtained when observers viewed the intact images. Additionally, in Experiment 2, the pupil responses are also correlated with sexual appeal for each image category.

The purpose of Chapter 3 is two-fold. First, this chapter addresses whether observers' pupil size during the viewing of people in natural scenes reflects their sexual orientation when these responses cannot be accounted for by person content and stimulus variation. This was achieved by comparing the pupil responses of non-paedophilic men with hetero-, homo- and bisexual orientations. In a second aim, this chapter also examines the sensitivity of pupil responses to targets at different stages of sexual development. This is important for forensic research and practice whereby such age distinctions are valuable (Blanchard et al., 2009; Dombert et al., 2013). Therefore, in this chapter, pupillary responses were recorded for stimuli from the Not Real People Picture Set which included people at five different stages of sexual development (Experiment 5).

The final empirical chapter examines whether pupillary responses to the visual presentation of men and women are influenced by different levels of sexual exposure, to determine which of these conditions provides the best index of sexual interest. Therefore, in Experiment 7 observers view images of adult men and women portrayed in three degrees of nudity (i.e., dressed, partially nude, and nude) while pupil responses and eye movements are recorded. Additional information concerning subjects' sexual orientation, attractions and fantasies, as well as appeal ratings for these images, are also reported related to pupil responses to specific categories.

These studies employed four independent groups of participants. In Chapter 2, heterosexual male and female observers were recruited via the online system, and those who took part in Experiment 1 were restricted from signing up for Experiment 2. In chapter 3, males of diverse sexual interests took part, however due to the low prevalence of homosexual and bisexual participants, Experiments 3 to 6 were completed by the same group of participants. In Chapter 4, a different group of heterosexual male and female participants were recruited to complete Experiment 7.

Chapter 2 Pupillary Responses to Natural Scenes of Adults and Children

Introduction

The measurement of sexual arousal and observers' sexual interests is important for psychological research and practice. For example, this is necessary to conduct research into sexual orientation causes and consequences (Mustanski, Chivers, & Bailey, 2002; Sell, 1997) and the assessment of unhealthy and inappropriate sexual desires in clinical and forensic practice (Gannon, Ward, & Polaschek, 2004; Laws & O'Donohue, 2008). Experimental psychology has contributed to this field by developing a number of assessment methods for this purpose (e.g., Gress, 2005; Laws & Gress, 2004; Mokros et al., 2010; Ó Ciardha & Gormley, 2012, 2013). Of these, viewing time, which reflects the duration for which particular person content is studied, is now a widely utilized measure of visual attention to sexually appetitive materials (e.g., Lykins et al., 2008; Rupp & Wallen, 2007). However, the viewing of visual content is also accompanied by automatic changes in observers' pupil size (Bradley, Miccoli, Escrig, & Lang, 2008), which appear to be particularly sensitive to sexual arousal (Bernick et al., 1971). While this pupillary measure was first explored 40 years ago with some elementary methods (Hess et al., 1965), it has received little attention since. This chapter attempts to replicate those early findings with contemporary eye-tracking equipment to determine if it can be used to inform us of a person's sexual interests. This chapter not only explores whether increased pupil size can provide an index of adults' sexual interest in other adults, but also whether this index is age-specific and not present for photographs of children. This distinction might be important for clinical and forensic practice.

Viewing time is a measure of attentional bias that is linked to a person's interests and motivations (Henderson, 2003; Isaacowitz, 2006). In relation to sexual interest, viewing time has been used to measure interest in preferred over non-preferred figures. One way for measuring viewing time in these paradigms is to record observers' response times while they rate the sexual appeal of pictures of men and women (see Gress, 2005; Gress, Anderson, & Laws, 2013; for reviews, see Akerman & Beech, 2012; Laws & Gress, 2004; Snowden et al., 2011). In these studies, longer response times for a specific stimulus type correspond to the reported sexual interest for that category (e.g., Quinsey et al., 1996) and physiological measures of sexual arousal (Abel et al., 1998). For example, healthy heterosexual males tend to make slower responses when rating female stimuli compared to male stimuli (Israel & Strassberg, 2009) and prepubescent children (Harris et al., 1996; Quinsey et al., 1996). Heterosexual women also show age preferences in these viewing time paradigms (Quinsey et al., 1996) but are inconsistent in their responses to sexually preferred and non-preferred adults (Israel & Strassberg, 2009; Lippa, Patterson, & Marelich, 2010; Quinsey et al., 1996).

While the response time-based assessment of viewing time is an indirect measure of sexual interest, it is possible to achieve similar results more directly by tracking observers' eye movements. During visual processing, eye gaze is directed towards scene content that matches a viewer's personal interest (Calvo & Lang, 2004), including longer fixations to sexually preferred human figures (Fromberger et al., 2012a; Hall et al., 2011; Rupp & Wallen, 2007; for a review, see Rupp & Wallen, 2008). Heterosexual male observers, for example, view female stimuli for longer than male stimuli (Lykins, et al., 2008). These viewing patterns also appear to correspond to the sexual content on display (e.g., Hall et al., 2011; Rupp et al., 2007; Suschinsky et al., 2007). For example, male and female observers predominantly study the faces of fully-clothed persons (e.g., Hewig et al., 2008), but female observers increase fixations to the body in semi-clothed stimuli (Rupp et al., 2007) and male observers show a corresponding shift to pictures of female nudes (Nummenmaa et al., 2012). These data therefore indicate that eye movements are sensitive to adult observers' sexual interest in other adults.

These viewing patterns also appear to be age-specific. For example, male and female adult observers fixate figures of their preferred age (20 year olds) more than babies and 60-year-olds (Hall et al., 2011). However, whereas non-paedophilic adult males preferentially fixate pictures of adults over children, paedophilic males show the reverse pattern (Fromberger et al., 2012b, 2013). This indicates that eye movements are not only sensitive to adult observers' sexual interest in other adults, but can also provide an index to distinguish between such interest in adults and children.

Despite these advantages, fixation behaviour is an index of sexual interest that is vulnerable to top-down control. Observers could, for example, conceal their sexual interest by diverting attention to other visual content (see Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007). This limitation could be overcome by considering only the initial fixation to a stimulus display, which might reflect a covert and automatic orientation response to pre-attentively selected stimuli of sexual interest. In line with this reasoning, heterosexual adult males tend to direct more initial fixations at adult females than adult men (56% vs. 44%) and young girls (57% vs. 43%; see Fromberger et al., 2012a). However, the size of these initial fixation biases is not indicative of a sensitive measure of involuntary behaviour.

This chapter explored an alternative eye-tracking measure that might be more sensitive and not under top-down control. The pupils respond automatically to external stimulation, such as changes in lighting conditions, by increasing (dilating) or decreasing (constricting) in size. A similar pattern is also found as an arousal response to pleasant and unpleasant stimuli (see Bradley et al., 2008). This dilation has been linked to the activation of the autonomic nervous system (Zuckerman, 1971) and appears to be impervious to top-down control. It has been shown, for example, that observers cannot enlarge or reduce pupil size at will in the absence of a visual stimulus (Laeng & Sulutvedt, 2014) and cannot suppress pupil dilation (for a review, see Laeng et al., 2012). These characteristics might make pupillary response an ideal measure for the assessment of sexual interest that cannot be manipulated easily by the observer.

While this is an interesting possibility, the pupillary response to sexual arousal has received comparatively little attention. In an early study in this field, Hess et al. (1965) showed five hetero- and five homosexual males' images of nude males and females while filming the observers' eyes at a rate of two frames per second. Twenty measurements were obtained for each stimulus by manually measuring the diameter of the pupil at each frame of the video footage. Despite this elementary approach, a clear pupillary response was found whereby all heterosexual males showed larger pupils when viewing the pictures of women. By contrast, all but one of the homosexual males showed larger pupil responses to pictures of men. These promising results were re-examined shortly after with the addition of female observers (Scott et al., 1967). Here, observers were presented with semi-nude and clothed images of men and women. Male observers demonstrated more pupil dilation to semi-nude female pictures than any other stimuli, whereas female observers did not show different pupil responses to semi-naked and clothed stimuli or to male and female targets. However, a subsequent experiment also recorded a pupil dilation effect in female observers that appeared to be related to sexual interest (Hamel, 1974). In this study, female observers showed increases in pupil size that were directly related to the degree of nudity of pictures of male, but not of female, models.

Despite these promising results, there have been no attempts to replicate these findings until recently. Rieger and Savin-Williams (2012) showed hetero-, homo- and bi-sexual observers sexually explicit videos while pupillary responses were recorded with contemporary eye-tracking equipment. This study replicated the clear relationship between sexual orientation and pupil dilation that Hess et al. (1965) observed in male observers. However, similar to Scott et al. (1967), pupillary responses in heterosexual female observers were comparable to male and female stimuli. In a subsequent experiment, Rieger et al. (2015) extended these findings to show that pupillary responses to sexually explicit images reflect the sexual orientation of male, but not heterosexual female, observers similarly to genital arousal. These findings indicate that pupillary response is a useful alternative for measuring sexual interest in male observers. In addition, the lack of specificity in heterosexual female observers converges with a broad range of assessment methods (e.g., genital arousal, self-report sexual arousal and attraction, response time and viewing time; see Chivers, 2005; Chivers et al., 2004; Ebsworth & Lalumière, 2012; Lippa, 2006, 2007; 2012; Lippa et al., 2010; Suschinsky et al., 2009). This is an interesting finding because it suggests that pupillary responses to sexual content are also consistent with more established measures in the literature.

While few studies have focussed on pupil dilation as a measure of sexual interest for photographs of adults, there has been even less research on pupillary responses to persons of different ages. An early study compared these responses in incarcerated male paedophiles and non-paedophiles to images of nude adult women and nude immature girls (Atwood & Howell, 1971). This experiment, which utilized a similar video analysis as Hess et al. (1965), revealed greater pupil dilation in all but one of the non-paedophilic observers to pictures of adult females but a pupil constriction in 80% of paedophiles. Conversely, images of immature females produced dilation in 90% of paedophiles and a constriction or no change in half of the non-paedophilic control subjects.

Up to now, there have been no documented attempts to replicate these findings. This is surprising considering the potential applied value of such a measurement (e.g., in the assessment of child sex offenders). Chapter 2 investigated whether pupil dilation can provide an indication of a person's sexual interests and, more importantly, whether this is age-specific. For this purpose, heterosexual male and female student observers were presented with images of beach scenes that contained semi-clothed adults and children, while their eye movements and pupil sizes were being recorded. These scenes contained only a single person or no persons in the case of a set of comparison landscape beach scenes. We expected the different person content of these scenes to draw attention depending on the sexual interests of the observers. For example, we anticipated male observers to fixate adult women more frequently than adult men (see Hewig et al., 2008; Lykins et al., 2008; Rupp et al., 2007). Of particular interest here was whether these observers would also show an increase in *pupil size* to images of sexually preferred adults in comparison with sexually non-preferred adults and children.

As a secondary aim, Chapter 2 also sought to examine how pupillary responses to people of sexual and non-sexual interest are affected by image luminance. The pupils constrict in response to light (i.e., increased luminance) to protect the cells of the retina (Bergamin & Kardon, 2003; Ellis, 1981). If such an effect is found for the scene stimuli in the current study, then this could undermine any concurrent pupillary responses that are driven by sexual interest. In turn, it is possible that the pupillary response to sexual content is enhanced when luminance is controlled across different stimulus categories. To explore this possibility, the original photographs of the beach scenes were compared with alternative versions, in which the mean luminance was equated across the different stimulus categories (e.g., males, females; adults, children; no-person scenes). This manipulation can decrease image quality by reducing light-dark contrasts. A third version of these scenes was therefore also included, in which image quality of the original photographs was enhanced with graphics software.

EXPERIMENT 1

Method

Participants

For this experiment, we sought a minimum sample size of 20 participants per group which is in line with eye-movement studies within the field (Fromberger et al., 2012; Hall et al., 2014), and is considerably greater than Hess et al's (1965; Hess & Polt, 1960) early studies with pupillary responses (N =

5 per group). In total, forty-four students (22 male and 22 female) from the School of Psychology at the University of Kent participated in this study in return for a small payment or course credits. Participants completed the Kinsey scale for the assessment of sexual orientation as part of a pre-screen on our online recruitment system. This is a seven-point scale in which a score of '0' represents complete heterosexuality and '7' complete homosexuality. Only participants that reported to be completely heterosexual (i.e., reporting '0' on the Kinsey scale) were invited to take part (Kinsey, Pomeroy, & Martin, 1948). The mean age of participants was 21.8 years (SD = 4.2; range = 18-35 years) and all reported normal or corrected-to-normal vision.

Materials

The stimuli consisted of natural beach scenes portraying male and female adults and children (5 scenes for each of these four categories). To determine the approximate age of these categories, ten observers (5 male, 5 female) estimated the age of the people in the scenes in a pilot study. This revealed a mean age of 26.4 years (SD = 2.1) for men, 22.8 years (SD = 2.6) for women, 5.7 years (SD = 1.1) for boys, and 4.7 years (SD = 1.4) for girls. The age of the children therefore corresponds to stage 1 (prepubescent) of the Tanner stages of sexual development (see Tanner, 1978). Additionally, a set of control beach scenes without any person content (5 scenes) was included, resulting in a total of 25 scenes. People were portrayed in swim or leisure wear. All of these stimuli were purchased from an internet photograph database (www.mostphotos.com) and were selected to be of similar composition and size, and to depict the persons in similar poses and with a comparable level of clothing (see Figure 2.1). To confirm that these targets were of similar size, their percentage occupancy area in the scenes was calculated. This showed that all person categories occupied a similar amount of space in our scenes (mean = 7.1%, SD = 0.03, range across person categories = 6.6% to 7.7%; one-factor ANOVA: $F(3, 16) = 0.14$, $p = 0.94$). The scenes were displayed in the centre of a uniform grey background subtending at approximately 17.8 degrees of visual angle vertically and 26.4 degrees horizontally at a viewing distance of 60cm.

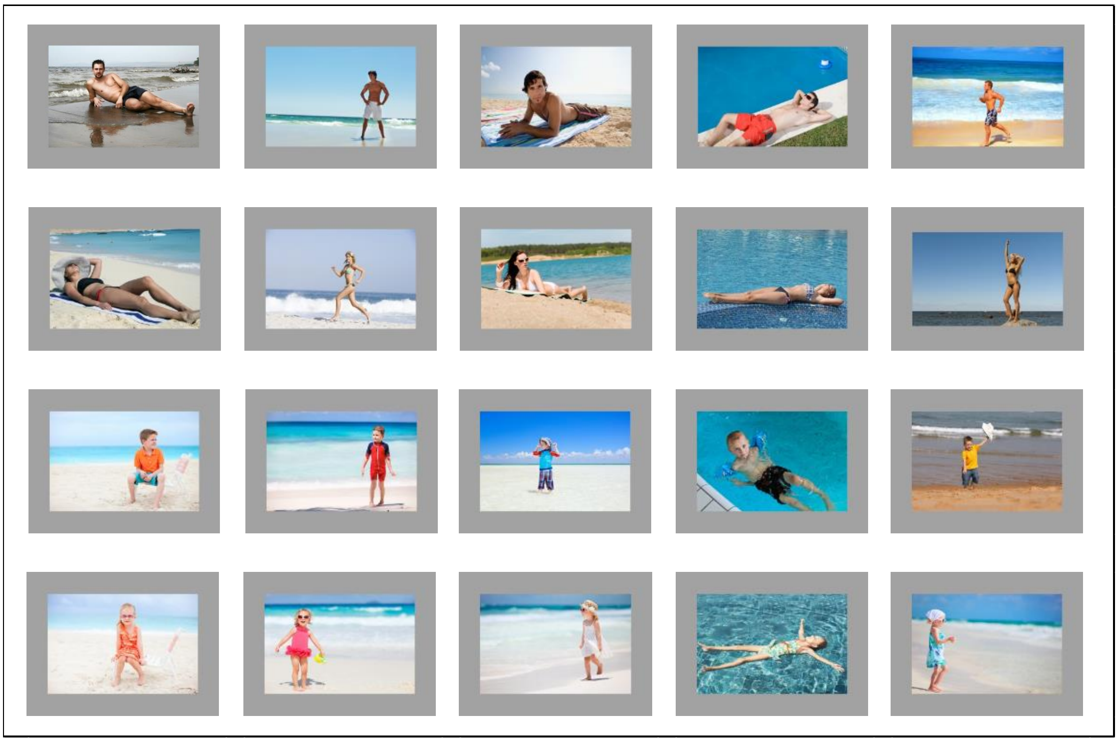

Figure 2.1 The stimuli of the original quality condition in Experiment 1.

In addition, three versions were created of each scene that were identical in all aspects except for image quality. This resulted in a total of 75 scene images. In the Original-quality condition, the image quality of the downloaded photographs was retained. In the High-quality version, the images were processed by applying the 'Auto Levels', 'Auto Contrast' and 'Auto Color' functions in Adobe Photoshop CS3 to artificially enhance the original photographs. Finally, to create a Luminance-controlled version of the stimuli, the photographs were divided into groups of five (one of each category) based on similar luminance values and standard deviation. A mean luminance value and standard deviation was calculated for each of the five groups. Each photo within a group was then re-adjusted to obtain a mean luminance and standard deviation that matches the group value. Therefore, at least one image from each category (man, woman, boy, girl, no person landscapes) had precisely matched luminance values. This particular group-based approach was adopted to avoid the extreme deviation from the natural luminance values of individual scenes that can occur when a single mean luminance value is derived for large stimulus sets, which can result in some highly distorted and unnatural looking images. Table 2.1 shows the overall mean luminance values and standard deviation for the different image categories for all scenes. Example stimuli are shown in Figure 2.2.

	Mean	SD	Max	Min
Original Quality				
Men	166	25	190	125
Women	160	29	200	125
Boys	169	42	218	111
Girls	190	35	224	133
No Person	165	28	190	127
High Quality				
Men	167	23	186	131
Women	163	20	182	130
Boys	171	41	221	123
Girls	184	38	211	122
No Person	152	16	180	143
Luminance Controlled				
Men	162	18	194	152
Women	162	18	194	152
Boys	162	18	194	152
Girls	162	18	194	152
No Person	162	18	194	152

Table 2.1 Mean Luminance, Standard Deviation, and the Minimum and Maximum Luminance Values of Images Within a Stimulus Category for the Original, High-quality and Luminance-controlled Images for All Scene Conditions.

Two questionnaires were also included in the experiment. The first was a general information scale relating to sexual interest and instructed participants to select one or more of five applicable statements ('no sexual interest in adults', 'strong sexual interest in female adults', 'some sexual interest in female adults', 'some sexual interest in male adults', 'strong sexual interest in male adults'). This was included to confirm the sexual interests that participants reported in the pre-screen. In addition, all participants completed the Interest in Child Molestation Scale to ensure that they were solely sexually interested in adults (Gannon & O'Connor, 2011). This scale consists of five short scenarios that describe incidents of child molestation, with three of these involving low-force and two involving high-force abuse. In response to these scenarios, participants have to rate their arousal, enjoyment and behavioural propensity to child sex abuse on 7-point Likert scales. This scale has high test-retest reliability (r = .94) and its sexual arousal subscale correlates with the Implicit Association Test, which provides an indirect measure of child sexualisation associations (see Gannon & O'Connor, 2011).

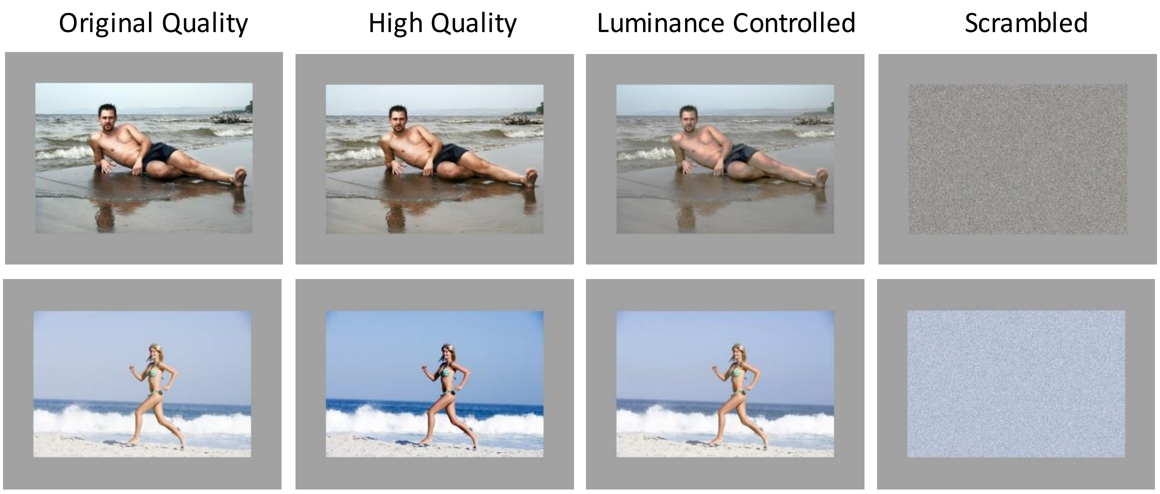

Figure 2.2 Example stimuli of the original quality, high quality, and the luminance controlled image conditions in Experiment 1 and the scrambled images in Experiment 2.

Eye-Tracking

The stimuli were displayed using SR-Research ExperimentBuilder software (version 1.1.0) on a 21" colour monitor, with a screen resolution of 1024 x 768 pixels. Eye movements were tracked using an SR-Research Eyelink II head-mounted eye tracking system. The Eyelink II was running at a 500 Hz sampling rate, a spatial resolution of < 0.01° of visual angle, a gaze position accuracy of < 0.5°, and a pupil size resolution of 0.1% of diameter. The Eyelink II eye-tracking system works by measuring corneal reflection and dark pupil with a video-based infrared camera. The device incorporates eye and head tracking that automatically compensates for minor head movements. During the recording of eye movements, participants are instructed to remain seated still but further immobilisation (e.g., a chinrest) is not required. This eye tracking system is compatible with most glasses and contact lenses.

Procedure

Participants were invited to take part in an experiment on sexual interest and informed that they would be viewing images of males and females of different ages while their eye movements were being recorded. However, participants were kept naïve to the full purpose of the experiment until the end. To fully understand observers' natural interests in these scenes, a free viewing paradigm was used so as not to constrain spontaneous eye movement patterns. Thus, participants were instructed simply to 'view the scenes as you naturally would' (for similar approaches, see, e.g., Bindemann, Scheepers, & Burton, 2009; Fromberger et al., 2012a, 2012b, 2013; Hall et al., 2011; Hewig et al., 2008; Lykins et al., 2008; Nummenmaa et al., 2012).

Subjects were seated in a quiet and windowless room with consistent artificial lighting and positioned approximately 60 cm from the display monitor. The participants' dominant eye was tracked and calibrated using the standard Eyelink procedure. To calibrate the eye tracker, observers fixated an initial series of nine target points on the display monitor, and their accuracy was then validated against a second series of nine fixation targets. Calibration was repeated if poor measurement accuracy was indicated. In the experiment, each trial began with a central fixation dot, which lasted for at least 500ms and allowed for drift correction. This also ensured that participants would be looking in the middle of the display at the beginning of each trial. The trial began with a grey screen displayed for 1000ms, and then the stimulus display for 5000ms, followed by another grey screen for 1000ms. This display duration is similar to other studies with static images (e.g., Fromberger et al., 2012a, 2012b, 2013; Hewig et al., 2008; Nummenmaa et al., 2012) and allows for approximately 15 fixations (based on an average fixation duration lasting 200-300ms, see Rayner, 1998), which is sufficient time to scan the entire scene.

Each participant viewed all 75 stimuli, which were presented in a randomized order that was uniquely generated for each participant by the EyeLink software. Participants were allowed short breaks every 25 trials, after which the calibration procedure was repeated. On completion of the eye-tracking task, participants answered the general information scale relating to their sexual interests and the Interest in Child Molestation Proclivity scale (see Gannon & O'Connor, 2011).

Results

Confirmation of Sexual Interests

To ensure that participants were not sexually interested in children, responses on the Interest in Child Molestation Scale were analysed first. An overall interest score was calculated for each participant by combining responses across all subscales (i.e., arousal, enjoyment, behavioural propensity) (for similar analysis, see Gannon & O'Connor, 2011). This produced a total score where a minimum of 15 (low sexual interest in children) and a maximum score of 105 (high sexual interest in children) is possible. The results here converge with those obtained in previous studies with a sample of non-offending community males (Gannon & O'Connor, 2011), such that male observers scored a mean of 18.1 (mode = 15, SD = 5.6, min = 15, max = 30) and 16.8 for female observers (mode = 15, SD = 5.6, min = 15, max = 41). However, an established cut-off point for this scale does not exist. A simple metric was adopted by considering only individuals with scores on the lowest third of the scale (i.e., with scores between 15 and 45). All participants fell within this range.

Sexual orientation was confirmed with the general information scale that was administered following the eye-tracking task (see Materials). In the 22 male observers, 19 reported 'strong sexual interest in women' and three selected 'some sexual interest in women'. Among the 22 females, 12 selected 'strong sexual interest in males' and 10 selected 'some sexual interest in males'. Participants reported no other sexual interests in this questionnaire.

Data preparation

For the analysis of the eye-tracking data, all eye movements were pre-processed by merging fixations of less than 80 ms with the preceding or following fixation if it fell within half a degree of visual angle (for similar approaches, see Attard & Bindemann, 2014; Bindemann et al., 2009; Bindemann, Scheepers, Ferguson, & Burton, 2010). In addition, all fixations that fell outside the dimensions of the display monitor or that were obscured by blinking were excluded. To analyse attention to specific areas within the visual scenes, each image was then coded to define three regions of interest (ROIs), which comprised the head (including the neck) and body of the persons and the scene background. To confirm that the sizes of the different body regions (head and body) did not differ across categories, their percentage size in relation to the entire scene was calculated. This showed that the ROIs did not differ across person categories for head (Mean = 1.0%, SD = 0.8, range across person categories = 0.3% to 2.6%; one-factor ANOVA: $F(3,16) = 0.24$, $p = 0.86$) and body (mean = 6.3%, SD = 3.04, range across person categories = 2.5% to 13.5%; one-factor ANOVA: $F(3,16) = 0.11$, $p = 0.95$). The mean percentage of fixations that fell on these ROIs was then calculated across observer groups (males, females) and stimulus categories (men, women, boys, girls).

For the measure of main interest – observers' pupillary responses – these were computed by taking the mean pupil area at each fixation, averaged across the whole duration of the stimulus display (1000-5000ms) and excluded fixations to the grey screen before and after the scene. These values were then used to compute an overall mean for each participant. A difference score was then calculated by subtracting each participant's overall mean pupil size from the mean pupillary values for each category (men, women, boys, girls, no person scenes), and converted into percentage. Accordingly, a score of 0% indicates no change in pupil size in response to a particular stimulus category, and positive and negative scores indicate increases and decreases, respectively (for similar approaches, see Dabbs, 1997; Laeng & Falkenberg, 2007).

Viewing behaviour

The viewing patterns that the persons in the scenes elicited in male and female observers were examined first. To examine this, the percentage fixations to the ROIs were calculated for all stimulus categories (see Figure 2.3). Overall, 63% of fixations fell on the figures in the scenes (range = 58% to 71% across conditions), which indicates that the person-content of the scenes was of most interest. A 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) x 2 (observer sex: male, female) mixed-factor ANOVA revealed a three-way interaction, $F(6, 252) = 8.01$, $p < 0.001$, partial $\eta^2 = 0.16$. To explore this interaction, two separate 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) within-subjects ANOVAs were performed for male and female observers.

For male observers, this analysis showed no main effect of category, $F(3, 63) = 0.32$, $p = 0.81$, partial $\eta^2 = 0.02$, but revealed a main effect of ROI, $F(2, 42) = 4.54$, $p < 0.05$, partial $\eta^2 = 0.18$, and an interaction between both factors, $F(6, 126) = 34.22$, $p < 0.001$, partial $\eta^2 = 0.62$. To explore this interaction, Bonferroni-adjusted pairwise comparisons of the stimulus categories were conducted for each ROI. These comparisons show that more fixations were directed at the background of scenes containing boys, girls, and men (39% to 42%) than scenes depicting women (30%), all ps < 0.01. In addition, boys (31%) and girls (32%) received more fixations to the head than men (27%) and women (22%), all ps < 0.01, and men's heads were also fixated more frequently than those of women, $p < 0.01$. By contrast, male observers directed more fixations to the bodies (48%) of women and men (34%) than those of boys (27%) and girls (26%), all ps < 0.001, and more at women's bodies than those of men, $p < 0.001$. None of the other comparisons reached significance, all ps ≥ 0.10

The equivalent analysis for female observers showed no main effect of category, $F(3, 63) = 0.16$, $p = 0.92$, partial $\eta^2 = 0.008$, but a main effect of ROI, F(2,

42) = 2.58, $p < 0.001$, partial $\eta^2 = 0.11$, and an interaction between factors, $F(6, 126) = 8.45$, $p < 0.001$, partial $\eta^2 = 0.29$. Bonferroni-adjusted pairwise comparisons of the stimulus categories show that more fixations landed on the head region of boys and girls (both 34%) than women (22%) and men (29%), all ps < 0.001, and on the heads of men than women, $p < 0.001$. By contrast, more fixations landed on women's bodies (40%) compared to boys (29%) and girls (31%), both ps < 0.01. No other comparisons reached significance, all ps ≥ 0.08. Overall, this pattern suggests a clear interest, whereby heterosexual males and females fixate men and women more frequently than children, but are particular biased towards the bodies of adult female targets.

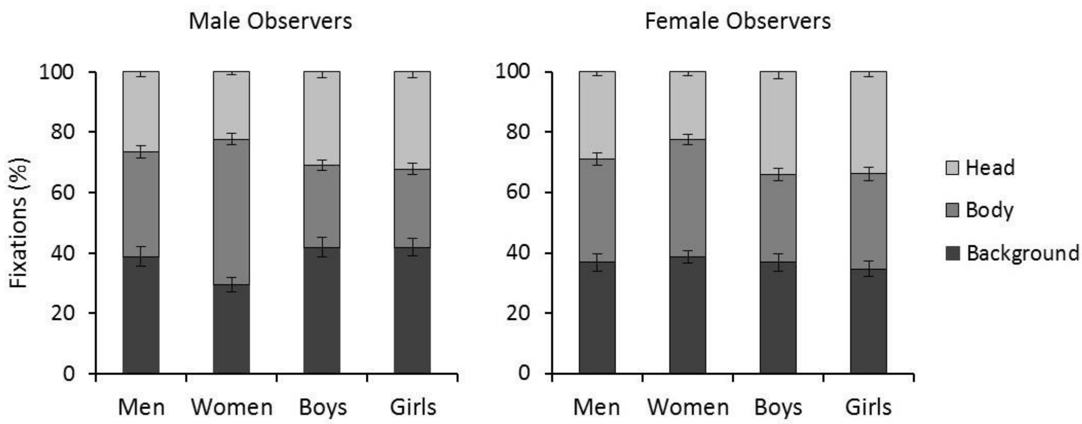

Figure 2.3 Mean percentage fixations to the head and body of the target persons and the scene background for male and female observers in Experiment 1.

Pupillary responses

The measure of main interest is pupillary response, which was analysed in two ways. In the first analysis, pupillary responses were compared for male and female observers across the stimulus categories and image conditions. This data is illustrated in Figure 2.4. A 3 (image quality: original, high, luminance-controlled) x 5 (category: men, women, boys, girls, no-person) x 2 (observer sex:

male, female) mixed-factor ANOVA revealed a main effect of category, $F(4, 168) = 20.35$, $p < 0.001$, partial $\eta^2 = 0.33$, but not of quality, $F(2, 84) = 1.75$, $p = 0.18$, partial $\eta^2 = 0.04$, or observer sex, $F(1, 42) = 1.00$, $p = 0.32$, partial $\eta^2 = 0.02$. However, an interaction between image quality and observer sex was found, $F(2, 84) = 3.36$, $p < 0.05$, partial $\eta^2 = 0.07$. Bonferroni-adjusted pairwise comparisons revealed only that female observers exhibited larger pupils than male observers during the viewing of luminance-controlled scenes, $p < 0.05$. No other differences were significant, all ps ≥ 0.09. An interaction between image quality and category was also found, $F(8, 336) = 2.17$, $p < 0.05$, partial $\eta^2 = 0.05$, as the no-person beach scenes elicited smaller pupils in the luminance-controlled than the high quality, $p < 0.01$, and original quality conditions, $p < 0.05$. No other differences between any of the person content scenes were found, all ps ≥ 0.16. Therefore, image quality was not analysed further.

An interaction between category and observer sex was also present, $F(4, 168) = 2.73$, $p < 0.05$, partial $\eta^2 = 0.06$. Bonferroni-adjusted pairwise comparisons revealed smaller pupils in male than female observers during the viewing of men, $p < 0.01$. Furthermore, in male observers, women elicited larger pupil sizes than men, boys, girls and no-person scenes, all ps ≤ 0.001. For female observers, women elicited larger pupil sizes than boys, girls and no-person scenes, all ps ≤ 0.05, but not men, $p = 0.26$. In addition, pupil responses were larger for scenes depicting boys than girls, $p < 0.05$. No other differences were observed, all $ps \geq 0.06$, and an interaction between the three factors was not found, $F(8, 336) = 1.10$, $p = 0.36$, partial $\eta^2 = 0.03$. Overall, these results therefore reveal a dilation response in male observers that appears to be consistent with self-reported sex- and age-preferences. Female observers' responses are also consistent with their age preferences, but do not correspond with their reported sexual interest in adult men.

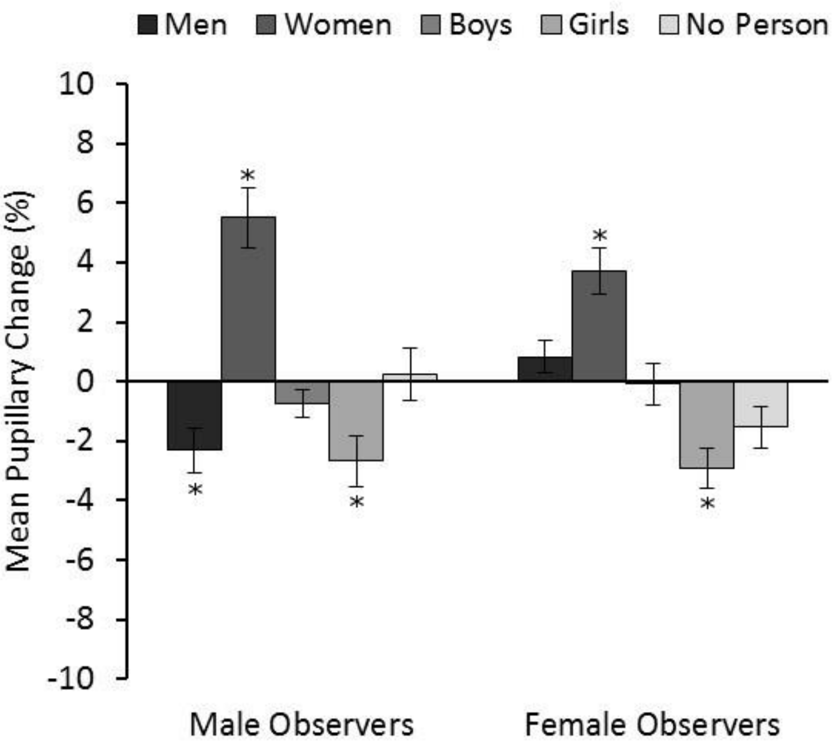

Figure 2.4 Percentage pupillary change for all stimulus categories for male and female observers in Experiment 1. *Note.* Asterisk represents $p < 0.01$ in the one sample t-tests (*alpha* corrected for multiple comparisons). Lines represent standard errors of means

In the second analysis, this pattern is confirmed when pupillary responses are compared via one-sample t-tests (with *alpha* corrected at $p < 0.01$ for multiple comparisons) with a baseline that reflects the mean pupil diameter across all stimuli (see Data Preparation). This analysis shows that the pupils of male observers were larger than baseline during the viewing of women, $t(21)$ =

5.43, $p < 0.001$, $d = 2.37$, and smaller during the viewing of men, $t(21) = -3.02$, $p = 0.006$, $d = 1.32$, and girls, $t(21) = -3.1$, $p = 0.005$, $d = 1.35$. In addition, pupil size was unchanged from baseline in response to boys and no person scenes, both *t*s ≤ -1.59, *p*s ≥ 0.126, *ds* ≤ 0.69. In female observers, pictures of men, $t(21) = 1.49$, $p = 0.15$, $d = 0.65$, boys, $t(21) = -0.12$, $p = 0.91$, $d = 0.05$, and landscape beach scenes (-1.53%), $t(21) = -2.19$, $p = 0.04$, $d = 0.96$ did not elicit a change in pupil size from baseline. The pupils were enlarged to scenes with women, $t(21) = 4.71$, $p < 0.001$, $d = 2.06$, and smaller than baseline during the viewing of girls, $t(21) = -4.33$, $p < 0.001$, $d = 1.89$.

Individual differences in pupillary responses

Chapter 2 also sought to explore whether pupillary responses can be informative about the sexual interests of individual observers. For this purpose, the difference in raw pupil size for specific image comparisons (e.g., scenes with male vs. female targets) separately for each participant was calculated. This data shows, for example, that all of the male observers (22/22) recorded larger pupil sizes during the viewing of women than men, and 91% (20/22) of male observers displayed larger pupils in response to women than girls. In addition, only 22% (5/22) of these participants showed a greater pupillary response to men than boys. With regards to female observers, 73% (16/22) showed more pupil dilation during the viewing of women than men, but 86% (19/22) of this participant group also exhibited larger pupils in response to women than girls, and 59% (13/22) recorded larger pupils to men than boys.

Discussion

The purpose of this experiment was to explore whether pupillary responses to the visual presentation of men and women can provide an indication of a person's sexual interests. More specifically, this chapter sought to determine whether this approach can be extended to reveal age-specific sexual interests. Fixation patterns on the person content in scenes were looked at first. Male observers showed a viewing preference for women over men and children, which was characterised by a high number of fixations on women's bodies. These results are consistent with other studies, which have shown that heterosexual male observers attend more to images of the opposite sex (Lykins et al., 2006, 2008; Rupp & Wallen, 2007; Suschinsky et al., 2007) and that such preferential viewing behaviour is also age-specific (Fromberger et al., 2012, 2013; Hall et al., 2011). Female observers also recorded fewer fixations on the faces of women than men and children, but more on women's bodies than those of children. Consistent with previous research, heterosexual females therefore showed age-specific viewing patterns but did not exhibit the same strong visual preferences to opposite-sex figures as men (Hall et al., 2011; Israel & Strassberg, 2009; Lykins et al., 2008; Rupp & Wallen, 2007).

To confirm that these fixation patterns were not driven by differences in the size of the target and ROIs between adults and children, the percentage space occupancy of the targets and proportion of ROIs within the scenes were calculated. This analysis revealed that these did not differ significantly between categories and therefore cannot explain the category and age specific viewing patterns found here.

The data of main interest were the pupillary responses. In heterosexual male observers, these responses were consistent with their reported sexual interests. Thus, pictures of women elicited a clear pupillary dilation that was not present during the viewing of men and children. In female observers, pupil dilation was also greatest when pictures of women were viewed. In these participants, pupillary recordings therefore do not correspond to their self-reported sexual orientation. However, these responses still appeared to be age-specific as the pupils remained unchanged or constricted during the viewing of children.

These results converge with a recent study that has shown a similar pattern of pupillary responses for heterosexual adult males and females (Rieger & Savin-Williams, 2012). Experiment 1 extends these findings by demonstrating that such pupillary responses are also age-specific. A question that arises, however, is whether these dilation effects could be attributed to a low level factor such as luminance. To explore this possibility, we also compared scene photographs in which contrast and colour were enhanced with a set in which luminance and contrast were equated. The results for these stimulus categories were highly comparable, which suggests that pupillary responses for the different person categories cannot be explained by general variation in luminance.

There is, however, a problem with the luminance adjustment that was employed in Experiment 1. While this manipulation was used to equate luminance across scenes, it does not control other low-level image aspects, such as colour, which might also affect pupillary responses (Kohn & Clynes, 1996; Lobato-Rincón et al., 2014). Such information was not matched across stimulus categories in Experiment 1. Consequently, the possibility remains that the results might reflect such image artefacts.

A second explanation is also possible for the observed pupillary responses. While the mean luminance of the scenes was adjusted, the sexual attractiveness of the target figures was not measured. As a result, this might have been mismatched across categories. Considering that photographs of women elicited more pupil dilation in both male and female observers, it is conceivable, for example, that these pictures were generally more sexually arousing than those of men. To investigate these possibilities, a second experiment was conducted.

EXPERIMENT 2

While Experiment 1 sought to control low-level image properties by equating luminance across scenes, this manipulation does not control for possible effects of colour on pupillary responses (Kohn & Clynes, 1996; Lobato-Rincón, et al., 2014). As a consequence, the possibility remains that the pattern of pupillary responses in Experiment 1 does not reflect the person content of these scenes but is an image artefact. To address this possibility, a new condition was created in Experiment 2, in which the pixels of the luminance-controlled images were randomized. These *scrambled* images are no longer recognizable as coherent scenes or visual objects, but provide an even distribution in terms of their colour content. If the pupillary responses in Experiment 1 reflect a low-level colour artefact, then the same pattern should therefore persist with the scrambled scenes in Experiment 2.

The experiment also sought to examine whether the pictures of men and women in Experiment 1 were matched in terms of their perceived attractiveness, as any differences in this dimension could explain the pupil dilation effect that was observed for female targets in *both* male and female observers. For this purpose, Experiment 2 employed two measures of attractiveness to rate the pictures of men and women. The first measured the *general* sexual appeal of our stimuli, which measures how sexually attractive observers thought the stimuli were to others (i.e., sexual appeal by 'societal standards'; for similar approaches, see Lippa et al., 2010). The second measures the sexual appeal that these images personally hold for the *individual* observer (see Ebsworth & Lalumière, 2012; Hewig et al., 2008). If the pupillary responses in Experiment 1 reflect sexual arousal then personal sexual appeal ratings should correlate with pupillary responses in Experiment 2.

Method

Participants

To determine the sample size for this experiment, an a priori power analysis based on data from the responses of male participants in Experiment 1 was performed. This was calculated with G*Power and used the effect sizes of matched t-tests comparing dilation for male versus female targets ($M_{difference}$ = 6.58, $SD_{difference}$ = 6.40, dz = 1.03), and for adult versus young female targets ($M_{difference}$ = 8.47, $SD_{difference}$ = 7.11, dz = 1.19). This analysis suggested a minimum N of 15 participants in each observer group for a .05 criterion of statistical significance.

Forty-one students (21 male) from the University of Kent participated in this study in return for a small payment or course credits. The mean age was 19.5 years (SD = 2.0; range = 18-31 years). All participants reported to be exclusively heterosexual on the Kinsey scale (Kinsey et al., 1948), which was completed as a pre-screen on our online recruitment system. None of the participants had taken part in the first experiment. All reported normal or corrected-to-normal vision.

Materials

This experiment employed the same eye-tracking set-up and luminance-controlled stimuli as in Experiment 1. To assess the contribution of colour *within* each of these 25 images (5 men, 5 women, 5 boys, 5 girls, 5 no person scenes) to pupillary response, the pixels of each image were randomized. The resulting images provide a 'scrambled' condition, in which the original image content is not discernible (see Figure 2.2; for similar approaches, see Jenkins, Lavie, & Driver, 2003; VanRullen, 2006).

Procedure

The experiment consisted of four blocks. In the first block, participants were shown the 25 scrambled scene images. This was followed, in the second block, by the 25 unscrambled versions of these stimuli. Both blocks were free-viewing tasks. Each trial therefore consisted of a drift correction, which was followed by a grey mask for 1 second. The scrambled/intact scene stimuli were then presented for 5 seconds, followed by the grey mask for a further second. In both blocks, participants were simply instructed to view these images naturally.

In the remaining blocks, the intact scenes of the men (5 images), women (5 images), and children (5 images each) were repeated. In block 3, participants were asked to provide subjective sexual attractiveness ratings for these people (i.e., based on how sexually attractive they themselves find these images), using a 7-point Likert scale, ranging from 1 ('not at all sexually appealing to me') to 7 ('extremely sexually appealing to me'). In block 4, participants were then asked to evaluate the people in the scenes objectively, based on their sexual attractiveness by societal standards using the same scale (for similar methods, see Lippa et al., 2010). For all four tasks, the stimulus sequence in each block was generated randomly by the display software for each participant. On completion of the eye-tracking task, participants completed the same general information scale and the Interest in Child Molestation proclivity scale as in Experiment 1.

Results

Once again the responses on the Interest in Child Molestation Scale were analysed first. One of the male participants produced a score of 52. In Experiment 1 and 2, this is the only score that falls above the lowest third of the Child Molestation Scale. It also exceeds the mean score (41.4) of paedophiles that have self-reported sexual acts with children (Mitchell & Galupo, 2015). This individual was therefore excluded from further analysis. For the remaining participants, means of 20.8 (mode = 15, SD = 6.2, min = 15, max = 34) and 16.3 (mode = 15, SD = 2.4, min = 15, max = 23) were obtained for male and female observers, respectively.

To confirm that participants showed a sexual interest towards the opposite-sex, their responses on the sexual interests' questionnaire were also analysed. Nineteen of the 20 males reported ‘strong sexual interest in women', and one reported ‘some sexual interest in women’. For the females, 14 of 20 reported ‘strong sexual interest in males’, while the remaining six participants reported ‘some sexual interest in males’. Participants reported no further sexual interests in this questionnaire.

Data preparation

The eye-tracking data was processed as in Experiment 1. Note that pupillary responses are reported for both free viewing tasks (block 1 and 2) but not for the two ratings tasks. In the latter tasks, 5.9 (SD = 3.7) and 6.5 (SD = 4.3) fixations were recorded on average per trial but the mean number of fixations varied greatly across observers (from 1 to 38). Consequently, these tasks did not provide reliable eye movement data for analysis. For completeness, eye fixations for the free viewing task with the intact scenes (block 2) are also reported. This data is not meaningful for the scrambled scene images in block 1 and is therefore omitted.

Viewing behaviour

Figure 2.5 shows the mean percentage fixations in all person conditions for male and female participants. A 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) x 2 (observer gender: male, female) mixed-factor ANOVA revealed a three-way interaction, $F(6, 228) = 10.06$, $p < 0.001$, partial $\eta^2 = 0.21$. To explore this interaction, separate 4 (category: men, women, boys, girls) by 3 (ROI: head, body, background) within-subjects ANOVAs were conducted for male and female observers.

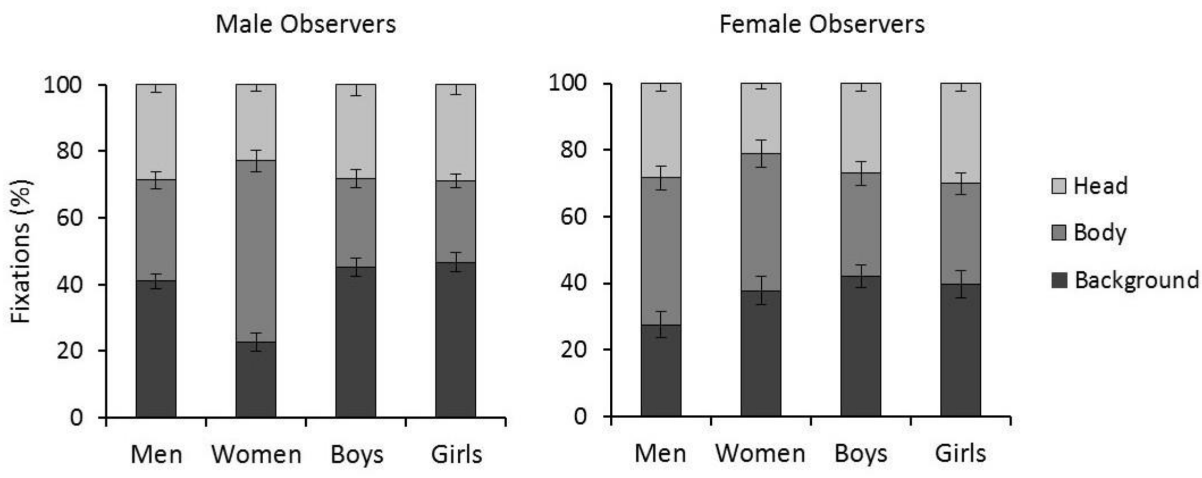

Figure 2.5 Mean percentage fixations to the head and body of the target persons and the scene background for male and female observers in Experiment 2.

For male observers, this analysis did not show a main effect of category, $F(3, 57) = 0.93$, $p = 0.43$, partial $\eta^2 = 0.05$, but revealed a main effect of ROI, $F(2, 38) = 6.98$, $p < 0.01$, partial $\eta^2 = 0.27$, and an interaction between these factors, $F(6, 114) = 20.59$, $p < 0.001$, partial $\eta^2 = 0.52$. To analyse this interaction, Bonferroni-adjusted pairwise comparisons of the stimulus categories were conducted for each ROI. These comparisons show that fewer fixations where directed at the background (23%) of female scenes than in any of the other person categories (41-47%), all *ps* < 0.001. This indicates that male observers fixate adult females more frequently than men, boys and girls. This pattern was also evident for the body regions, which these observers fixated more often in women (54%) than in men (30%), boys (27%) and girls (24%), all *ps* < 0.001. By contrast, the heads of women (23%) were fixated less frequently than those of men (29%), $p < 0.05$. No other comparisons reached significance, all *ps* ≥ 0.20.

For female observers, this analysis showed no main effect of category, $F(3, 57) = 0.44$, $p = 0.73$, partial $\eta^2 = 0.02$, and ROI, $F(2, 38) = 2.82$, $p = 0.72$, partial $\eta^2 = 0.13$, but an interaction between factors, $F(6, 114) = 0.13$, $p < 0.001$, partial $\eta^2 = 0.13$. Pairwise comparisons show that female observers directed fewer fixations towards the background when scenes contained men (28%) than scenes with women and boys (38% and 42%), both *ps* < 0.05. By contrast, a higher proportion of fixations were directed at the bodies of men (44%) and women (41%) than of boys (31%) and girls (30%), all *ps* < 0.01. Finally, fewer fixations were directed at the heads of women (21%) than men (28%), boys (27%) and girls (30%), all *ps* < 0.05. No other comparisons reached significance, all *ps* ≥ 0.11

Pupillary responses

The data of main interest were the pupillary responses. As in Experiment 1, the mean percentage change in pupil size was calculated for male and female observers for the person categories (see Figure 2.6) and was analysed in two ways. First, a 5 (category: men, women, boys, girls, no-person) x 2 (observer sex: male, female) mixed-factor ANOVA showed a main effect of category, $F(4, 152) = 32.16$, $p < 0.001$, partial $\eta^2 = 0.46$. Post-hoc analysis revealed overall larger pupils during the viewing of women compared to all other categories, all *ps* ≤ 0.001, and larger pupils to men than boys, girls and no-person scenes, all *ps* ≤ 0.01. No other differences were found, all *ps* ≥ 0.34. A main effect of observer sex, $F(1, 38) = 0.05$, $p = 0.82$, partial $\eta^2 = 0.001$, and an interaction between factors, $F(4, 152) = 2.01$, $p = 0.96$, partial $\eta^2 = 0.05$, was not found.

For completeness these responses were also analysed with one-sample t-tests (with *alpha* corrected at $p < 0.01$ for multiple comparisons), by comparing the change in pupil size for each stimulus category with a baseline of zero (see Data Preparation). For male observers, this analysis revealed pupil dilation during the viewing of women, $t(19) = 7.58$, $p < 0.001$, $d = 3.48$, and pupil constriction during the viewing of boys, $t(19) = -4.40$, $p < 0.001$, $d = 2.02$ and no-person scenes, $t(19) = -4.62$, $p < 0.001$, $d = 2.12$. A change in pupil size was not detected in response to images of men, $t(19) = 1.26$, $p = 0.22$, $d = 0.58$ and girls, $t(19) = -1.23$, $p = 0.24$, $d = 0.56$.

In female observers, dilation was also observed in response to pictures of women, $t(19) = 7.25$, $p < 0.001$, $d = 3.33$. However, in this case, dilation was also found for pictures of men, $t(19) = 3.30$, $p = 0.004$, $d = 1.51$. In contrast, the pupils appeared to be smaller than baseline during the viewing of boys, $t(19) = -2.65$, $p = 0.02$, $d = 1.22$, girls, $t(19) = -2.05$, $p = 0.05$, $d = 0.94$, and the no-person scenes, $t(19) = -2.25$, $p = 0.04$, $d = 1.03$, but these changes were not significantly below zero (with *alpha* corrected at $p < 0.01$ for multiple comparisons).

In summary, this analysis shows that male observers' pupils dilate in response to pictures of women but not men or children. Female observers show a dilation response to both men and women, but not to children. These results therefore replicate the sex-specific effect in male observers and the age-specific pattern that was observed in male and female observers in Experiment 1.

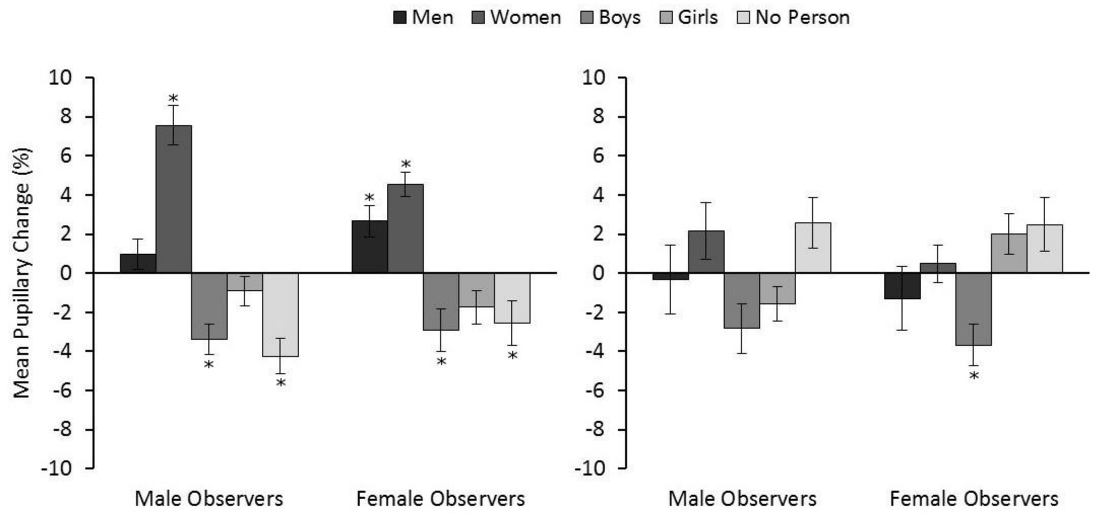

Figure 2.6 Percentage pupillary change for all stimulus categories for male and female observers in Experiment 2 for intact scenes (left graph) and scrambled scenes (right graph). *Note.* Asterisk represents $p < 0.01$ in the one sample t-tests (*alpha* corrected for multiple comparisons). Lines represent standard errors of the means.

Scrambled scenes

The pupillary responses to scrambled scenes were analysed next. As in the analysis of intact scenes, the mean pupillary responses for each category (men, women, boys, girls, no-person scenes) were transformed to measure mean percentage change (see Figure 2.6). A 5 (category: men, women, boys, girls, no-person) x 2 (observer sex: male, female) mixed-factor ANOVA did not show a main effect of observer sex, $F(1, 38) = 0.00$, $p = 1.00$, partial $\eta^2 = 0.001$, or an interaction between factors, $F(4 ,152) = 0.97$, $p = 0.43$, partial $\eta^2 = 0.03$, but revealed a main effect of category, $F(4, 152) = 4.34$, $p < 0.01$, partial $\eta^2 = 0.10$. Post-hoc Bonferroni comparisons showed that observers' pupils were smaller whilst viewing scrambled images of boys than those of women, $p < 0.01$, and no-person scenes, $p < 0.01$. No other differences between categories were found, all $ps \geq 0.20$.

Once again, these responses were also analysed via a series of one-sample t-tests (with alpha corrected at $p < 0.01$) to compare the change in pupil size to a baseline of zero (see Data Preparation). This analysis showed no change in pupil size across categories in male observers, all ts ≤ 2.23, ps ≥ 0.04, ds ≤ 1.02. The pupils of female observers were smaller during the viewing of scrambled scenes of boys, $t(19) = 3.46$, $p < 0.01$, but no other differences were found, all ts ≤ 1.83, ps ≥ 0.08, ds ≤ 1.59. We also correlated pupil sizes for scrambled and intact scenes. This revealed no relationship between these conditions in male and female observers, r(98) = 0.06, $p = 0.58$ and $r(98) = 0.04$, $p = 0.72$, respectively. These results therefore indicate that pupillary responses to intact scenes do not reflect low-level image artefacts, such as colour.

Individual differences in pupillary responses

As in Experiment 1, a simple analysis of individual performance based on the differences between stimulus categories in raw pupil size during the free-viewing task (block 2) was also performed. This data shows that 80% (16/20) of the male participants displayed larger pupils when viewing women than men, 95% (19/20) displayed larger pupils to adult women than girls, and 85% (17/20) displayed larger pupils to men than boys. Of the female observers, 65% (13/20) recorded larger pupils to women than men, 90% (18/20) displayed larger pupils to women than girls, and 90% (18/20) displayed larger pupils to men than boys.

Personal sexual appeal ratings

The next step of the analysis explored the extent to which personal sexual appeal judgements of the persons in the scenes relate to pupil responses in the free viewing task. For this purpose, the mean sexual appeal ratings for each of the person categories were analysed first. A 4 (category: men, women, boys, girls) x 2 (observer sex: male and female) mixed-factor ANOVA of this data did not show a main effect of observer sex, $F(1, 38) = 0.02$, $p = 0.88$, partial $\eta^2 = 0.00$, but revealed a main effect of category, $F(3, 114) = 83.26$, $p < 0.001$, partial $\eta^2 = 0.69$, and an interaction between factors, $F(3, 114) = 87.53$, $p < 0.001$, partial $\eta^2 = 0.70$. Bonferroni-corrected post-hoc comparisons showed that male observers rated women as more sexually appealing (M = 5.4, SD = 0.9) than men (M = 1.6, SD = 0.8), boys (M = 1.2, SD = 0.8) and girls (M = 1.2, SD = 0.7), all *p*s < 0.001. In contrast, female observers rated men as more sexually appealing (M = 4.3, SD = 1.40) than women (M = 2.1, SD = 1.2), boys (M = 1.3, SD = 0.9) and girls (M = 1.5, SD = 1.3), all *p*s < 0.001. No other differences were found. Overall, these sexual appeal ratings therefore converge clearly with observer's self-reported sexual interest in adults of the opposite sex.

Next, a correlation between the mean pupillary change (%) in the free viewing task (block 2) and the sexual appeal ratings was performed.[1] This analysis combined the person categories (men, women, boys, girls) but was performed separately for male and female observers (see Figure 2.7). The distribution of observers' sexual appeal ratings was skewed. Therefore, non-

[1] When this analysis was performed *within* category groups, no correlations between pupillary response and appeal ratings were found, all *p*s ≥ 0.06. We attribute this to the low number of images in each stimulus category (five) and the low variance in sexual appeal ratings within categories. For example, male observers' mean sexual appeal rating for female figures was 5.36 with a standard deviation of only 0.89.

parametric Spearman's correlations are reported. For male observers, a strong positive correlation between pupil change and sexual appeal ratings was found, $r_s(78) = 0.64$, $p < 0.001$. This correlation also persisted when only the adult targets (men and women) were considered, $r_s(38) = 0.58$, $p < 0.001$, which suggests that it reflects observers' sexual interests in specific adults. For female observers, the correlation across all person categories (men, women, boys, girls) was weaker, $r_s(78) = 0.28$, $p < 0.01$, and was not reliable when the child categories were excluded from analysis, $r_s(38) = -0.22$, $p = 0.17$. Overall, these data therefore suggest that pupillary responses provide a good index of sexual interest in male, but not female, observers.

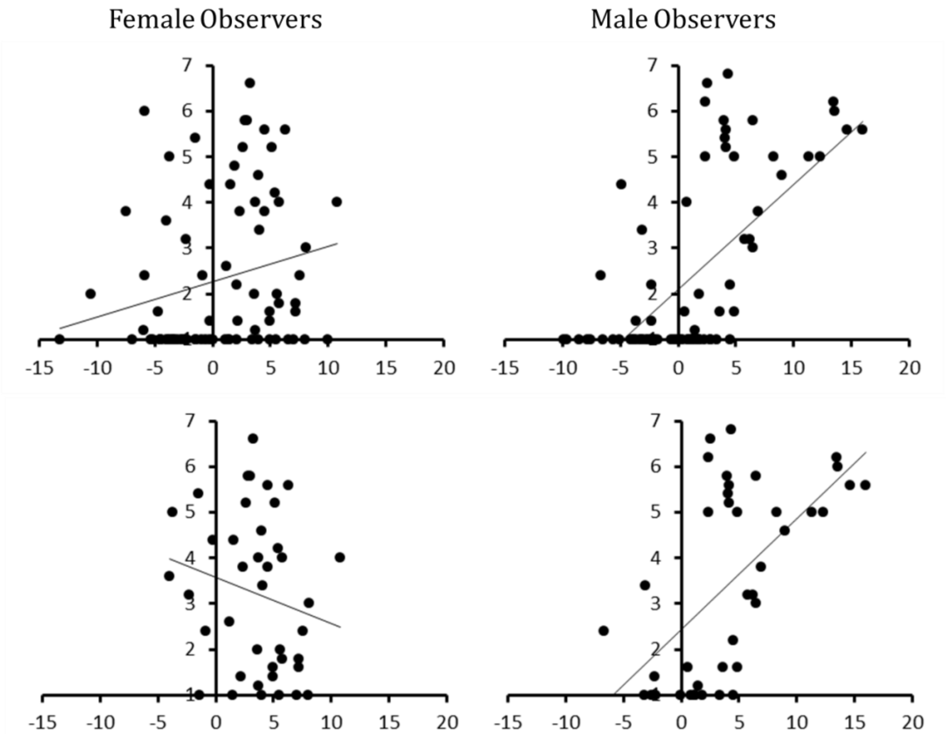

Figure 2.7 Correlations between the mean pupillary change (%) in the free viewing task (block 2) (on x-axis) and the sexual appeal ratings (on y-axis) for male and female observers when all categories are included (top), and when child categories are excluded from analysis (bottom).

General sexual attractiveness ratings

In block 4, the subjects were asked to objectively rate the persons in the scenes on their sexual attractiveness based on how they thought the general population would respond. The mean ratings were analysed with a 4 (category: men, women, boys, girls) by 2 (observer sex: male and female) ANOVA. This analysis did not show a main effect of observer sex, $F(1, 38) = 0.45$, $p = 0.51$, partial $\eta^2 = 0.01$, but a main effect of category, $F(3, 114) = 331.15$, $p < 0.001$, partial $\eta^2 = .90$, and an interaction between factors, $F(3, 114) = 2.96$, $p < 0.035$, partial $\eta^2 = 0.07$. Bonferroni-corrected post-hoc comparisons revealed that male observers rated the women in scenes (M = 6.0, SD = 0.6) higher on sexual attractiveness than men (M = 4.8, SD = 1.02), $p < 0.001$. Both adult categories were also rated higher than boys (M = 1.4, SD = 0.9) and girls (M = 1.4, SD = 0.9), all *p*s < 0.001. Female observers rated men (M = 5.6, SD = 1.0) and women (M = 5.7, SD = 1.1) more similarly ($p = 1.00$), and more sexually attractive than boys (M = 1.4, SD = 1.0) and girls (M =1.5, SD = 1.2), both *p*s < 0.001. No other differences were observed, *p*s ≥ 1.0.

A non-parametric Spearman's correlational analysis between these ratings and observers' pupillary responses (% change), which combined the data from all person categories (men, women, boys, girls), revealed a correlation for male and female observers, $r_s(78) = 0.62$, $p < 0.001$ and $r_s(78) = 0.55$, $p < 0.001$, respectively. Similar to the previous analysis, a second correlation for which the data for child targets was excluded was performed. This correlation was not significant in male, $r_s(38) = 0.29$, $p = 0.07$, or female observers, $r_s(38) = 0.01$, $p = 0.99$ (see Figure 2.8).

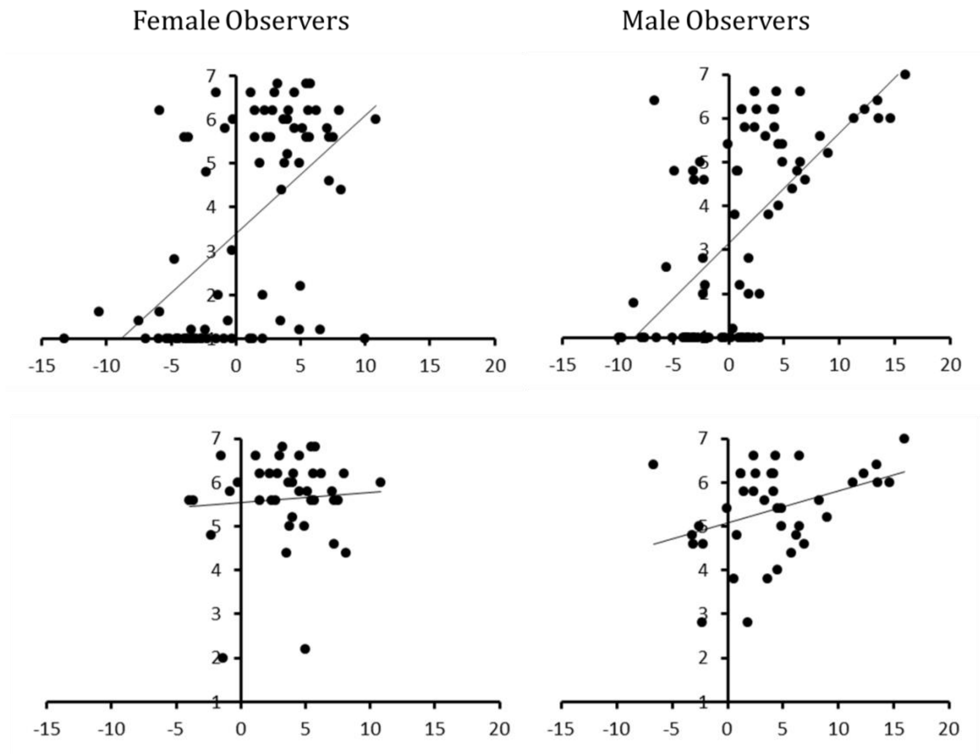

Figure 2.8 Correlations between the mean pupillary change (%) in the free viewing task (block 2) (on x-axis) and the sexual attractiveness ratings (on y-axis) for male and female observers when all categories are included (top), and when child categories are excluded from analysis (bottom).

Discussion

This experiment assessed further whether observers' pupillary responses reflect their sexual interest in a seen stimulus. For this purpose, Experiment 2 compared pupillary responses to pictures of men and women with personal sexual appeal ratings and general attractiveness ratings (by societal standards). The pupils of male observers dilated to pictures of women but not men or children. Female observers showed pupillary dilation to pictures of women and men but not to children. This experiment therefore replicates the age-specific dilation effects in male and female observers that were shown in Experiment 1, and also the sex-specific dilation effect in males.

The personal sexual appeal ratings support the notion that these pupillary responses reflect the sexual interests of heterosexual male observers (Rieger & Savin-Williams, 2012; Rieger et al., 2015). For example, these observers rated the photographs of women as much more sexually attractive than those of men and children, and these ratings correlated strongly with pupillary responses. This was evident when data from all person categories was combined, but also when the children were omitted from the analysis. This suggests that the pupillary responses of male observers reflect the sexual interest that is triggered by the stimuli.

In line with their reported sexual orientation, heterosexual female observers rated male targets as most sexually appealing, while women and children received low ratings. These ratings diverge from their pupillary responses, which indicate dilation to pictures of men *and* women. In addition, a correlation between sexual appeal ratings and pupillary responses was found, but this did not hold when child categories were excluded from analysis. This pattern deviates from our findings with heterosexual male observers. It is interesting to note, however, that such discrepancies were also obtained for pupil dilation and subjective arousal in a recent experiment (Rieger et al., 2015) and are commonly observed in studies comparing self-reported and physiological measures of sexual arousal in heterosexual women (Rieger et al., 2015; Suschinsky et al., 2009; Suschinsky & Lalumière, 2012; for a meta-analysis, see Chivers et al., 2010).

Experiment 2 also investigated whether the pupillary responses of male and female observers might reflect differences in the *general attractiveness* of the stimulus categories, by measuring how sexually attractive observers thought the stimuli were to others. Male observers rated children and adult males as less generally attractive than adult females. However, the difference between male and female stimuli was smaller than for the personal appeal ratings, indicating some adjustment. This difference was smaller still in female observers, who perceived men and women to be of similar general sexual attractiveness. Moreover, while the general attractiveness ratings correlated with pupillary responses, this did not hold for male or female observers when the child categories were excluded from analysis. This suggests that the general sexual attractiveness of male and female adult stimuli was not grossly mismatched in the current experiments, or that this was the key determinant of pupillary responses.

We also explored whether the pupillary pattern could arise from low-level artefacts within the scene images (Kohn & Clynes, 1969; Lobato-Rincón, et al., 2014). To investigate this possibility, a control condition of scrambled images was included, which are no longer recognizable as coherent scenes but retain their colour content. These scrambled scenes failed to produce pupillary dilation that corresponds with responses to the intact scenes. These findings therefore converge with the sexual appeal and attractiveness ratings to indicate that the pupillary responses in this study are driven by the person content of the scenes.

GENERAL DISCUSSION

The study examined whether pupillary responses to photographs of people can provide an indication of an observer's sexual interests and specifically sought to determine whether such responses are sensitive to images of adults or children. Experiment 1 showed that pupils of heterosexual male observers dilated during the presentation of women but not during the viewing of men and children. This suggests that these pupillary responses are linked to the sexual interest of these observers (i.e., females) and are also age-specific (adults). However, the pupils of female observers also dilated to images of women and to a lesser extent to men, but not to children. In these observers, pupillary response therefore appeared to be age-specific but do not correspond to their self-reported sexual interests (i.e., adult males).

In light of these different effects in male and female observers, a further experiment was conducted to explore more directly whether the pupillary responses are linked to observers' sexual interest. For this purpose, pupillary responses to male and female adults and children were recorded but observers were also asked to rate these target persons in terms of their sexual attractiveness. Therefore two measures were recorded for this purpose, which sought to measure the sexual attractiveness that these stimuli personally hold for an observer and also their general sexual attractiveness to others. The pupillary responses in this experiment replicated the sex- and age-specific effect in male observers and the age-specific effect in female observers that had also been found in Experiment 1. This suggests, once again, that pupillary response can provide a measure of sexual interest for male observers but not for females.

This finding received further support from the ratings tasks. The relationship between personal sexual appeal ratings and pupillary responses was weak for females and driven by the age of the persons in the scenes. However, the ratings of male observers showed a clear preference for adult females and correlated well with pupillary response, which suggests that it reflects the sexual interests of the males in this study. By contrast, when asked to rate the general sexual attractiveness of the stimuli, both groups of observers perceived the male and female adults to be more comparable and these ratings did not correlate with pupillary response. Taken together, these findings suggest that pupillary responses reflect the personal sexual interests of male but not female observers, but are age-specific in both groups.

The responses of male observers to images of women converge with previous research, which has also shown an increase in pupil size to such content (Hess et al., 1965; Rieger & Savin-William, 2012; Rieger et al., 2015). Female observers recorded pupil dilation in response to images of men in Experiment 2 but also displayed larger pupils for images of women across both experiments. The reason for this is unclear, but this absence of sex-specific pupillary responses for female observers is also consistent with studies of other paradigms in this field, such as viewing time studies (e.g., Israel & Strassberg, 2009; Lippa et al., 2010), as well as subjective self-reports and physiological arousal (e.g., Chivers, Rieger, Latty, & Baily, 2004; Chivers et al., 2010; Steinman, Wincze, Sakheim, Barlow, & Mavissakalian, 1981; Suschinsky et al., 2009). For example, in these studies women frequently show increased physiological arousal to images of both sexes (e.g., Chivers et al., 2004; Wincze & Qualls, 1984) and weaker correlation with self-reported preference and sexual arousal (Chivers et al., 2004; Schmidt, 1975). These findings indicate that women's sexual interests are organized differently to those of men (Lippa, 2006, 2007; Suschinsky et al., 2009) and may not be as strongly linked to arousal patterns as those of men (for a review, see Chivers, 2005). The current experiments suggest that this also applies to pupillary responses.

It is noteworthy that our pupillary responses in males and females are also consistent with a small set of studies from the 1960s, which first assessed pupil dilation with an elementary video-frame analysis (Hess et al., 1965; Scott et al., 1967), and a recent study that verified these findings with contemporary eye-tracking equipment (Rieger & Savin-Williams, 2012). The current experiments extend this recent work by demonstrating that such pupillary responses are also age-specific, whereby the pupils of non-paedophilic observers dilate to pictures of adults but not children. This age-specific effect represents, in fact, the most consistent aspect of our results, as this was evident in male and female observers, in all our pupillary measures, and in attractiveness ratings.

This is an important finding that raises the possibility that pupillary response could be used as a measure of deviant sexual interest in children in the assessment and rehabilitation of offending populations (Gannon et al., 2004; Laws & O'Donohue, 2008). To this point, it is notable that the lack of pupil dilation by male observers during the viewing of images of boys and girls is consistent with an old study that compared paedophilic and non-paedophilic males with a more elementary approach (Atwood & Howell, 1971). In that study, pupillary response appeared to provide an index of age-specific sexual interests in 77% of individual observers. The current study also recorded larger pupillary responses to women than men in the majority of male observers (100% and 80% of participants in Experiment 1 and 2, respectively), and to women than girls (91 and 95% of participants in Experiment 1 and 2). This indicates that, in male observers at least, pupillary response is a sensitive measure that, with further development, could operate reliably at the level of the individual.

To begin to assess the reliability of our measure further, Chapter 2 also explored whether our dilation effects could be attributed to variation in image luminance or colour across the different person categories (see e.g., Bergamin et al., 2003; Kohn & Clynes, 1996). To explore this possibility, a condition was included in Experiment 1 in which the mean luminance and contrast of the scenes was equated across the person categories. This yielded a very similar pattern of pupillary responses to the original scenes, in which luminance was not controlled. Experiment 2 also showed that sex and age-specific pupillary responses are not found when the colour information of the scenes is preserved but the content is scrambled. The results therefore suggest that pupillary responses cannot be explained simply by general variation in scene luminance and colour. In the context of the effects of observer sex and person content for the same stimuli, these findings indicate that image category (men, women, boy, girl) was modulating pupil response here.

Despite these promising findings, this study was limited in some respects. For example, these experiments sought to increase ecological validity by using images of beach scenes, as these provide a natural setting to display semi-naked people (i.e., wearing only beachwear) to enhance sexual arousal. However, this approach also resulted in variation of the person content in terms of body posture, facial expression, eye gaze of the targets, and so forth. This could have affected eye fixations around the scenes and pupillary responses (see e.g., Birmingham, Bischof, & Kingstone, 2008). This is addressed in Chapter 3 by using more controlled stimuli.

Furthermore, the pattern of female responding was highly similar to that produced by heterosexual men in Experiments 1 and 2. Although such responses are found in the wider sex literature with a range of measures (Chivers et al., 2004; Israel & Strassberg, 2009; Lippa et al., 2010), this creates difficulty for interpreting the patterns found in male observers. As an alternative, such experiments could compare pupillary responses of heterosexual, homosexual and bisexual male observers. If pupillary response provides a robust measure of sexual interest, rather than reflecting other factors within natural scenes, then this should reflect the specific sexual interests of these different observer groups. This is therefore addressed in Chapter 3.

Chapter 3 Men's Pupillary Responses to Persons at Different Stages of Sexual Development

Introduction

Chapter 2 examined whether pupillary response can provide an age-specific measure of sexual interest using highly-sensitive, contemporary eye-tracking equipment. In that study, the pupil sizes of heterosexual men and women (whose sexual interests were exclusive to adults) were recorded to scene photographs containing adults (with a perceived age of ~ 25 years) and young children (perceived age of ~ 5 years). Consistent with previous research, heterosexual male observers displayed larger pupils during the viewing of adult women (Hess et al., 1965; Rieger et al., 2012, 2015). Importantly, these findings were accompanied by clear age effects for male and female observers, such that no pupil dilation was observed to images of children. Therefore, these findings suggest that pupil size, as measured with sensitive eye-tracking equipment, may not only provide an index of sexual interest that is sensitive to observers' sex preferences, but also to sexual age preferences.

Despite these promising findings, this exploratory study was limited in some important respects. One caveat is the pupils of heterosexual female observers' also revealed dilation during the viewing of women, which is inconsistent with the sex preferences of these participants *and* similar to the response of heterosexual men. This pattern of female responding is common in the wider sex literature and has been obtained with a range of measures and paradigms, such as viewing and response times (Israel & Strassberg, 2009; Lippa et al., 2010), and self-report sexual and genital arousal (e.g., Chivers et al., 2004; Chivers et al., 2010; Steinman et al., 1981; Suschinsky et al., 2009).

However, in combination with the use of visual scenes, which were employed as a natural context for the presentation of the person stimuli and to provide alternative non-person content to view, the possibility arises that these pupillary response are driven by additional non-person aspects of the stimuli. For example, as the pupils also vary in size as an automatic response to light changes (Ellis, 1981; Bergamin & Kardon, 2003), it is conceivable that scene stimuli with female adult targets might have contained a darker luminance profile, which might have served as low-level visual triggers of pupil dilation in both male *and* female observers (see Ellis, 1981; Bergamin & Kardon, 2003). To reduce this possibility, the mean luminance of scenes across stimulus categories (i.e., males, females; adults, children) was equated (Experiment 1) and included control conditions in which all image pixels were randomised (Experiment 2). However, these manipulations cannot eliminate the possibility that the scenes in different conditions might have differed in other aspects, such as the distribution of luminance within scenes or other image-based factors. Consequently, it remains unresolved whether the pupillary responses of heterosexual male observers also provide a reliable reflection of their sexual interest, and whether these are truly age-specific. This therefore raises the possibility that these pupillary responses do not reflect age- and sex-specific sexual interests but are stimulus-based effects.

The current chapter seeks to address this issue by comparing the pupil responses of non-paedophilic men with hetero-, homo- and bisexual orientations. Only male participants were tested due to their high concordance between self-reported sexual orientation and physiological measures of sexual interest (see e.g., Chivers, 2005; Chivers et al., 2010; Rieger et al., 2012, 2015). The inclusion of three male groups with different sexual orientations circumvents the issue of equating low-level aspects of the visual stimuli that might not be fully understood or cannot be easily identified. Thus, if the same pattern of pupillary responses is obtained across observers, irrespective of sexual orientation, then this pattern must arise from low-level visual-attributes of the stimuli rather than their content (i.e., independent of whether male or female persons are depicted). In turn, if pupillary responses are consistent with observers' self-reported sexual orientation (e.g., larger to female targets in heterosexual observers, larger to male targets in homosexual observers), then this would confirm that these provide a measure of sexual interest. In turn, this would support the idea that the pupillary responses in Experiments 1 and 2 are also reflective of age-specific sexual interest.

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

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

EXPERIMENT 3: Free-viewing of people in natural scenes

This experiment examined whether pupil responses of hetero-, homo- and bisexual non-paedophilic adult males correspond to their reported sex and age sexual preferences. For this purpose, observers viewed natural scenes depicting adult and prepubescent children, as well as landscape scenes with no person content as a comparison. If pupillary responses to these scenes are related to observers' sexual interests, then pupil size should be greatest during the viewing of targets that match observers' self-reported sex and age sexual preferences. Thus, the pupils should be largest during the viewing of women in heterosexual males compared to men, larger to men than women in homosexual observers, and comparable in size to men and women in bisexual observers. In addition, and importantly, in all of these observers, pupillary response to their preferred adult targets should be smaller than to images of children.

Method

Participants

Participants were first recruited via the University's online recruitment system which completed the sample of heterosexual men. However, to complete the sample of the less-prevalent gay and bisexual males a more targeted approach was implemented (see Rieger & Savin-William, 2012; Rieger et al., 2015), whereby the study was also advertised on the University's student social media page for the LGBT society. One hundred male university students with diverse sexual interests (59 hetero-, 20 homo- and 21 bisexual) participated in this study in return for a small payment or course credit. The mean age was 21.6 years (SD = 5.6, range = 18 - 50 years) for heterosexual men, 24.5 years (SD = 7.6, range = 18 – 47 years) for homosexual men, and 21.1 years (SD = 2.5, range = 18 – 28 years) for bisexual men. All participants reported normal or corrected-to-normal vision. These participants also completed Experiment 2, 3 and 4.

Eye-Tracking

The stimuli were displayed using SR-Research ExperimentBuilder software (version 1.1.0) on a 21" colour monitor, with a screen resolution of 1024 x 768 pixels. Eye movements were tracked using an SR-Research Eyelink 1000 eye tracking system. The Eyelink 1000 was running at a 1000 Hz sampling rate, a spatial resolution of < 0.01° of visual angle, a gaze position accuracy of < 0.5°, and a pupil size resolution of 0.1% of diameter. The Eyelink 1000 eye-tracking system works by measuring corneal reflection and dark pupil with a video-based infrared camera. This system computes the number of camera pixels that are occluded by participants' pupils and records the area of the pupil (i.e., pupil size) as an integer that ranges from 400-1600. During the recording of eye movements, participants are instructed to place their head on a chinrest to minimize head movements. This eye tracking system is compatible with most eye-glasses and contact lenses.

Materials

In this experiment, a total of 25 images that portrayed adult men and women, and prepubescent boys and girls (5 scenes for each of these four categories) on beaches were used (as in Chapter 2). In addition, a set of control beach scenes with no person content was included (5 scenes). In a previous study, the mean ages of the targets were estimated to be 26.4 years (SD = 2.1) for men, 22.8 years (SD = 2.6) for women, 5.7 years (SD = 1.1) for boys, and 4.7 years (SD = 1.4) for girls. People were portrayed in swim or leisure wear and depicted in similar non-sexually explicit poses. All stimuli were purchased from an internet photograph database (www.mostphotos.com) and were selected to be of similar composition and size. To confirm that these targets were of similar size, percentage occupancy area in the scenes was calculated. These confirmed that all person categories occupied a similar amount of space in these scenes (mean = 7.1%, SD = 3.4, range across person categories = 6.6% to 7.7%; one-factor ANOVA, $F(3, 19) = 0.14$, $p = 0.94$). The scenes were displayed in the centre of a uniform grey background subtending approximately 17.8 degrees of visual angle vertically and 26.4 degrees horizontally at a viewing distance of 60cm.

Two questionnaires relating to sexual interests were also included. The first was a general information scale and instructed participants to select one or more of five applicable statements ('no sexual interest in adults', 'strong sexual interest in female adults', 'some sexual interest in female adults', 'some sexual interest in male adults', 'strong sexual interest in male adults'). The second questionnaire was an Interest in Child Molestation Scale, which participants completed to confirm that they were exclusively sexually interested in adults (Gannon & O'Connor, 2011). This scale consists of five short scenarios that describe incidents of child molestation. Three of these describe low-force and two describe high force sexual acts on children. In response to these scenarios, participants have to rate their arousal, enjoyment and behavioural propensity to child sex abuse on 7-point Likert scales.

Procedure

Participants were invited to take part in an experiment on sexual interests and informed that they will be viewing photographs of male and female persons of varying ages whilst their eye movements were being recorded. Participants were kept naïve to the full purpose of the experiment until the end. On arrival, participants were seated in front of the SR Eyelink 1000 eye tracking system where they positioned their head on the chin rest at a set distance of approximately 60 cm from the display monitor. The participants' left eyes were tracked at a rate of 1000Hz, and calibrated and validated using the standard nine-point fixation Eyelink procedure. This process was repeated if poor measurement accuracy was indicated.

For this experiment, a free viewing paradigm was adopted so as not to constrain spontaneous eye movements. Therefore, participants were instructed to view the images as 'naturally as they normally would' (for similar approaches, see e.g., Fromberger et al., 2012a, 2012b, 2013; Hall et al., 2011). Each trial began with a fixation dot, which allowed for drift correction, and ensuring that participants were looking at the centre of the display when the trial began. The experimenter then initiated the trial via a button press. The trial began with a grey screen which was displayed for 1 second, and then the stimulus display for 10 seconds, followed by another grey screen for 1 second. Each participant viewed all 25 images once in a random order that was generated individually for each participant by the EyeLink software. Participants then completed the general information scale relating to their sexual interests and the Interest in Child Molestation Proclivity Scale (see Gannon & O'Connor, 2011). As participants took part in all four experiments, these scales were only completed once, on completion of the last eye-tracking task.

Results

To confirm the participants' sexual orientation, their responses on the sexual interest questionnaire were analysed first. Of the 100 participants, 59 indicated 'some' (n = 6) or 'strong' (n = 53) sexual interest in females with no sexual interest in males. We categorised these individuals as heterosexual. Twenty individuals indicates 'some' (n = 1) or 'strong' (n = 19) sexual interest in males without any interest in females and were therefore categorised as homosexual. Of the remaining twenty-one participants, 14 selected both 'strong sexual interest in adult females' and 'some sexual interest in adult males', five selected both 'some sexual interest in adults females' and ' some sexual interest in adult males', and two participants selected 'strong sexual interest in adult females' and 'strong sexual interest in adult males'. These were therefore categorised as holding bisexual interests. Participants were also asked to indicate 'roughly, how many different sexual partners have you had?' To this question, 50 of the participants that were categorised as heterosexual indicated a previous sexual relationship with women only, the remaining nine participants stated that they had a relationship with a male only (N = 2), both male and female (N = 1) or were not involved in a previous relationship (N = 7). For the homosexual participants, 12 said to have been in a previous relationship with males only, while others reported sexual relations with both males and females (N = 6) or no prior relationship (N = 2). Participants that were categorised as bisexual reported having had relationships with both males and females (N = 8), females only (N = 10), males only (N = 1), and no previous sexual relationship (N = 2).

The responses on the Child Molestation Scale were analysed next to ensure that participants were not sexually interested in children. A total interest score was calculated for each participant by summing up responses across the five scenarios and three subscales (i.e., arousal, enjoyment, behavioural propensity; for similar analysis, see Gannon & O'Connor, 2011; Mitchell & Galupo, 2015). This produced a score that ranged from a minimum of 15 (low sexual interest in children) to a maximum of 105 (high sexual interest in children). A cut-off point for sexual deviancy does not currently exist. We therefore adopted a simple metric by considering only individuals whose scores fell within the lowest third of the scale (i.e., scores between 15 and 45). The scores of four individuals fell above this range, which resulted in the exclusion of two heterosexual men (with scores 51 and 52) and two bisexual men (with scores 49 and 59). For the remaining participants, means of 20.4 (mode = 15, SD = 7.4, min = 15, max = 41) for heterosexual observers, 17.1 (mode = 15, SD = 4.4, min = 15, max = 32) for homosexual observers, and 18.4 (mode = 15, SD = 6.2, min = 15, max = 40) for bisexual observers were recorded.

Data preparation

To analyse the eye tracking data, eye movements were first pre-processed by combining fixations of less that 80ms with the preceding or following fixations if it fell within half a degree of visual angle (for similar approaches, see e.g., Attard & Bindemann, 2014; Bindemann et al., 2010). Fixations that fell outside the dimensions of the display monitor or that were obscured by eye blinks were excluded. Three regions of interest (ROIs), which comprised the head, body and scene background, were defined and the percentage of fixations that fell on these ROIs was then calculated.

Next, observers' pupillary responses to each stimulus category were calculated as a percentage change from observers overall pupil mean. For this, pupillary responses were first computed by taking the mean pupil area at each fixation, averaged across the whole duration of a stimulus display and excluding the grey screen displayed before and after the stimulus. An overall mean, across all stimuli in all conditions, was then computed from these values for each participant. The percentage difference (i.e., an increase or decrease) in pupil area for each stimulus category (men, women, boys, girls, no person scenes) from the overall mean was then computed, using the formula: (mean pupil area for category * 100) / overall pupil mean. Accordingly, a score of 100% indicates that the pupillary response to a stimulus category does not differ from the overall mean. Scores above or below this value indicate comparatively larger or smaller pupil sizes (for similar approaches, see Dabbs, 1997; Laeng & Falkenberg, 2007).

To simplify the expression of these patterns, these scores were then deducted from 100 so that no change in pupil size is indicated by zero and positive or negative scores reflect relatively larger (dilation) or smaller (constriction) pupil sizes in response to a stimulus category.

Viewing behaviour

Observers' percentage fixations to the ROIs for all stimulus categories are illustrated in Figure 2.1. Overall, the person content in the scenes accounted for 63% of fixations (with a range of 55% to 77% across conditions and observer groups). A 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) x 2 (sexual orientation: hetero-, homo-, bisexual) mixed-factor ANOVA found a three-way interaction, $F(8, 372) = 52.78$, $p < 0.001$, partial $\eta^2 = 0.53$. To analyse this further, three 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) within-subjects ANOVAs were performed separately for hetero-, homo- and bisexual male observers.

For heterosexual observers, this analysis showed no main effect of category, $F(3, 168) = 1.13$, $p = 0.34$, partial $\eta^2 = 0.02$, but revealed a main effect of ROI, $F(2, 112) = 18.53$, $p < 0.001$, partial $\eta^2 = 0.45$, and an interaction between both factors, $F(6, 336) = 45.87$, $p < 0.001$, partial $\eta^2 = 0.45$. To explore this interaction, Bonferroni-adjusted pairwise comparisons of the stimulus categories were performed for each ROI. These comparisons show that more fixations were directed at the background of scenes comprising men, boys, and girls (39% to 44%) than scenes portraying women (28%), all *p*s < 0.001. Furthermore, men, boys and girls received more fixations to the head (25% to 30%) than women (21%), all *p*s < 0.01, and girls also received more fixations to the head than boys and men, both *p*s < 0.01. By contrast, heterosexual males fixated the bodies of women (51%) and men (35%) more than those of boys (30%) and girls (26%), all *p*s < 0.001, and also looked at women's bodies more than those of men, $p <$ 0.01. Overall, this pattern indicates a clear interest for adult females, whereby heterosexual males fixate the bodies of women more frequently than any other person categories.

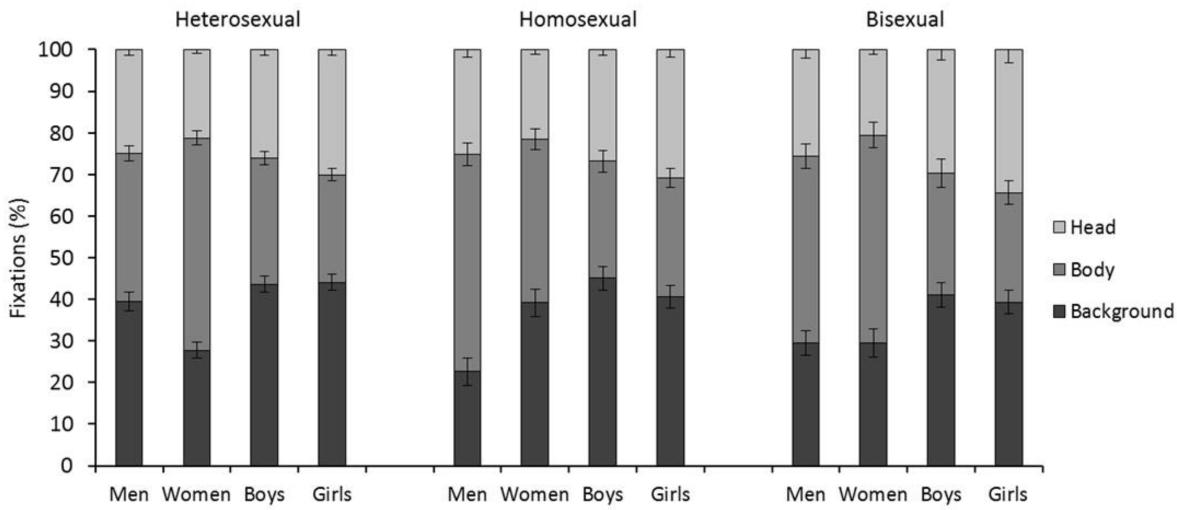

Figure 2.1 Mean percentage fixations to the heads and bodies of the target persons and the scene backgrounds for hetero-, homo- and bisexual male observers in Experiment 3. Vertical lines represent standard errors of means.

The analogous analysis for homosexual male observers showed no main effect of category, $F(3, 57) = 2.23$, $p = 0.10$, partial $\eta^2 = 0.11$, but a main effect of ROI, $F(2, 38) = 7.32$, $p < 0.05$, partial $\eta^2 = 0.28$, and an interaction between factors, $F(6, 114) = 25.00$, $p < 0.001$, partial $\eta^2 = 0.57$. Bonferroni-adjusted pairwise comparisons of the stimulus categories revealed that fewer fixations landed on the background of the scenes depicting men (23%) than scenes comprising women, boys and girls (39% to 45%), all *ps* < 0.01. By contrast, more fixations were directed at the bodies of men (52%) and women (39%) compared to boys (28%) and girls (29%), *ps* < 0.001, and more at men's than women's bodies, $p < 0.05$. This pattern therefore indicates a particular interest in adult men, with a bias towards the bodies of these targets compared to the other person categories.

Finally, the equivalent analysis for bisexual male observers showed no main effect of category, $F(3, 54) = 0.83$, $p = 0.48$, partial $\eta^2 = 0.04$, but revealed a main effect of ROI, $F(2, 36) = 4.02$, $p < 0.05$, partial $\eta^2 = 0.18$, and an interaction between both factors, $F(6, 108) = 14.13$, $p < 0.001$, partial $\eta^2 = 0.44$. Bonferroni-adjusted pairwise comparisons show that more fixations where directed towards the background in scenes depicting boys (41%) and girls (39%) than scenes depicting men and women (both 29%), *ps* < 0.05. In addition, more fixations landed on the head region of girls (34%) than men (26%), women (21%) and boys (30%), all *ps* < 0.05, and more fixations landed on the head region of boys than women, $p < 0.01$. These observers also directed a comparable proportion of fixations at the bodies of men (45%) and women (49%), $p = 1.00$, and this was greater than the percentage of fixations on the bodies of boys (29%) and girls (26%), all *ps* < 0.001. No other comparisons reached significance, all *ps* ≥ 0.08. In summary, bisexual males directed a comparable number of fixations at the bodies of adult male and females, and fixated these regions more than the bodies of children. By contrast, more fixations landed on the background region of scenes with children, and the head region of girls.

Pupillary responses

The data of most interest were observers' pupillary responses, which were analysed in two ways. First, pupillary responses were compared for hetero-, homo- and bisexual observers across the stimulus categories. This data is illustrated in Figure 3.2. A 5 (category: men, women, boys, girls, no-person) x 3 (sexual orientation: hetero-, homo- and bisexual) mixed-factor ANOVA revealed a main effect of category, $F(4, 372) = 27.52$, $p < 0.001$, partial $\eta^2 = 0.23$, but not of sexual orientation, $F(2, 93) = 0.46$, $p = 0.64$, partial $\eta^2 = 0.10$. However, an interaction between category and sexual orientation was also found, $F(8, 372) = 3.18$, $p < 0.01$, partial $\eta^2 = 0.06$.

To explore this interaction, Bonferroni-adjusted pairwise comparisons were conducted to compare the responses of observers for each stimulus category. This analysis revealed that the pupil sizes of homosexual males were larger than those of heterosexual males during the viewing of men, $p < 0.01$. By contrast, the pupils of heterosexual males were larger during the viewing of women than those of homosexual and bisexual observers, $p < 0.001$ and $p < 0.05$, respectively. No other differences were found, all ps ≥ 0.13.

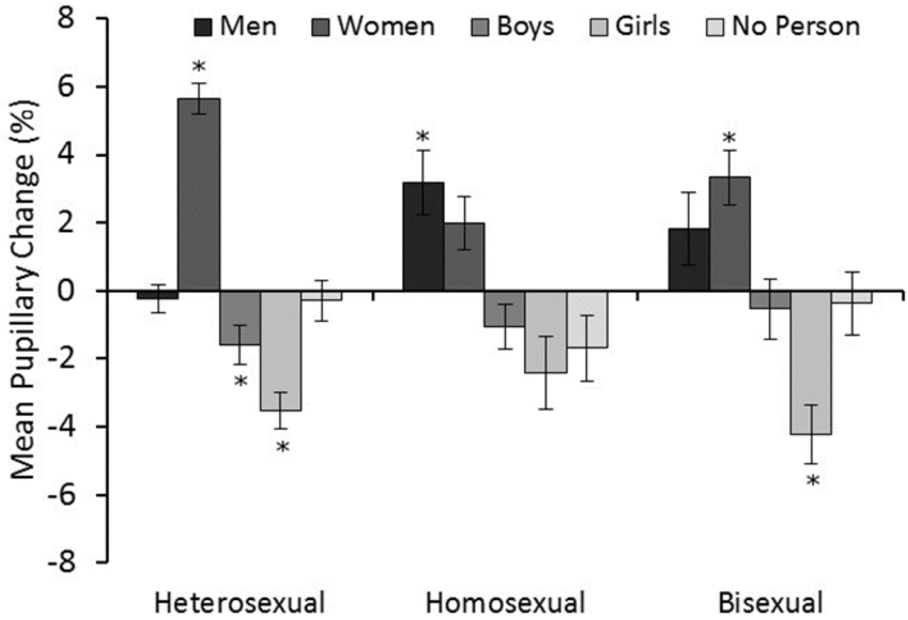

Figure 3.2 Mean percentage pupillary change (no change = 0; increase > 0; decrease < 0) for the stimulus categories in Experiment 3 for hetero-, homo-, and bisexual observers. Vertical lines represent standard errors of means. *Note.* Asterisk represents p < 0.01 in the one sample t-tests (*alpha* corrected for multiple comparisons)

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

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

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

Taken together, these results reveal a dilation response in hetero-, homo- and bisexual male observers that appears to be largely consistent with their self-reported sex- and age- sexual preferences. This is evident when responses for a specific category are compared across observer groups. These differences are also apparent when within-subject comparisons are made, such that larger pupils are recorded when observers view their preferred stimulus categories compared to other non-preferred categories. In bisexuals however, a reliable dilation was only found for one of the two preferred categories (i.e., for women but not men).

Discussion

This experiment compared pupillary responses of hetero-, homo- and bisexual males while viewing natural scenes containing adults and children. First, eye movements to these images were analysed to ensure that participants were attending to the person content in the scenes. In line with previous research, the person content captured the most interest, with more fixations directed at the bodies of adults and the heads of children (e.g., Fromberger et al., 2012, 2013;

Hall et al., 2011; Lykins et al., 2006, 2008; Rupp & Wallen, 2007; Suschinsky et al., 2009). Viewing patterns for adult stimuli were also reflective of observers' sexual orientation, such that heterosexual males fixated more on the bodies of women than men. In contrast, homosexual males directed more fixations to the bodies of men, while bisexual males did not differ in the percentage of fixations directed at the bodies of both adult categories.

Importantly, the results for the pupil responses also demonstrate dilation patterns that appear to be consistent with observers' self-reported sex-preferences and preferences for adults. Thus, when compared to the baseline, female stimuli evoked the largest dilation response in heterosexual males. In contrast, male stimuli elicited a reliable dilation response in homosexual men. Note that female stimuli also elicited some dilation in homosexual men, however this was not reliably above zero. The data is somewhat less clear for bisexual men, who displayed dilation to pictures of men and women, but this was only reliable for the latter category. Importantly, however, no such dilation responses were observed for images of children. These responses are therefore consistent with observers' recording a sexual preference for adults in the Interest in Child Molestation Scale (Gannon & O'Connor, 2011).

EXPERIMENT 4: Sexual appeal ratings to natural scenes

Experiment 3 demonstrated that pupil responses corresponded with observers' self-reported sexual orientation. However, as a free-viewing task, which was designed to capture natural viewing interests, this task stopped short of relating these responses directly related to the sexual interest value that those images hold for the observers. To address this issue, Experiment 4 examined combined pupillary responses for the different person categories with observers' sexual appeal judgements for these targets. For this purpose, participants were instructed to rate the target images for their sexual appeal on a Likert scale. If pupillary responses are strongly linked to sexual interest then these ratings should correlate with the pupillary responses to the different categories.

Method

The eye-tracking set up and procedure were identical to Experiment 3, except for the following differences. The same natural scenes as in the previous experiment were used here, with the exception of the no-person beach scenes, as these did not contain persons that could be rated in terms of their sexual appeal. In the experiment, participants were instructed to rate the sexual appeal of these targets on a 7-point Likert scale. Responses were made with a standard keyboard, where number key 1, for example, corresponded with 'not at all sexually appealing' and 7 with 'extremely sexually appealing'. Once a response was registered, the image was removed from view and the next trial began. As in previous experiments, trial order was randomized for each participant.

Results

Viewing behaviour

As before, the percentage of fixations to the face, body and background ROIs were calculated for all stimulus categories and are illustrated in Figure 3.3. Overall, 62% of fixations were directed towards the person content in the scenes, with a range of 56% to 73% across conditions. A 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) x 2 (sexual orientation: hetero-, homo-, bisexual) mixed-factor ANOVA found a three-way interaction, $F(12, 558) = 2.04$, $p < 0.05$, partial $\eta^2 = 0.04$. To analyse this further, three 4 (category: men, women, boys, girls) x 3 (ROI: head, body, background) within-subjects ANOVAs were performed to analyse this data separately for the hetero-, homo- and bisexual observers.

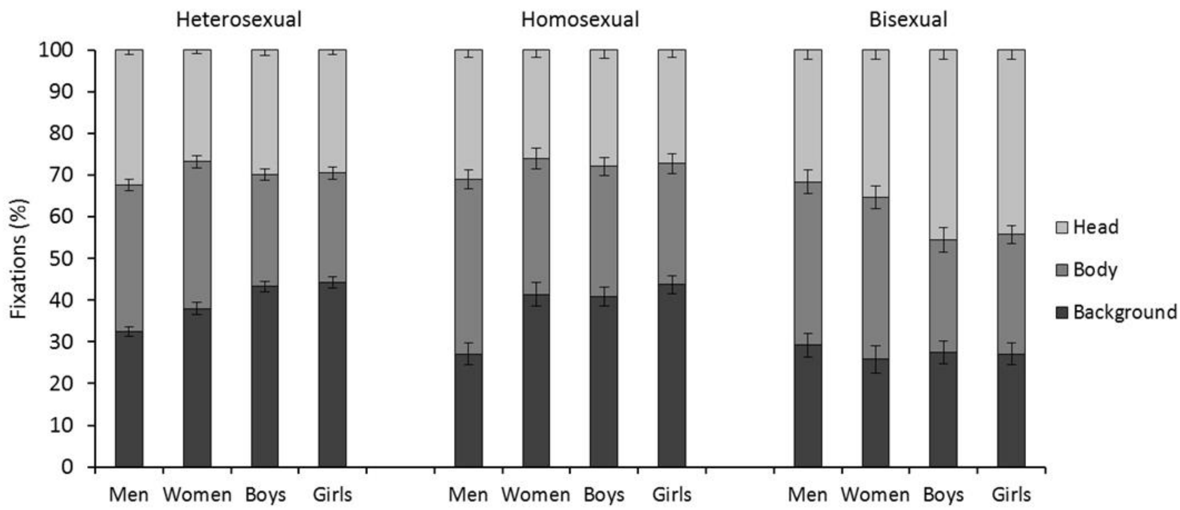

Figure 3.3 Mean percentage fixations to the heads and bodies of the target persons and the scene backgrounds for hetero-, homo- and bisexual male observers in Experiment 4. Vertical lines represent standard errors of means

For heterosexual males, this analysis did not show a main effect of category, $F(3, 168) = 0.14$, $p = 0.94$, partial $\eta^2 = 0.002$, but revealed a main effect of ROI, $F(2, 112) = 19.31$, $p < 0.001$, partial $\eta^2 = 0.26$, and an interaction of both factors, $F(6, 336) = 20.68$, $p < 0.001$, partial $\eta^2 = 0.27$. To analyse this interaction, Bonferroni-adjusted pairwise comparisons of the stimulus categories were performed for each ROI. These comparisons reveal that fewer fixations landed on the background of the scenes depicting men (32%) than women (38%), boys (43%) and girls (44%), all ps < 0.05. Additionally, more fixations were directed towards the bodies of men and women (both 35%) than those of boys and girls (both 26%), all *p*s < 0.05. Finally, the head region of women (26%) received fewer fixations than that of men (32%), $p < 0.01$. No other differences were found, all *p*s ≥ 0.11.

For homosexual males, this analysis also showed no effect of category, $F(3, 57) = 0.10$, $p = 0.96$, partial $\eta^2 = 0.005$, but revealed an effect of ROI, $F(2, 38) = 5.21$, $p < 0.05$, partial $\eta^2 = 0.22$, and an interaction between factors, $F(6, 114) = 14.91$, $p < 0.001$, partial $\eta^2 = 0.44$. Bonferroni-adjusted pairwise comparisons revealed that scenes comprising men received fewer fixations to the background (27%) than all other categories (40% to 44%), all *p*s < 0.001. Additionally, these observers fixated more on the bodies of men (42%) compared to those of women (33%), boys (31%) and girls (29%), all *p*s ≤ 0.001. Fewer fixations were also directed towards the head region of women (26%) than men (31%), $p < 0.05$. Overall, this pattern shows that homosexual men fixate male targets more frequently with a particular bias towards the bodies of these figures. No other comparisons reached significance, all *p*s ≥ 0.11.

The equivalent analysis for bisexual men also showed no effect of category, $F(3, 54) = 0.37$, $p = 0.78$, partial $\eta^2 = 0.02$, but found an effect of ROI, $F(2, 36) = 4.16$, $p = 0.02$, partial $\eta^2 = 0.19$, and an interaction, $F(6, 108) = 12.83$, $p < 0.001$, partial $\eta^2 = 0.42$. Bisexual observers directed fewer fixations to the background of scenes comprising men (29%) and women (35%) than boys (46%) and girls (44%), all *p*s < 0.05, and fewer fixations to the background of scenes with men than women, $p = 0.05$. Additionally, the body region of men and women (both 39%) received more fixations than the corresponding region in boys (27%) and girls (29%), all *p*s ≤ 0.01. Therefore, the bisexual men directed a similar amount of fixations to the bodies of adult figures, and this was greater than the fixations directed towards the bodies of children. No other comparisons reached significance, all *p*s ≥ 0.11.

Pupillary responses

The same analysis as in Experiment 3 was performed for the pupillary data here and this data is illustrated in Figure 3.4. A 4 (category: men, women, boys, girls) x 3 (sexual orientation: hetero-, homo- and bisexual) mixed-factor ANOVA revealed a main effect of category, $F(3, 279) = 41.52$, $p < 0.001$, partial $\eta^2 = 0.31$, but not of sexual orientation, $F(2, 93) = 0.12$, $p = 0.89$, partial $\eta^2 = 0.003$. However, an interaction of category and sexual orientation was also found, $F(6, 279) = 3.95$, $p < 0.001$, partial $\eta^2 = 0.08$. To explore this interaction, Bonferroni-adjusted pairwise comparisons were conducted for each category. These showed that during the viewing of men, homosexual and bisexual males showed larger pupils than heterosexual males, both *p*s < 0.05. When viewing scenes depicting women, heterosexual males showed larger pupils than homosexual, $p < 0.001$, and bisexual men, $p < 0.05$. No other differences were found, all *p*s ≥ 0.41.

As with previous experiments, these responses were also analysed via a series of one-sample *t*-tests (with *alpha* corrected at $p < 0.0125$ for multiple comparisons) to compare the change in pupil size a baseline of zero (see Data Preparation). This analysis was performed separately for observer groups. For heterosexual males, this analysis revealed dilated pupils during the viewing of women, $t(56) = 10.33$, $p < 0.001$, $d = 2.76$, and constricted pupils during the viewing of boys and girls, both *t*s ≥ -5.03, *p*s < 0.001, *d*s ≥ 1.34. No change in pupil size was recorded in response to images of men, $t(56)$, $p = 0.38$, $d = 0.24$.

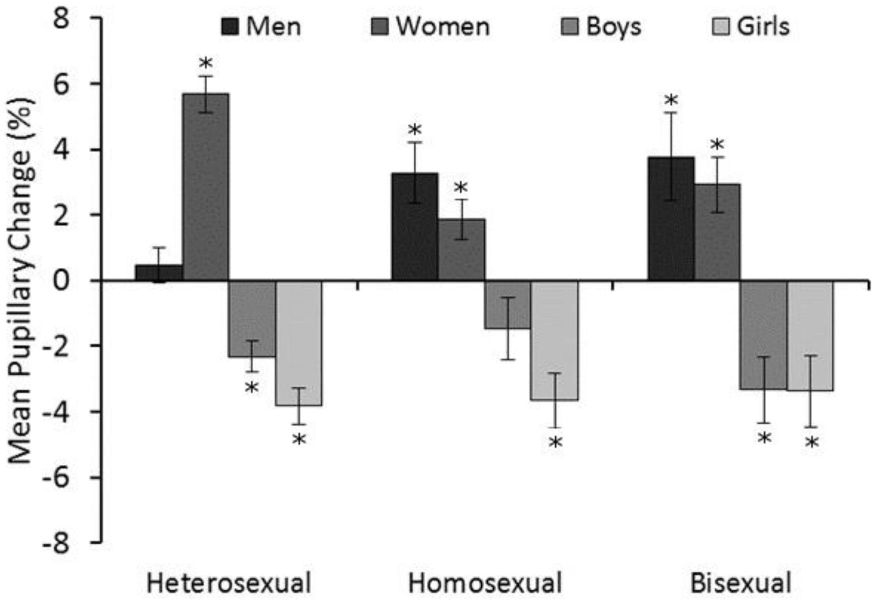

Figure 3.4 Mean percentage pupillary change (no change = 0; increase > 0; decrease < 0) for the stimulus categories in Experiment 4 for hetero-, homo-, and bisexual observers. Vertical lines represent standard errors of means. *Note.* Asterisk represents p < 0.0125 in the one sample t-tests (*alpha* corrected for multiple comparisons)

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

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

In summary, this analysis therefore shows that observers' pupillary responses are largely consistent with their age and sex preferences. This effect was such that heterosexual men's pupils dilate to adult females but constrict to young boys and girls. In contrast, homosexual and bisexual men's pupils dilate to both adult sexes, but show either a constriction or no change when viewing children.

Sexual appeal ratings

Observers' sexual appeal of the persons depicted in the scenes are summarized in Table 3.1. These judgements converge with observers' self-reported age and sex preferences, whereby children scored the lowest ratings from all groups (with a range of 1.00 to 1.22) and the *preferred* adults for each group of observers received the highest ratings (with a range of 3.86 to 5.67). The mean sexual appeal ratings were analysed first with a 4 (category: men, women, boys, girls) x 3 (sexual orientation: hetero-, homo-, bisexual) mixed-factor ANOVA. This analysis did not find a main effect of sexual orientation, $F(2, 93) = 1.98$, $p = 0.14$, partial $\eta^2 = 0.04$, but revealed a main effect of category, $F(3, 279) = 336.50$, $p < 0.001$, partial $\eta^2 = 0.78$, and an interaction, $F(6, 279) = 97.99$, $p < 0.001$, partial $\eta^2 = 0.68$. To analyse this interaction, Bonferroni-adjusted pairwise comparisons of observer groups were performed for each stimulus category. This analysis found that hetero- and bisexual men recorded higher ratings for women than homosexual men, both *p*s < 0.01, and the ratings by heterosexual men were also higher than those of bisexual men for these images, $p < 0.001$. The opposite pattern was found for images of men, whereby homosexual and bisexual men recorded higher ratings than heterosexual men, *p*s < 0.05, and these ratings were also higher in homosexual compared to bisexual men, $p < 0.001$. No differences in sexual appeal ratings were found for images of boys and girls, all $ps \geq 0.79$.

	Heterosexual	Homosexual	Bisexual
Natural Scenes			
Men	1.81(1.08)	5.11(1.17)	3.86(1.29)
Women	5.67(0.70)	2.23(1.35)	4.97(1.19)
Boys	1.14(0.60)	1.19(0.63)	1.00(0.00)
Girls	1.22(0.61)	1.20(081)	1.04(0.11)

Note. Standard deviations are in parentheses.

Table 3.1 Participants' Mean Sexual Appeal Ratings for Persons in Natural Beach Scenes for Hetero-, Homo- and Bisexual Observers in Experiment 4.

We next performed a correlation between pupil size and sexual appeal ratings. This analysis was performed separately for hetero-, homo- and bisexual males, but the responses for the person categories (men, women, boys, girls) were combined and correlate with mean percentage pupillary change scores (see Figure 3.5). The distribution of observers' responses for the sexual appeal ratings was skewed therefore non-parametric Spearman's correlations are reported. This analysis showed a positive correlation between pupil change and sexual appeal ratings for heterosexual, $r_s(226) = 0.60$, $p < 0.001$, homosexual, $r_s(78) = 0.56$, $p < 0.001$, and bisexual observers, $r_s(74) = 0.53$, $p < 0.001$.

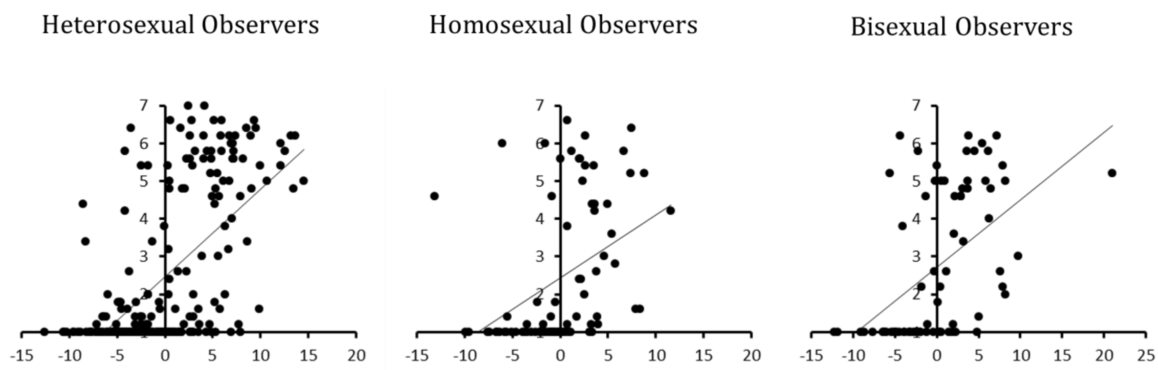

Figure 3.5 Correlations between the mean pupillary change (%) (on x-axis) and the sexual appeal ratings (on y-axis) for hetero-, homo- and bisexual male observers in Experiment 4.

Discussion

Observers' viewing patterns in Experiment 4 replicated those found in Experiment 3, whereby over half of all fixations were directed at the person content in the scenes, and this was higher for the sexually preferred person categories. Additionally, sexually preferred adult stimuli received more fixations on the body than the head, whereas the reverse pattern was found for scenes depicting children.

The pupillary responses that were obtained during the evaluation of the sexual appeal of these persons were also similar to those obtained in the free-viewing task in Experiment 3. Thus, the pupils of heterosexual males dilated to images of women, but not men, and a reduction in pupil size to scenes with boys and girls was found. In this experiment, homosexual males' pupils responded similarly to bisexual males such that dilation was recorded for both men and women. However, for both groups, pupil constriction or no change to scenes with boys and girls. In addition, these pupillary responses correlated positively with observers' sexual appeal ratings. These findings therefore provide further evidence that pupillary responses provide an index that reflects the age-specific sexual interests of hetero-, homo- and bisexual men.

EXPERIMENT 5: Sexual appeal ratings to Tanner stimuli

The preceding experiments found distinct pupillary response patterns when observers viewed photographs of people of different age groups, which consisted of children with a perceived age of ~5 years and adults of approximately ~25 years of age (see Materials section in Experiment 3). However, questions remain about the age sensitivity of these pupillary responses that cannot be addressed from such different age groups. To investigate this further, Experiment 4 depicted people at five stages of sexual maturity, defined by Tanner's categorization (Tanner, 1978). While these stages range from infancy to adult, they are not defined by specific age groups but by the developmental sexual characteristics of the depicted persons. Similar to Experiment 4, participants were asked to rate these persons according to their sexual appeal, which should produce a graded response with higher appeal ratings with increasing age (among non-paedophilic participants). The primary aim was to determine whether pupil sizes during the rating of these persons produce a similar response pattern.

Method

This experiment employed the same eye-tracking method and procedure as Experiment 4, except that the scene stimuli were replaced with images from the Not Real People (NRP) picture set (Pacific Psychological Association Corporation, 2004). These images depicted male and female persons at the five different Tanner stages of sexual development (see Tanner, 1978). Tanner stage I corresponds to prepubescent infants, II corresponds to onset of puberty, and III represent intermediate pubertal stages, Tanner stage IV corresponds to post-pubescent adolescence, and Tanner V represent early adulthood (Dombert et al., 2013). A total of 40 images were used, comprising four males and four females at each Tanner stage. The persons in these stimuli were similar in size, depicted people in undergarments similar to swimwear and poses that were not sexually explicit. In contrast to the natural beach scenes used in Experiments 1-4, these targets are computer generated images and are controlled for size and composition. Stimuli were displayed in the centre of a uniform grey background subtending approximately 20.7 degrees of visual angle vertically and 14.3 degrees horizontally at a viewing distance of 60cm. Example of stimuli are illustrated in Figure 3.6. Similar to Experiment 4, participants were instructed to rate the sexual appeal of these persons on a 7-point Likert scale.

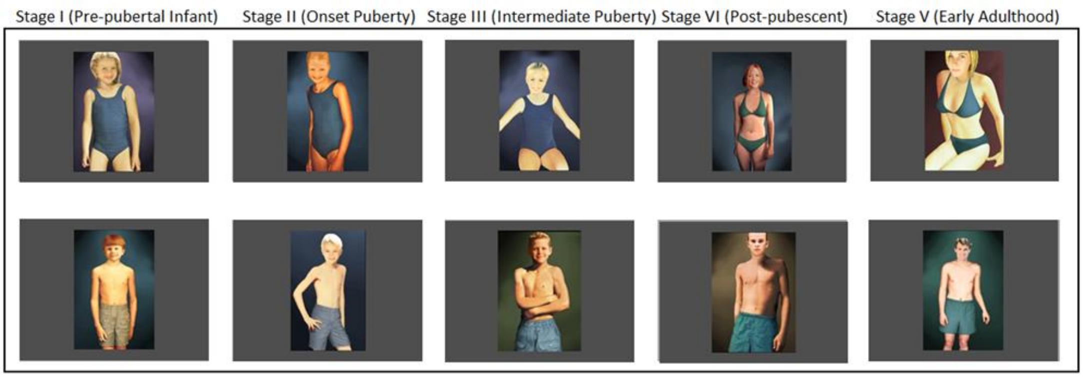

Figure 3.6 An example of the Not Real People (NRP) stimuli illustrating all five Tanner stages in Experiment 5.

Results

Viewing behaviour

Eye movements were processed as in the preceding experiments. We then analysed the mean percentage fixations to the head, body and image background of the persons in the different sex categories (male and female figures) and Tanner stages (I to V). As can be seen in Figure 3.7, 97% of fixations (range = 93% to 99%) were directed at the people in the stimulus displays. A 2 (category: male, female) x 3 (ROI: head, body, background) x 5 (Tanner stage: I, II, III, IV, V) x 2 (sexual orientation: hetero-, homo-, bisexual) mixed-factor ANOVA found three-way interactions for category and Tanner stage with ROI, $F(8, 744) = 8.23$, $p < 0.001$, partial $\eta^2 = 0.08$, and with sexual orientation, $F(8, 372) = 2.00$, $p < 0.05$, partial $\eta^2 = 0.04$. Interactions for sexual orientation and ROI with category, $F(4, 186) = 2.71$, $p < 0.05$, partial $\eta^2 = 0.06$, and with Tanner stage, $F(16, 744) = 1.67$, $p < 0.05$, partial $\eta^2 = 0.04$, were also found. To analyses this data further, fixations to male and female persons are considered separately.

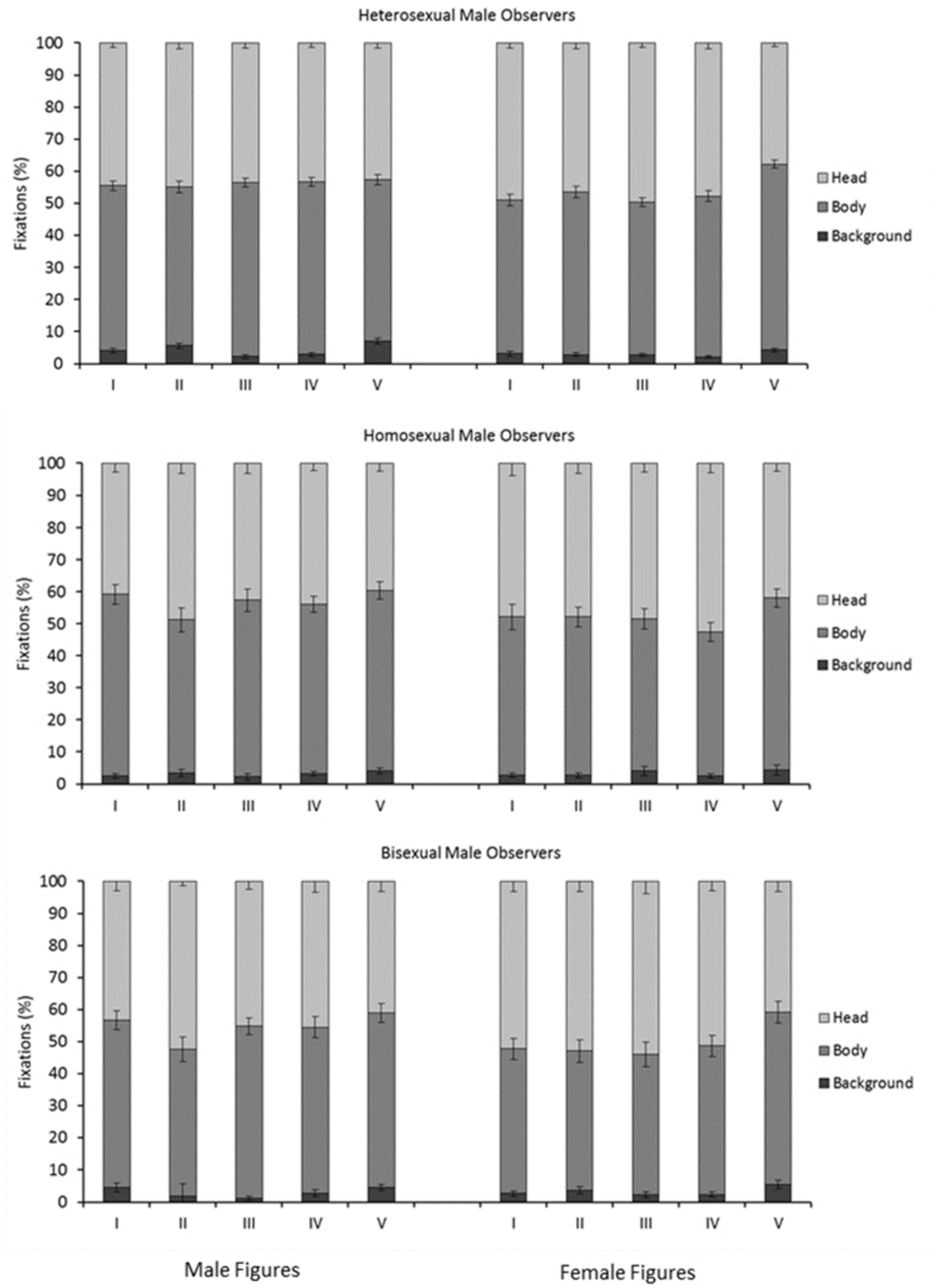

Figure 3.7 Mean percentage fixations to the heads and bodies of the target persons and the scene backgrounds for hetero-, homo- and bisexual male observers in Experiment 5, as a function of Tanner category. Vertical lines represent standard errors of means.

Female persons: Three 3 (ROI: head, body, background) x 5 (Tanner stage I, II, III, IV, V) within-subjects ANOVAs were performed to analyse the percentage fixations to female targets separately for hetero-, homo- and bisexual observers. For heterosexual males, the analysis did not show a main effect of Tanner stage, $F(4, 224) = 1.42$, $p = 0.23$, partial $\eta^2 = 0.025$, but revealed a main effect of ROI, $F(2, 112) = 480.96$, $p < 0.001$, partial $\eta^2 = 0.90$, and an interaction between these factors, $F(8, 448) = 14.35$, $p < 0.001$, partial $\eta^2 = 0.21$. Bonferroni-adjusted pairwise comparisons for each ROI were performed to explore this interaction. These comparisons show that fewer fixations landed on the head region of Tanner V females (38%) than all other Tanner categories (47% to 50%), all *p*s ≤ 0.001. In addition, more fixations were directed at the body region of Tanner V females (58%) than the bodies of Tanner I-IV females (48% to 51%), all *p*s ≤ 0.001. Finally, more fixations also landed on the background of images depicting Tanner V females (4%) than Tanner IV females (2%), $p < 0.001$. No other differences were found, all *p*s ≥ 0.23.

For homosexual males, the same analysis did not show a main effect of Tanner stage, $F(4, 76) = 1.14$, $p = 0.34$, partial $\eta^2 = 0.06$, but also revealed a main effect of ROI, $F(2, 38) = 93.19$, $p < 0.001$, partial $\eta^2 = 0.83$, and an interaction between factors, $F(8, 152) = 3.10$, $p < 0.01$, partial $\eta^2 = 0.14$. Pairwise comparisons show that fewer fixations landed on the head region of Tanner V females (42%) than Tanner IV females (53%), $p < 0.05$, and more fixations landed on the bodies of Tanner V females (54%) than Tanner IV females (45%), $p < 0.01$. No other differences were significant, all *p*s ≥ 0.24.

Finally, bisexual males also did not show a main effect of Tanner stage, $F(4, 72) = 1.03$, $p = 0.40$, partial $\eta^2 = 0.05$, but main effect of ROI, $F(2, 36) = 80.06$,

$p < 0.001$, partial $\eta^2 = 0.82$, and an interaction of both factors, $F(8, 144) = 5.31$, $p < 0.001$, partial $\eta^2 = 0.23$. Pairwise comparisons show that fewer fixations were directed at the heads of Tanner V females (41%) than all other Tanner categories (51% to 54%), all $ps < 0.05$. By contrast, the body of Tanner V females received more fixations (54%) than Tanner III females (44%), $p < 0.05$. No other differences were found, all $ps \geq 0.07$.

Overall, these fixation patterns indicate a preference for adult women, whereby hetero-, homo- and bisexual males fixated the bodies of adult women more frequently than the bodies of prepubescent and adolescent females.

Male persons. A second set of 3 (ROI: head, body, background) x 5 (Tanner stage I, II, III, IV, V) within-subjects ANOVAs was performed for the male stimuli. For heterosexual men, this analysis revealed a main effect of Tanner Stage, $F(4, 224) = 2.71$, $p < 0.05$, partial $\eta^2 =0.05$, and ROI, $F(2, 12) = 491.59$, $p < 0.001$, partial $\eta^2 = 0.90$, and an interaction between factors, $F(8, 448) = 2.80$, $p < 0.01$, partial $\eta^2 = 0.05$. Bonferroni-adjusted pairwise comparisons were performed to explore this interaction further. This revealed that these observers directed more fixations at the background of images depicting Tanner V (7%) and Tanner II (6%) males than images with Tanner III (2%) and IV (3%) males, all $ps < 0.05$. More fixations also landed on the background of Tanner I (4%) than Tanner III (2%) males, $p < 0.05$. No other differences were detected, all $ps \geq 0.15$.

The corresponding analysis for homosexual men did not reveal a main effect of Tanner stage, $F(4, 76) = 0.63$, $p = 0.64$, partial $\eta^2 = 0.03$, but showed an effect of ROI, $F(2, 38) = 101.26$, $p < 0.001$, partial $\eta^2 = 0.84$, and an interaction between factors, $F(8, 152) = 4.68$, $p < 0.001$, partial $\eta^2 = 37.47$. Bonferroni-adjusted pairwise comparisons show that the head region of Tanner V males

(37%) received fewer fixations than the corresponding region in Tanner II males (49%), which in turn received more fixations than Tanner I males (41%), both *p*s < 0.05. In addition, these observers directed more fixations to the bodies of Tanner V males (56%) than Tanner II males (48%), $p < 0.05$. However, more fixations also landed on the body region of Tanner I males (56%) than Tanner II males, $p = 0.05$. No other differences were found, all *p*s ≥ 0.14

Bisexual men also showed a main effect of Tanner stage $F(4, 72) = 6.43$, $p < 0.001$, partial $\eta^2 = 0.26$, and ROI, $F(2, 36) = 96.11$, $p < 0.001$, partial $\eta^2 = 0.17$, and an interaction between factors, $F(8, 114) = 3.79$, $p < 0.001$, partial $\eta^2 = 0.17$. Pairwise comparisons show that more fixations were directed at the head region of Tanner II (52%) than Tanner I males (43%), $p < 0.01$. No other differences reached significance, all *p*s ≥ 0.06.

In summary, no clear viewing preference was found for hetero-, and bisexual males for male targets at different stages. Homosexual males directed more fixations to the bodies of adult men than males at onset of puberty (Tanner II), however these did not differ from fixations to bodies of prepubescent males (Tanner I) and males in intermediate puberty and post-pubescent stages (Tanner III and IV).

Pupillary responses

Once again, the data of main interest were observers' pupillary responses. This data is illustrated in Figure 3.8. A 3 (sexual orientation: hetero-, homo- and bisexual) x 2 (target sex: male, female) x 5 (Tanner stage: I, II, III, IV, V) mixed-factor ANOVA revealed a main effect of target sex, $F(1, 95) = 28.11$, $p < 0.001$, partial $\eta^2 = 0.23$, and Tanner stage, $F(4, 380) = 3.94$, $p < 0.01$, partial $\eta^2 =$

0.04, but not of sexual orientation, $F(2, 95) = 0.66$, $p = 0.52$, partial $\eta^2 = 0.01$. The interaction between Tanner stage and sex orientation was not significant, $F(8, 380) = 0.79$, $p = 0.62$, partial $\eta^2 = 0.02$. However, interactions of target sex and sexual orientation, $F(2, 95) = 23.92$, $p < 0.001$, partial $\eta^2 = 0.34$, and target sex and age, $F(4, 380) = 18.67$, $p < 0.001$, partial $\eta^2 = 0.16$, and a three-way interaction were found, $F(8, 380) = 2.53$, $p < 0.05$, partial $\eta^2 = 0.05$.

To explore the three-way interaction, Bonferroni-adjusted pairwise comparisons were performed comparing sexual orientation for all stimulus categories. This analysis showed that during the viewing of Tanner IV males, the pupils of bisexual males did not differ from those of homosexual, $p = 0.80$, and heterosexual males, $p = 0.18$. Additionally, for Tanner IV males the pupils of homosexual males were larger than those of heterosexual males, $p < 0.01$. During the viewing of Tanner V males, the pupils of bisexual and homosexual males did not differ, $p = 0.20$, but were both larger than those of heterosexual males, $ps < 0.01$. No differences were found for Tanner I, II and III males, all $ps \geq 0.21$.

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

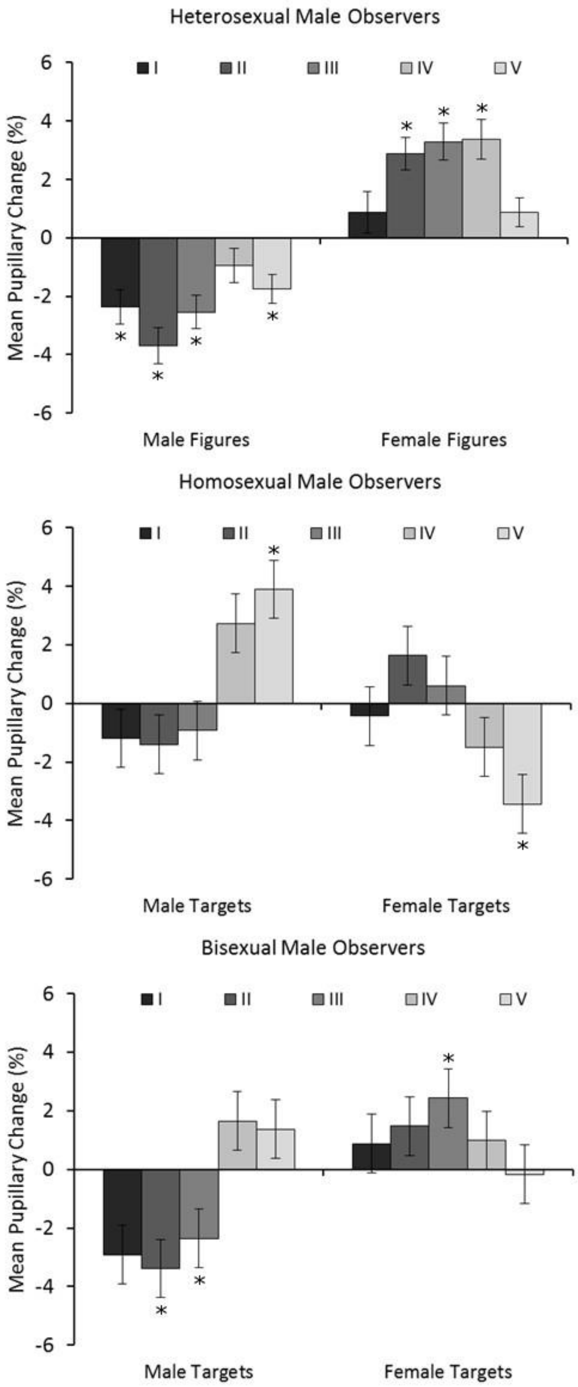

Figure 3.8 Mean percentage pupillary change (no change = 0; increase > 0; decrease < 0) for hetero-, homo-, and bisexual observers in Experiment 5, as a function of Tanner category. Vertical lines represent standard errors of means. *Note.* Asterisk represents $p < 0.005$ in the one sample t-tests (*alpha* corrected for multiple comparisons)

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

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

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

Sexual Appeal Ratings

The mean sexual appeal ratings for each stimulus category are summarized in Table 3.2. These ratings appear consistent with observers' self-reported age and sex preferences. Heterosexual males, for example, rated female stimuli as most sexually appealing and these ratings increased across the Tanner stages (i.e., from I to V). Homosexual males displayed the reverse pattern, with highest ratings for adult males, and bisexual males found adults of both most sexes particularly appealing.

To analyse these observations, a 2 (category: males, females) x 3 (sexual orientation: hetero-, homo-, bisexual) x 5 (Tanner stage: I, II, III, IV, V) mixed-factor ANOVA was conducted, which revealed an interaction between all three factors, $F(8, 372) = 52.78$, $p < 0.001$, partial $\eta^2 = 0.53$. To analyse this interaction, Bonferroni-adjusted pairwise comparisons of observer groups were performed for each stimulus category and Tanner stage. For Tanner IV and V females, this analysis found that ratings of heterosexual and bisexual men did not differ, *ps* ≥ 0.22, but were both higher than those recorded by homosexual men, *ps* < 0.001. No differences were found for Tanner I, II and II females, all *ps* ≥ 0.18. For Tanner IV and V males, ratings of homosexual and bisexual men did not differ, all *ps* ≥ 0.43, and were higher than those recorded by heterosexual men, *ps* < 0.001. Homosexual men also recorded higher ratings for Tanner I and III males than heterosexual men, both *ps* < 0.05, but not bisexual men, both *ps* ≥ 0.26. No differences were found for Tanner II males, all *ps* ≥ 0.08.

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

Note. Standard deviations are in parentheses.

Table 3.2 Participants' Mean Sexual Appeal Ratings for Persons in Not Real People Scenes (Tanner Stages I-V) for Hetero-, Homo- and Bisexual Observers in Experiment 5.

The relationship between personal sexual appeal judgements and pupil responses to the depicted persons was examined next (see Figure 3.9). For this analysis, sexual appeal ratings and pupillometry data was combined across the Tanner categories. Spearman's correlational analysis revealed a positive relationship between these measures for heterosexual, $r_s(568) = 0.24$, $p < 0.001$, homosexual, $r_s(198) = 0.26$, $p < 0.001$, and bisexual men, $r_s(188) = 0.27$, $p < 0.001$. This suggests that pupillary response relate to the sexual appeal that the stimuli hold for observers.

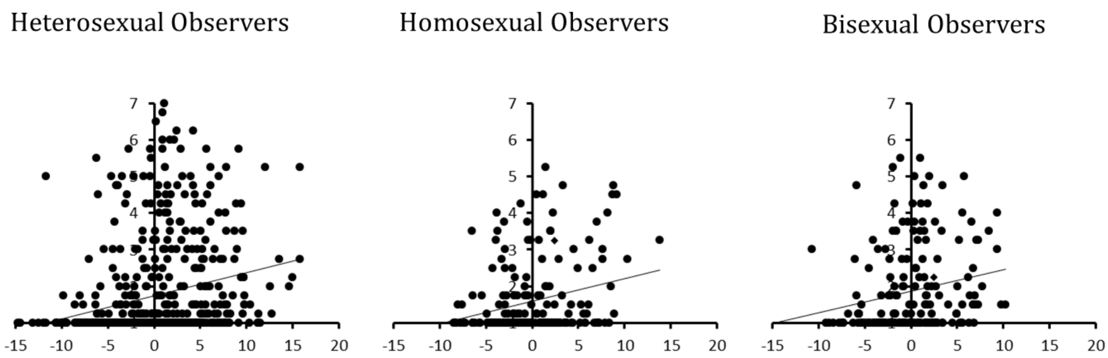

Figure 3.9 Correlations between the mean pupillary change (%) (on x-axis) and the sexual appeal ratings (on y-axis) for hetero-, homo- and bisexual male observers in Experiment 5.

Discussion

This experiment compared the eye movements and pupillary responses of hetero-, homo-, and bisexual men to images of males and females at five different stages of sexual development (Tanner, 1978). Eye movements showed that the pattern of fixations to specific body regions corresponded with observers' sexual age preferences. Heterosexual males, for example, directed more fixations at the bodies of adult females compared to younger females

(Tanner I to IV), for which more fixations were directed towards the head. However, these differences were not consistent. For example, although homosexual males directed more fixations to the bodies of adult men than males at onset of puberty (Tanner II), these did not differentiate from fixations to bodies of prepubescent males (Tanner I) and males in intermediate puberty and post-pubescent stages (Tanner III and IV).

For pupillary responses, homosexual men showed the dilation responses that were most consistent with their sex-preferences. In these observers, images of post-pubescent adolescent and adult males (Tanner IV and V) provoked reliable dilation effects, whereas depictions of younger males evoked no change in pupil size. By contrast, a decrease in pupil size was obtained for female adults (Tanner V) and no change from baseline for the younger female categories (Tanner I to IV). Heterosexual male observers also showed a pupil dilation pattern that corresponded to their sex preferences, such that their pupils dilated during the viewing of female models and constricted to males. Within the female category, the largest increase in pupil size was detected for images of post-pubescent adolescents (Tanner IV). Surprisingly, however, images of pubescent females also dilated observers' pupils, but pictures of adult women (Tanner V) did not. Finally, the bisexual group showed a constriction in pupil size to prepubescent males (Tanner I-III) and a dilation response emerged for adolescent and adult males (Tanner IV and V), which is generally consistent with these observers' interest in men. However, these dilation effects for adolescents and adults did not reach significance when compared to the baseline. For female figures, the pattern was less clear, with only Tanner III eliciting a reliable change (dilation) from baseline.

Overall, the pupillary responses therefore show a clear pattern for homosexual men, whereas these responses suggest more interest in younger females than was expected in heterosexual and bisexual males, and are generally least clear for the latter group. Two aspects might underlie this pattern of effects. Firstly, the pupillary responses of all observers indicate some interest in pubertal (Tanner III) or post-pubescent (Tanner IV) targets. Considering the average age of this sample (mean ~ 22 years), it is possible that these adolescent targets were still within the age range that is of sexual interest to these observers. In one study, 20-year old men reported that they would pursue a relationship with women aged 18 to 32 years. In contrast, men aged 30 reported interest in women of at least 22 years of age, and this minimum age was higher still for 40, 50 and 60 year old men (Buunk et al., 2001). This explanation would converge with previous reports that male student participants favour the adolescent and adult females in this stimulus set (Mokros et al., 2011). In line with these observations, we also note that adults and adolescents were rated as most sexually appealing in the current study, and these ratings generally correlated with observers' pupillary responses.

Secondly, although the pattern of pupillary responses in this experiment appears to correspond with self-reported sex preference and interest in adults, adult females (Tanner V) did not elicit a strong dilation response in both heterosexual and bisexual observers. The reason for this is unclear. It is notable, however, that sexual appeal ratings for adult females (and males) were somewhat low. Heterosexual males, for example, rated the sexual appeal of Tanner V females at 4.45/7 (with a range of 1.8 to 6.8), and these scores were lower still, at 3.91/7 (with a range of 1.8 to 5.5), in bisexual observers. These low ratings might reflect the age and composition of the NRP stimulus set. Each image in this set was constructed by combining the face and body parts of several persons, and features such as hair and eyes, pose and clothing were modified with graphics software (Laws & Gress, 2004). These modifications might have given these stimuli an unnatural appearance that might interfere with sexual interest responses.

To address these concerns and evaluate further when pupillary responses reflect sexual interest in our observers, a final experiment was conducted. The stimuli in this study depicted only adult males and females, and therefore cannot speak to the age-specificity of these effects. However, in contrast to the preceding experiments, these stimuli are highly controlled by eliminating extraneous information such as scene background (c.f. Experiment 3 and 4), and provided more carefully controlled pictures of males and females.

EXPERIMENT 6: Sexual appeal ratings to Morph stimuli

Previous research shows that lower levels of attractiveness in images of males and females can produce reduced sexual interest scores in measures, such as response times (Lippa, 2012). In the current study, Experiment 5 did not find a clear dilation pattern for adult female targets, so it is possible that attractiveness of the targets could have influenced such responses, too. It is also conceivable that the results of Experiments 5 were caused partially by other stimulus aspects, such as the combination of heads and bodies from different people. In a final experiment, pupillary responses were therefore compared for carefully controlled images of attractive adult men and women (see Ó Ciardha & Gormley, 2012). In contrast to the preceding experiments, these images also eliminated extraneous background (c.f. Experiment 3 and 4) and were highly similar in composition, posture and facial expression. While these stimuli did not depict children and adolescents, and could therefore not be used to assess the age effects that are of most interest here, the aim was to clarify the sex specificity in the pupillary responses of the current sample of observers.

Method

The eye-tracking set up and procedure were identical to Experiments 3 and 4, except from the following changes. In Experiment 6, a total of 36 computer-generated stimuli comprising 18 adult men and 18 adult women were used (see Ó Ciardha & Gormley, 2012). All of these persons were depicted in black undergarments, similar frontal poses, and similar facial expression (see Figure 3.10). Similar to Experiment 5, these targets are computer generated images and are controlled for size and composition. The targets were displayed in the centre of a uniform grey background subtending approximately 16.9 degrees of visual angle vertically and 10.6 degrees horizontally at a viewing distance of 60cm. In the main experiment, participants were asked to rate the sexual appeal of these persons on a 7-point Likert scales while their eye movements and pupillary responses were recorded.

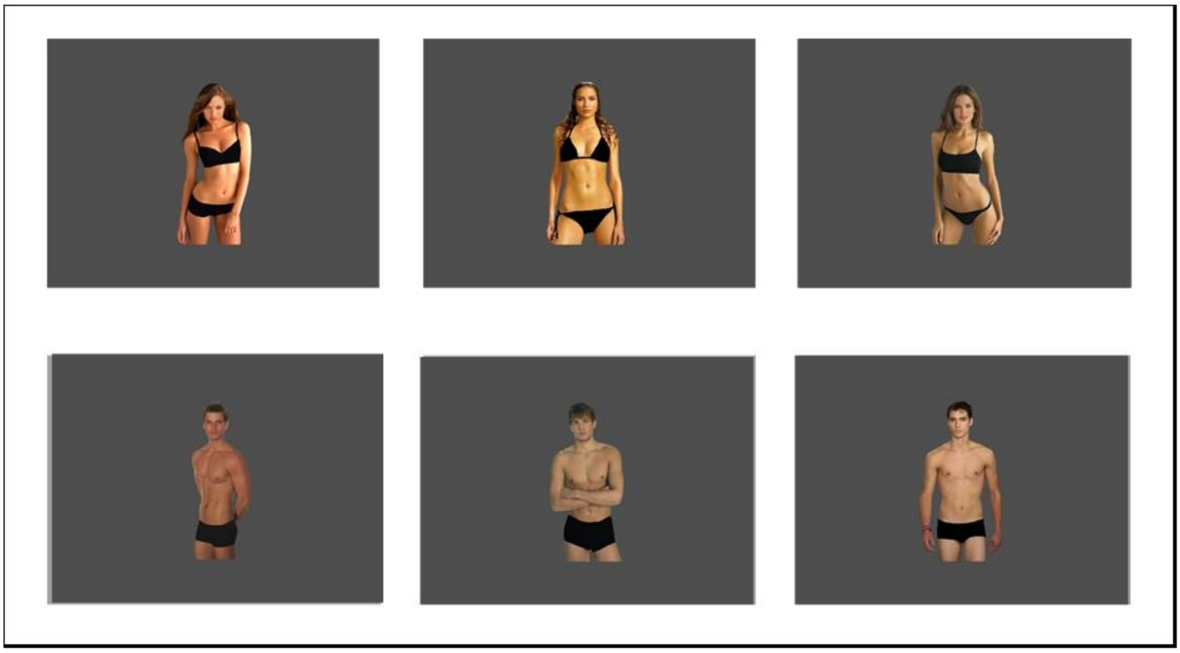

Figure 3.10 An example of the Morph stimuli in Experiment 6.

Results

Viewing behaviour

We examined the viewing patterns that the persons in the scenes elicited in hetero-, homo- and bisexual male observers by calculating the percentage fixations to the face, body and background ROIs for both stimulus categories (men and women; see Figure 3.11). Overall, 96% of fixations landed on the person content in the scenes. A 2 (category: male, female) x 3 (ROI: head, body, background) x 2 (sexual orientation: hetero-, homo-, bisexual) mixed-factor ANOVA was performed first and revealed a three-way interaction, $F(4, 186) = 4.28$, $p < 0.05$, partial $\eta^2 = 0.08$. To explore this interaction, three 2 (category: men, women) x 3 (ROI: head, body, background) within-subjects ANOVAs were performed separately for the three observer groups.

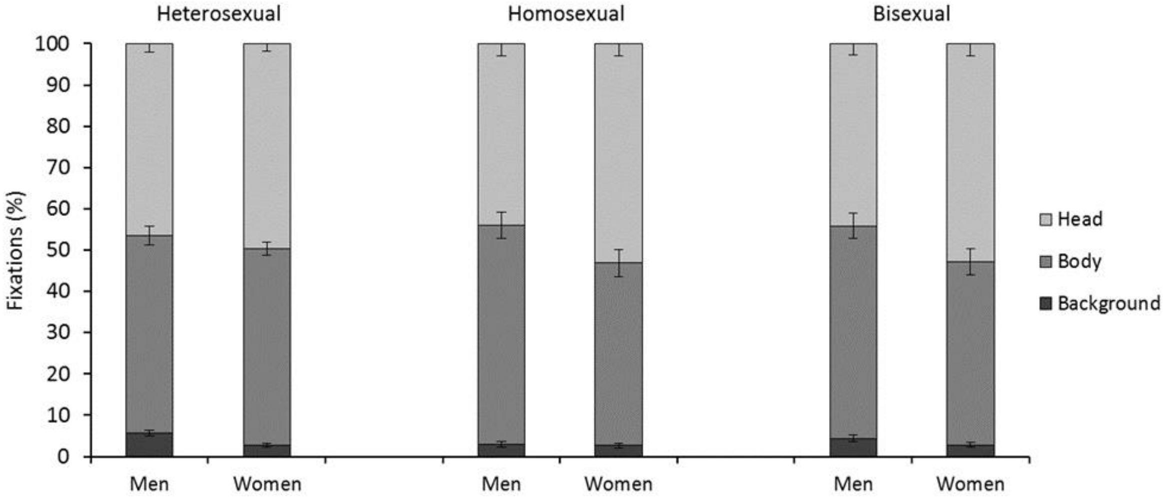

Figure 3.11 Mean percentage fixations to the heads and bodies of the target persons and the scene backgrounds for hetero-, homo- and bisexual male observers in Experiment 6. Vertical lines represent standard errors of means.

For heterosexual men, a main effect of category, $F(1, 56) = 1.02$, $p = 0.32$, partial $\eta^2 = 0.02$, and an interaction were not found, $F(2, 112) = 2.71$, $p = 0.07$, partial $\eta^2 = 0.05$, but a main effect of ROI, $F(2, 112) = 211.02$, $p < 0.001$, partial $\eta^2 = 0.79$, as more fixations were directed to the head and body than the background, all ps < 0.001. No other differences were significant, all ps = 1.00.

For homosexual observers, the analysis did not reveal a main effect of category, $F(1, 19) = 3.04$, $p = 0.10$, partial $\eta^2 = 0.14$, but showed a main effect of ROI, $F(2, 38) = 78.02$, $p < 0.001$, partial $\eta^2 = 0.80$, and an interaction between the two, $F(2, 38) = 42.85$, $p < 0.001$, partial $\eta^2 = 0.69$. Bonferroni adjusted pairwise comparisons revealed that homosexual men directed more fixations at the bodies of men (53%) than women (44%), whereas the reverse effect was observed for the head regions (53% vs. 44 %), all ps < 0.001. No other differences were found, all ps ≥ 0.45.

The analysis for the bisexual observers also did not reveal a main effect of category, $F(1, 18) = 2.20$, $p = 0.16$, partial $\eta^2 = 0.11$, but showed an effect of ROI, $F(2, 36) = 76.51$, $p < 0.001$, partial $\eta^2 = 0.81$, and an interaction, $F(2, 36) = 34.87$, $p < 0.001$, partial $\eta^2 = 0.66$. More fixations were directed towards the bodies of men (51%) than those of women (44%), and more fixations to the heads of women (53%) than those of in men (44%), all *p*s < 0.001. No other differences were found, all *p*s ≥ 0.65.

Pupillary responses

As in the previous experiments, the mean pupillary responses were transformed to mean percentage change (see Figure 3.12). In contrast to all of the preceding experiments, in which this measure incorporated data from adolescent (Experiment 5), child (Experiments 3-5), and no person stimuli (Experiment 3), this measure was now based only on pupillary responses to pictures of adult men and women. As in the preceding experiments, this analysis should therefore reveal pupil dilation (i.e., a score above 0) for stimuli of the preferred sex in hetero- and homosexual observers, and the reverse effect to non-preferred sex images. By contrast, bisexual men should not show a difference for pictures of men and women (as both are combined to provide the baseline data; see Data Preparation of Experiment 3).

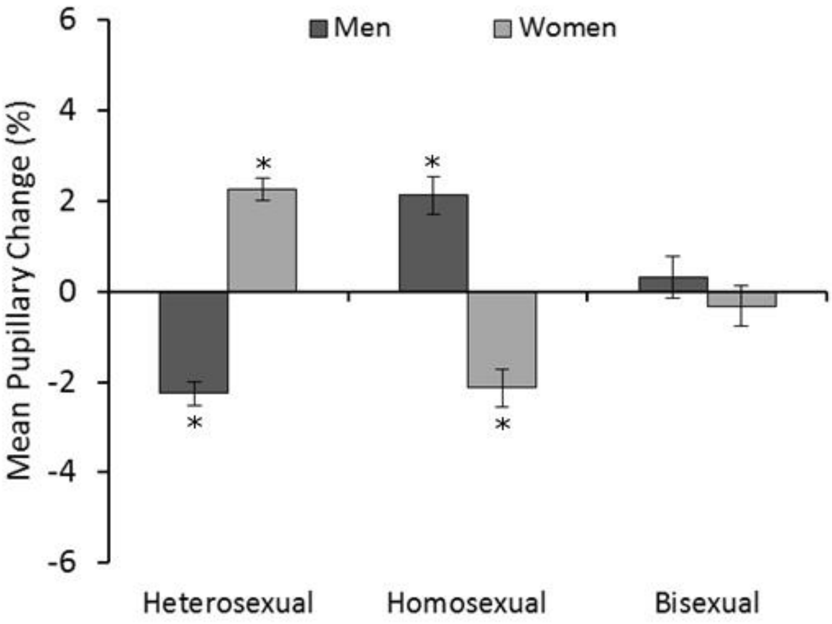

Figure 3.12 Mean percentage pupillary change (no change = 0; increase > 0; decrease < 0) for the stimulus categories in Experiment 6 for hetero-, homo-, and bisexual observers. Vertical lines represent standard errors of means. *Note.* Asterisk represents $p < 0.05$ in the one sample t-tests.

In line with these predictions, a 2 (category: male, female) x 3 (sexual orientation: hetero-, homo- and bisexual) mixed-factor ANOVA did not find a main effect of category, $F(1, 93) = 0.15$, $p = 0.70$, partial $\eta^2 = 0.00$, and sexual orientation, $F(2, 93) = 0.001$, $p = 1.00$, partial $\eta^2 = 0.00$, but revealed an interaction between these factors, $F(2, 93) = 45.97$, $p < 0.001$, partial $\eta^2 = 0.50$. To explore this interaction, Bonferroni-adjusted pairwise comparisons contrasted the sexual orientation groups in each stimulus category. This analysis shows that during the viewing of men, the pupil change from baseline was greater in homosexual men than in heterosexual and bisexual men, both $ps < 0.001$. However, the pupils of bisexual men were also larger than those of heterosexual men when viewing these stimuli, $p < 0.05$. The opposite effect was found during the viewing of women, such that the pupils of heterosexual men were larger than those of homosexual and bisexual men, both *p*s < 0.001 and those of bisexual men were larger than those of homosexual men, $p < 0.05$. This pattern is therefore consistent with observer's self-reported sexual preferences.

These responses were also analysed with one-sample t-tests, by comparing the change in pupil size for each stimulus category with a baseline of zero (see Data Preparation for Experiment 1). The analysis showed that the pupils of heterosexual men were enlarged during the viewing of women, $t(56) = 8.66$, $p < 0.001$, and reduced for men, $t(56) = -8.66$, $p < 0.001$. In contrast, pupils of homosexual males dilated for images of men, $t(19) = 6.24$, $p < 0.001$, but not women, $t(19) = -6.24$, $p < 0.001$. Finally, bisexual observers did not show a difference from baseline (men + women) for both stimulus categories, both $ts(18) \leq 0.95$, $ps \geq 0.36$. This confirms that these pupil responses reflect observers' specific sexual interest, whereby these were larger for sexually preferred than non-preferred categories.

Sexual appeal ratings

A summary of the mean sexual appeal ratings are presented in Table 3.4. These ratings show a pattern that is consistent with observers' self-reported sexual preferences. Thus, heterosexual male observers rated women as more appealing than men, homosexual males produced the reverse pattern, and bisexual males produced similar ratings for both categories. A 2 (category: male, female) x 3 (sexual orientation: hetero-, homo-, bisexual) mixed-factor ANOVA of this data showed a main effect of sexual orientation, $F(2, 93) = 9.85$, $p < 0.001$, partial $\eta^2 = 0.18$, and category, $F(1, 93) = 14.61$, $p < 0.001$, partial $\eta^2 = 0.14$, and an interaction, $F(2, 93) = 142.45$, $p < 0.001$, partial $\eta^2 = 0.75$. To analyse this interaction, Bonferroni-adjusted pairwise comparisons of observer groups were performed for each stimulus category. For images of women, this analysis found that ratings of hetero- and bisexual men did not differ, $p = 0.09$, but were higher than those recorded by homosexual men, both $ps < 0.001$. For images of men, homo- and bisexual men recorded higher ratings than heterosexual men, $ps < 0.05$. These ratings were also higher in homosexual compared to bisexual men, $p = 0.05$.

	Heterosexual	Homosexual	Bisexual
Morphs			
Men	1.66(1.04)	4.60(2.08)	4.02(1.39)
Women	5.63(0.80)	1.10(1.43)	4.98(1.50)

Note. Standard deviations are in parentheses.

Table 3.4 Participants' Mean Sexual Appeal Ratings for Persons in Morphs for Hetero-, Homo- and Bisexual Observers in Experiment 6

Non-parametric Spearman's correlations were performed next to explore the relationship between change in pupil response and these sexual appeal ratings (see Figure 3.13). This analysis showed a strong positive relationship for heterosexual, $r_S(112) = 0.75$, $p < 0.001$ and homosexual males, $r_S(38) = 0.62$, $p < 0.001$. For bisexual males, this correlation was not significant, $r_S(36) = 0.29$, $p = 0.08$, due to men and women producing similar sexual appeal ratings (see Table 3.11) and pupillary responses (see Figure 3.12).

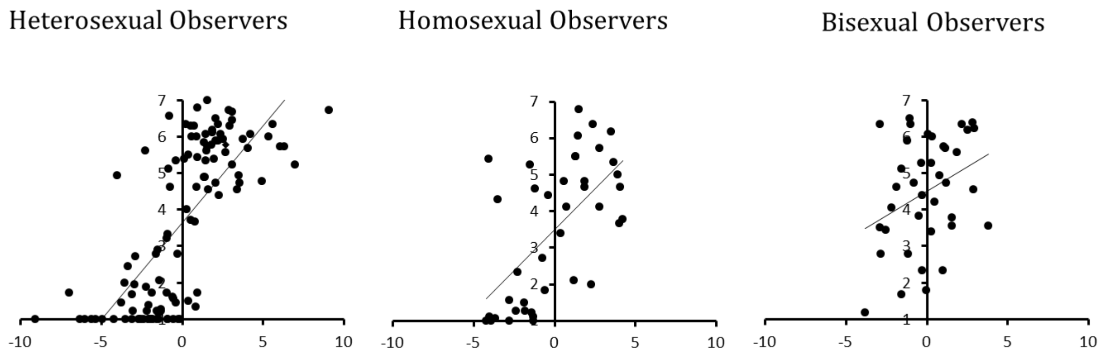

Figure 3.13 Correlations between the mean pupillary change (%) (on x-axis) and the sexual appeal ratings (on y-axis) for hetero-, homo- and bisexual male observers in Experiment 6.

Discussion

In this experiment, viewing behaviour and pupil responses to highly controlled images of adult men and women were compared for each group. The viewing data showed that both homosexual and bisexual males fixated bodies of men more than those of women, whereas heterosexual men did not show a difference between these sex categories. More importantly, observers' pupillary responses clearly reflected their self-reported sexual preferences. Thus, the pupils of heterosexuals were larger than baseline for images of women, the pupils of homosexual men were larger during the viewing of men, and bisexual observers showed no difference in pupillary responses for the two sexes. In line with these observations, strong positive correlations were obtained for sexual appeal ratings and pupil size in the heterosexual and homosexual men. Unsurprisingly, the same correlation was not present for bisexual men, as these observers produced similar sexual appeal ratings and pupillary responses for pictures of men and women.

Overall, this data therefore produces the clearest pattern yet that the pupillary response of the hetero-, homo- and bisexual observers, who took part in all of the four experiments reported here, reflects their sexual interest. In turn, this lends credence to the pattern of effects that was observed in the preceding experiments, which employed less controlled stimuli and contained more age groups.

GENERAL DISCUSSION

This study investigated whether pupillary responses to images of adults and children reflect the sexual interest of hetero-, homo-, and bisexual males. Specifically, this study examines whether this measure corresponds to sexual age preferences (i.e., preference for adults in a non-paedophilic sample). Viewing behaviour was analysed first and showed that the body region generally received more fixations than the head region during the viewing of adults. In contrast, the head region received the most fixations during the viewing of children. This is consistent with previous research, whereby observers with an exclusive sexual interest in adults direct more attention towards sexually relevant areas (i.e., the body), while allocating more attention to the face when viewing children (Hall et al., 2011).

With regards to the measure of main interest, pupillary responses to pictures of adolescents and adults (i.e., Tanner IV and V) generally corresponded to observers' sexual orientation. In all four experiments, the pupils of heterosexual men dilated during the viewing of women but not men, although this effect was only reliable for Tanner IV females, but not Tanner V, in Experiment 5. Similarly, homosexual observers consistently showed pupil dilation to images of men across all experiments. For bisexual men, pupil dilation was observed for pictures of women in Experiment 3, and a similar effect was observed for men, though this did not reach significance. In Experiment 4, dilation was observed for men and women. In Experiment 6, neither men nor women produced a change in pupil size from baseline, which, in this particular experiment, also indicates sexual interest in both categories. Overall, these results therefore converge with previous reports that pupillary responses provide an index of sexual interest that correspond with self-reported sexual orientation (Hess et al., 1965; Rieger & Savin-Williams, 2012; Rieger et al., 2015).

However, for bisexual observers the pattern was less clear in Experiment 5, which revealed no clear dilation for male and female adults. In the sex literature, there is conflicting evidence regarding the response patterns of bisexual males. Some viewing time studies have revealed responses in bisexual men that were indistinguishable to images of adult men and women (Ebsworth & Lalumiére, 2012; Lippa, 2013; Rosenthal, Sylva, Safron & Bailey, 2011). Other studies, using measures of genital arousal, have recorded greater arousal for the same or the opposite sex but not both (Rieger et al., 2005). The current studies add to this data to show that bisexual males produce pupillary responses that are generally consistent with their self-reported sexual interest in three of the experiments reported here. However, the same males can also produce a pattern that is more difficult to interpret in this sense, depending on the stimuli and the task demands (i.e., as in Experiment 5).

Of main interest in the current study was the extent to which these pupillary responses also provide an age-specific index of sexual interest. In Experiment 3 and 4, images of children produced either a constriction in pupil size or no change from baseline in all conditions. In the context of dilation effects for adults of sexual interest, this indicates that pupillary responses are age specific, in the sense that these can distinguish interest in adults and very young children (with a perceived age of ~ 5 years, see Materials for Experiment 3). This pattern is consistent with a study that compared paedophilic and non-paedophilic males when viewing images of young girls and adult women (Atwood & Howell, 1971). In that study, non-paedophilic males only dilated to images of women but not to images of girls. This is also in line with Experiments 1 and 2 which compared the responses of non-paedophilic heterosexual males and females to natural images of adults and children, and observed pupil dilation for pictures of adults but not of children. These findings indicate that pupil dilation is not only sensitive to sex but also preferences for distinct age groups.

In addition to these broad age distinctions, we also assessed whether these responses are sensitive to a range of ages. For this purpose, participants were shown images of people at five different stages of sexual development in Experiment 5, which ranged from pre-pubescent infants to adults (Tanner, 1978). In this experiment, a pattern emerged for homosexual males in accordance with their sex preferences and preference for adults. For example, during the viewing of males, the pupils of these observers were smallest for the pre-pubescent infants and pubescent boys (Tanner I, II and III), and increased for images of post-pubescent adolescents and adult males (Tanner IV and V). Furthermore, no dilation was detected when homosexual men viewed images of females, and images comprising adult women elicited a reliable decrease in pupil size.

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

The responses of heterosexual and bisexual males were less clear. Pupil dilation was not elicited by the youngest stimuli, which comprised pre-pubescent infants (Tanner I), in any of the participant groups. These effects therefore converge with the results of Experiment 3 and 4. However, although heterosexual men's pupils dilated for the preferred sex category, the adult women did not elicit the strongest dilation. Instead, dilation was detected for images of pubescent and post-pubescent adolescents (Tanner II, III and IV). Similarly, bisexual men showed a pupil dilation effect for pubescent females (Tanner III), but not for older females. While the reason for this is unclear, we note that we tested a sample of relatively young adults with a mean age of 22 years. In a previous study, 20-year old men reported being sexual interested in women as young as 18 years (Buunk et al., 2001). It is therefore possible that these adolescent targets were still within the age range that is of sexual interest to these observers. Alternatively, these responses might reflect the age and composition of this stimulus set, which is not designed to provide sexually evocative content.

This notion gains some support from the final experiment, which provided images of adult men and women of comparable composition, posture and facial expression. While this experiment did not include pictures of children and adolescents, it showed the clearest pupil dilation pattern here, whereby heterosexual males dilated more when viewing women, homosexual males dilated more to men, and bisexual males did not show a difference in dilation between the two sexes. While only adult versions of these stimuli were available at the time of this study, there is a clear need to replicate our effects with pictures of children and adolescents that are of similar quality.

Despite the mixed effects in Experiment 5, which could suggest that pupillary response are of limited sensitivity to finer differences in age, we note that observers sexual appeal ratings increased with the age of the depicted sexually preferred persons. Furthermore, these ratings correlated well with pupil size in Experiments 4-6. This supports the idea that pupil dilation is an age specific index of sexual interest, albeit one that might be limited in its ability to distinguish between interest in pubescent and post-pubescent adults in the Tanner stimuli.

In summary, the current findings converge with recent research, which has shown that pupillary responses are sensitive to sexual orientation in hetero-, homo- and bisexual males (Rieger & Savin-Williams, 2012; Rieger et al., 2015). However, the question remained of whether these responses also reflect age-specific sexual interests. Experiments 1 and 2 (Chapter 2) could not address this issue completely due to the similar response patterns that were obtained in heterosexual male and female observers. This raised the possibility that these pupillary responses do not reflect age-specific but stimulus-based effects. The experiments presented here extend this work in an important way by demonstrating consistently that this measure can distinguish sexual interest in adult targets from those in young children. Crucially, this was found with non-paedophilic male observers with diverse sexual orientations, which rules out stimulus-based effects. These findings therefore support the theory that pupillary responses reflect age-specific sexual interest. The current experiments show that this measure also correlates well with the subjective sexual appeal that people of different ages hold for an observer, which provides further evidence for a direct relationship between sexual interest, the age of an observed target person, and pupil size. However, we note that the sensitivity of this method to distinguish specific age groups of adolescents and adults remains difficult to resolve.

Chapter 4 Pupillary Responses to Portraits of Nude versus Dressed Adults

Introduction

The presentation of male and female adults elicits changes in observers' pupil size that are consistent with sexual interest. This effect is observed with a variety of stimuli, ranging from static images of partially dressed adults (Hamel, 1974) to photographs of nudes (Hamel, 1974; Hess & Polt, 1960; Hess et al., 1965) and sexually explicit video (Rieger et al., 2015; Rieger & Savin-Williams, 2012). It remains unclear, however, whether different levels of sexual exposure affect pupillary responses, which level of exposure provides the strongest index of sexual interest, and whether this interacts with observer sex.

An early investigation provides evidence that nude images selectively enhance pupillary responses to people of sexual interest (Hamel, 1974). In this study, heterosexual female observers viewed images of two male and two female models presented in various stages of undress. Observers exhibited greatest pupillary dilation to images of naked men in comparison to partially and fully dressed men. However, this effect was only present for some of the male images, and no difference was found for images of women. Moreover, male observers were not included in this study and pupillary responses were measured crudely with a manual technique.

In a subsequent study, naked images elicited a generalized pupillary response in heterosexual men and women that did not differentiate target sex (Aboyoun & Dabbs, 1998). In contrast to Hamel's (1974) findings, this indicates that nudity might also interfere with the measurement of sex preference effects.

However, more recent investigations with more precise eye-tracking equipment also indicate that the pupillary responses of heterosexual male observers to nude (Rieger et al., 2015; Rieger & Savin-Williams, 2012) and partially nude people (in Chapters 2 and 3) reflect their sexual interests. By contrast, the pupils of heterosexual female observers dilated indiscriminately for both sexes (Rieger et al., 2015), or more to same-sex stimuli (Rieger & Savin-Williams, 2012). However, these studies did not directly compare responses to nude and partially nude stimuli with images of dressed persons and therefore cannot address whether these image types provide different indexes of sexual interest.

To provide a more direct comparison, a recent investigation recorded observers' pupillary responses to video footage of nude persons performing sexual acts and dressed persons discussing the weather (Watts et al., in press). In female observers, nude and dressed person stimuli produced moderate correspondence of pupil dilation with sexual orientation. In male observers, on the other hand, this correspondence was enhanced for nude compared to dressed stimuli. However, these stimuli were grossly mismatched for person identity and scene content, which raises the possibility that other factors contributed to the pupillary response patterns. Consequently, it remains unresolved how the level of nudity affects pupillary responses, and how this interacts with observer sex.

To investigate these questions, the present study directly compared the pupillary responses of heterosexual men and women to dressed and fully naked photographs of male and female adult film actors. An intermediate stage of nudity was also presented, by blurring genital and chest areas of the naked stimuli. In contrast to previous studies, the dressed, naked and blurred stimuli were controlled for identity and pose, and pupillary responses were always assessed with sensitive contemporary eye-tracking equipment. In addition, pupillary responses were correlated with observers' sexual appeal ratings of the targets.

EXPERIMENT 7

Method

Participants

Fifty-two (28 females, 24 males) students from the University of Kent, with a mean age of 22.4 years (SD = 5.7), participated in this study. Only participants who reported to be exclusively or predominantly heterosexual, by recording '0' or '1' on the Kinsey Scale (Kinsey et al., 1948) in an online prescreen, were invited to take part.

Materials

Photographs of six men and six women were selected from 'XXX 30 Porn-Star Portraits' (Greenfield-Sanders, 2009). Each of these targets was portrayed dressed and naked in matching poses on a plain background, which measured 600 by 768 pixels at a resolution of 72 ppi. To create an intermediate nudity condition, the pelvic region of the naked male targets and the breast and pelvic region of the naked female targets were blurred using a graphics software (Adobe Photoshop CS3, Gaussian Blur with 340 pixel radius). This resulted in a total of 36 photographs, comprising 12 images for each of three exposure conditions (dressed, blurred, and naked).

Control stimuli were also created to assess the potential effect of low-level stimulus properties on pupillary responses, by randomizing the pixels in each photograph (for an illustration, see Figure 4.1). The content of the resulting images is no longer recognizable but colour and mean image luminance are retained (for similar approaches, see Henderson, Bradley, & Lang, 2014). All images were displayed at a viewing distance of 60cm and presented in the centre of a uniform grey background subtending approximately 25.4 degrees of visual angle vertically and 20 degrees horizontally.

Measures of sexual orientation

To confirm sexual orientation, participants completed the Kinsey scale. On this 7-point range, '0' represents complete heterosexuality and'6' complete homosexuality (Kinsey et al., 1948). The Modified Klein Sexual Orientation Grid (MKSOG) was also administered as a more detailed measure of sexual orientation (Klein, Sepekoff, & Wolf, 1985). On this scale, participants report sexual attractions ('to whom are you sexually attracted?') and fantasies ('about whom do you have sexual fantasies?') for the past, present and ideal future on 7-point Likert scales, which range from 'other sex only' to 'same sex only'.

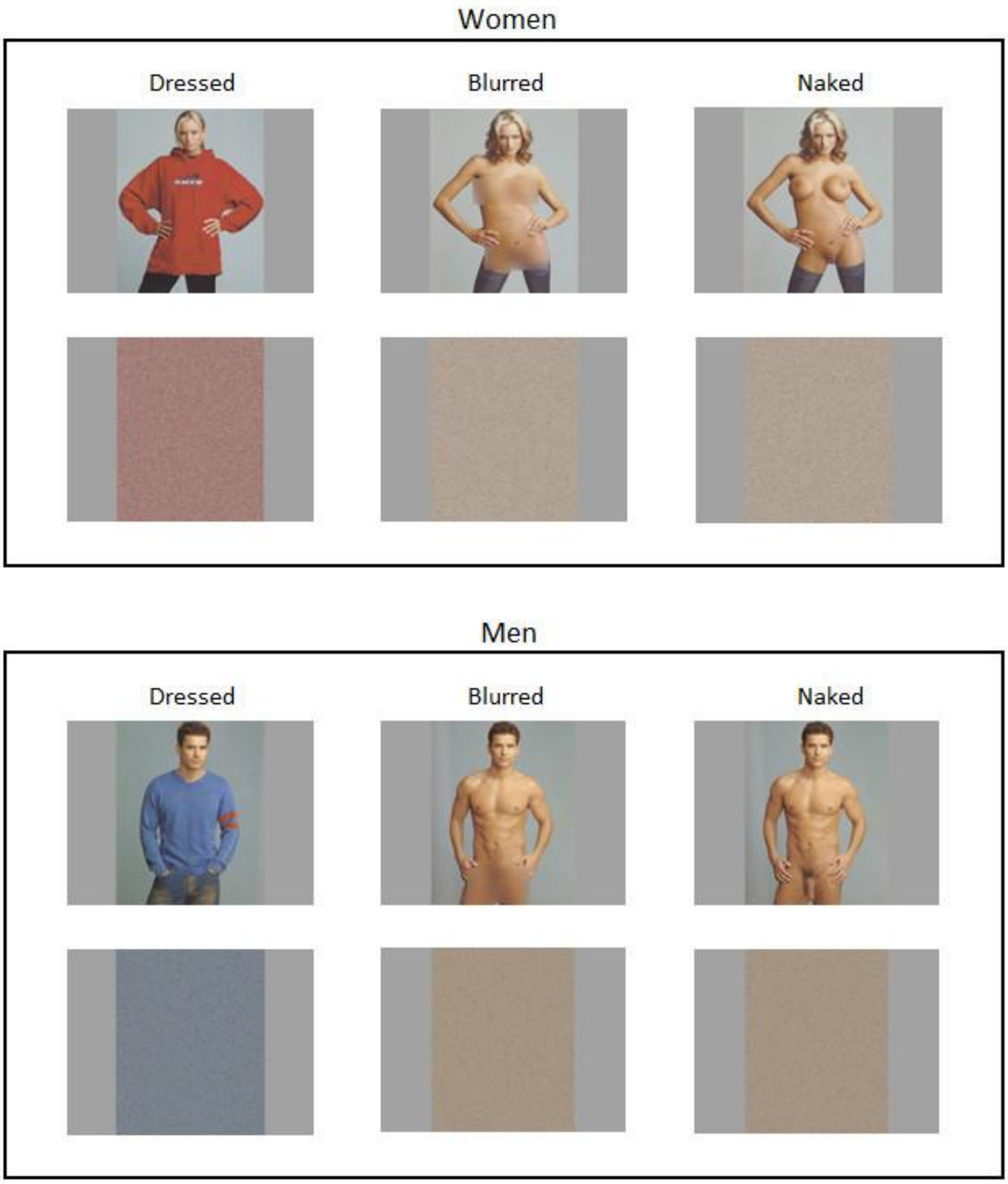

Figure 4.1 Example stimuli of dressed, blurred and naked women and men, and the corresponding control images (bottom row of each panel).

Eye-tracking

Eye movements and pupillary responses were recorded with an SR-Research Eyelink 1000 eye tracker, running at 1000Hz sampling rate, a spatial resolution of < 0.01° of visual angle, a gaze position accuracy of < 0.5°, and a pupil size resolution of 0.1% of area. The Eyelink 1000 measures corneal reflection and dark pupil with a video-based infrared camera, and computes the number of pixels that are occluded by participants' pupils. In this system, a measurement of pupil diameter is recorded at every fixation point as an integer that ranges from 400 to 16000 units. The stimuli were displayed on a 21" colour monitor, with a screen resolution of 1024 x 768 pixels. Viewing was binocular but only participants' left eye was tracked. A chin rest was applied to minimize head movements and maintain a viewing distance of 60 cm from the display monitor.

Procedure

Participants were invited to take part in an experiment on sexual interest that involved viewing images of dressed and naked men and women, but were kept naïve to the full purpose until the end. Subjects were seated in a quiet windowless room with consistent artificial lighting. The participants' left eye was tracked and calibrated using the standard Eyelink procedure. Thus, participants fixated a series of nine target points on the display monitor. Fixation accuracy was then validated against a second series of nine targets. Calibration was repeated if poor measurement accuracy (< 0.5°) was indicated.

Participants were instructed to rate the personal sexual appeal of all 72 images. Each trial started with a drift correction, which required fixation of a central target point, followed by a grey screen for 1000 milliseconds, and the target stimulus. Participants recorded their responses on a standard keyboard using a 7-point scale ranging from 1 ('not at all sexually appealing') to 7 (‘extremely sexually appealing’). Participants were instructed to keep their fingers on these keys at all times. Once a response was recorded, the target was replaced with a grey screen for 1000 milliseconds, after which the next trial began. The intact scenes and control images were randomly intermixed for each participant by the Eyelink software and interspersed by a short break every 24 trials. On completion of the eye-tracking task, participants completed the Kinsey scale and MKSOG.

Results

Confirmation of sexual interests

Of 24 male observers, 23 reported to be ‘completely heterosexual’ and one selected ‘predominantly heterosexual’ (corresponding to ‘0’ and ‘1’, respectively) on the Kinsey scale. Of 28 female observers, 17 reported to be ‘completely heterosexual’ and 11 selected ‘predominantly heterosexual’ on this scale. These responses were confirmed with the MKSOG. Responses for sexual attraction and fantasies were combined and revealed means of 1.2 (SD = 0.2) and 1.6 (SD = 0.4) for male and female participants, indicating a strong sexual preference for the opposite sex. Participants with a score that was three standard deviations above these means were excluded from further analysis. This resulted in the exclusion of four male and two female observers.

Sexual appeal ratings

The mean sexual appeal ratings for each stimulus sex (men, women) and exposure condition (dressed, blurred, naked) are illustrated in Figure 4.2 for male and female observers. A 2 (observer sex) x 2 (stimulus sex) x 3 (exposure condition) mixed-factor ANOVA revealed a three-way interaction, $F(2, 86) = 20.82$, $p < 0.001$, partial $\eta^2 = 0.33$. To analyse this interaction, separate 2 (stimulus sex) x 3 (exposure condition) ANOVAs were performed for male and female observers.

For male observers, this revealed an interaction between stimulus sex and exposure condition, $F(2, 38) = 15.27$, $p < 0.001$, partial $\eta^2 = 0.45$. Bonferroni-corrected pairwise comparisons show that male observers rated female targets as more sexually appealing than male targets in all exposure conditions, all ps < 0.001. In addition, men rated naked women as more sexually appealing than blurred and dressed women, both ps ≤ 0.01, and blurred women as more appealing than dressed women, $p < 0.001$.

The equivalent analysis also revealed an interaction of stimulus sex and exposure condition in female observers, $F(2, 48) = 7.84$, $p < 0.001$, partial $\eta^2 = 0.25$. Bonferroni-corrected pairwise comparisons showed that female observers rated men as more sexually appealing than women in the blurred and naked conditions, both ps < 0.001, but not in the dressed condition, $p = 0.15$. Furthermore, naked and blurred men were rated as more sexually appealing than dressed men, both ps < 0.01, but did not differ from each other, $p > 0.25$.

Finally, a separate 2 (observer sex) x 2 (stimulus sex) x 3 (exposure condition) ANOVA was conducted on the sexual appeal ratings for the control images. This did not reveal main effects or interactions, all Fs ≤ 2.62, ps ≥ 0.08, partial η^2s ≤ 0.06.

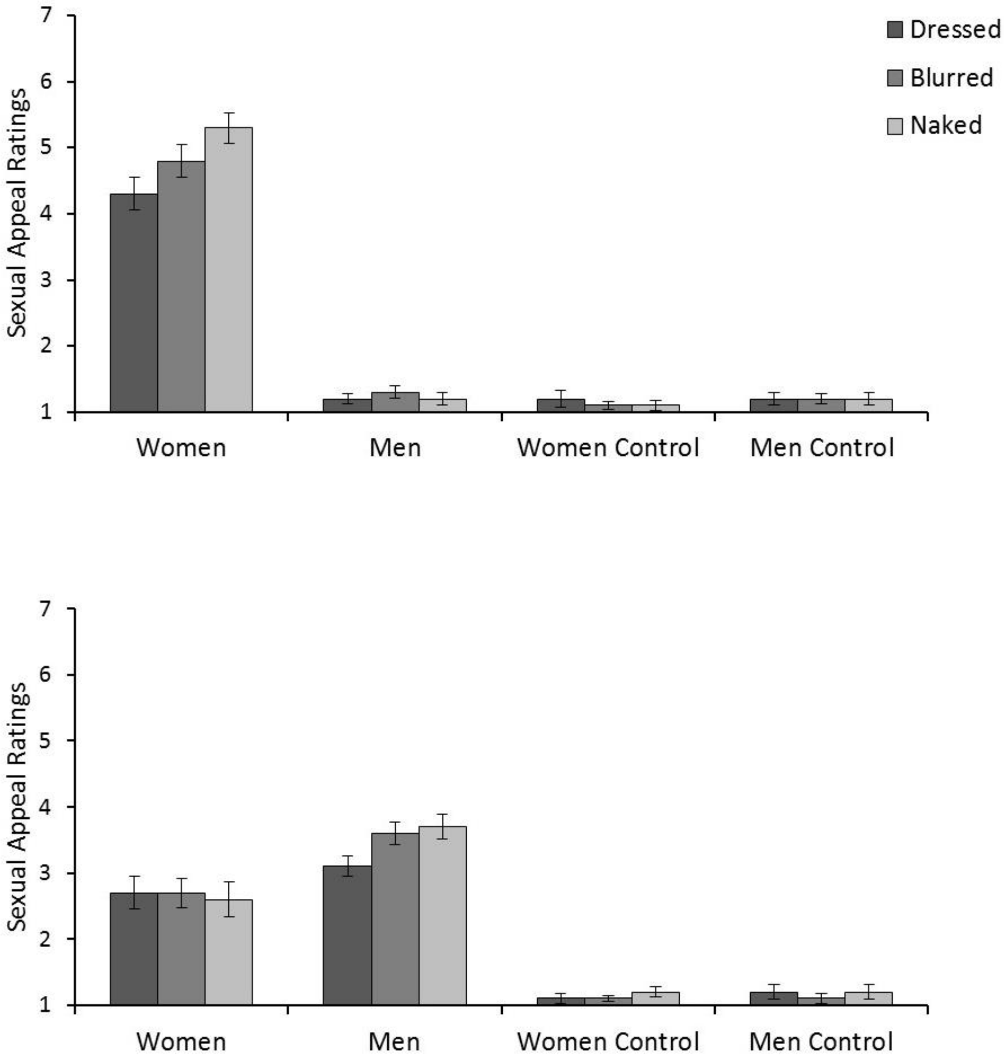

Figure 4.2 Sexual appeal ratings for male (top) and female (bottom) observers. Error bars represent the standard error of the means.

Data preparation

All eye movements were pre-processed by merging fixations of less than 80 ms with the preceding or following fixation if that fell within half a degree of visual angle (for similar approaches, see Attard & Bindemann, 2013; Bindemann et al., 2010). Blinks and fixations outside the display monitor were excluded.. Pupillary responses were then computed by taking the mean pupil area at each fixation, averaged across the whole duration of each stimulus display and excluded fixations to the grey screen before and after the scene. These values were used to compute an overall mean, across all stimuli, for each participant. These pupillary responses were evaluated for outliers, which resulted in the exclusion of one female participant with a score three standard deviations above the group mean. The percentage difference (i.e., an increase or decrease) in pupil size from the overall mean was then computed for all conditions, using the formula: 100 – (mean pupil size for condition * 100 / overall pupil mean). For the resulting scores, a value of zero indicates no change in pupil size and positive or negative scores reflect relatively larger (dilation) or smaller (constriction) pupil sizes for a stimulus category (for similar approaches, see Dabbs, 1997; Laeng & Falkenberg, 2007).

Viewing behaviour

We first examined whether eye movements generally targeted the person information in the scenes. For this purpose, the fixations of each trial were fitted with a Gaussian (radius = 3° of visual angle) and a z-scored distribution of these Gaussians was plotted (for similar analysis, see Bindemann et al., 2010; Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Figure 4.3 shows these fixation maps superimposed on silhouettes of example images from each person-category for male and female observers. These data reveal that observers fixated the targets' faces in all conditions but increased attention to the chest and pelvis in the naked conditions.

Next we analysed the percentage fixations to the head, chest and pelvis in more detail. For this, three regions of interest (ROIs), which comprised the head, body and scene background, were defined and the percentage of fixations that fell on these ROIs was then calculated. Observers' percentage fixations to the ROIs for all stimulus categories are illustrated in Figure 4.4.

Overall, 96% of fixations fell on the figures in the scenes (range = 94% to 98% across conditions), which indicates that the person-content of the scenes was of most interest. A 2 (stimulus category: men, women) x 3 (exposure: dressed, blurred, naked) x 4 (ROI: head, chest, pelvis, other body) x 2 (observer sex: male, female) mixed-factor ANOVA revealed a four-way interaction, $F(6, 252) = 2.48$, $p < 0.05$, partial $\eta^2 = 0.06$. To explore this interaction, a 2 (stimulus category) x 3 (exposure) x 4 (ROI) within-subjects ANOVAs was performed separately for male and female observers.

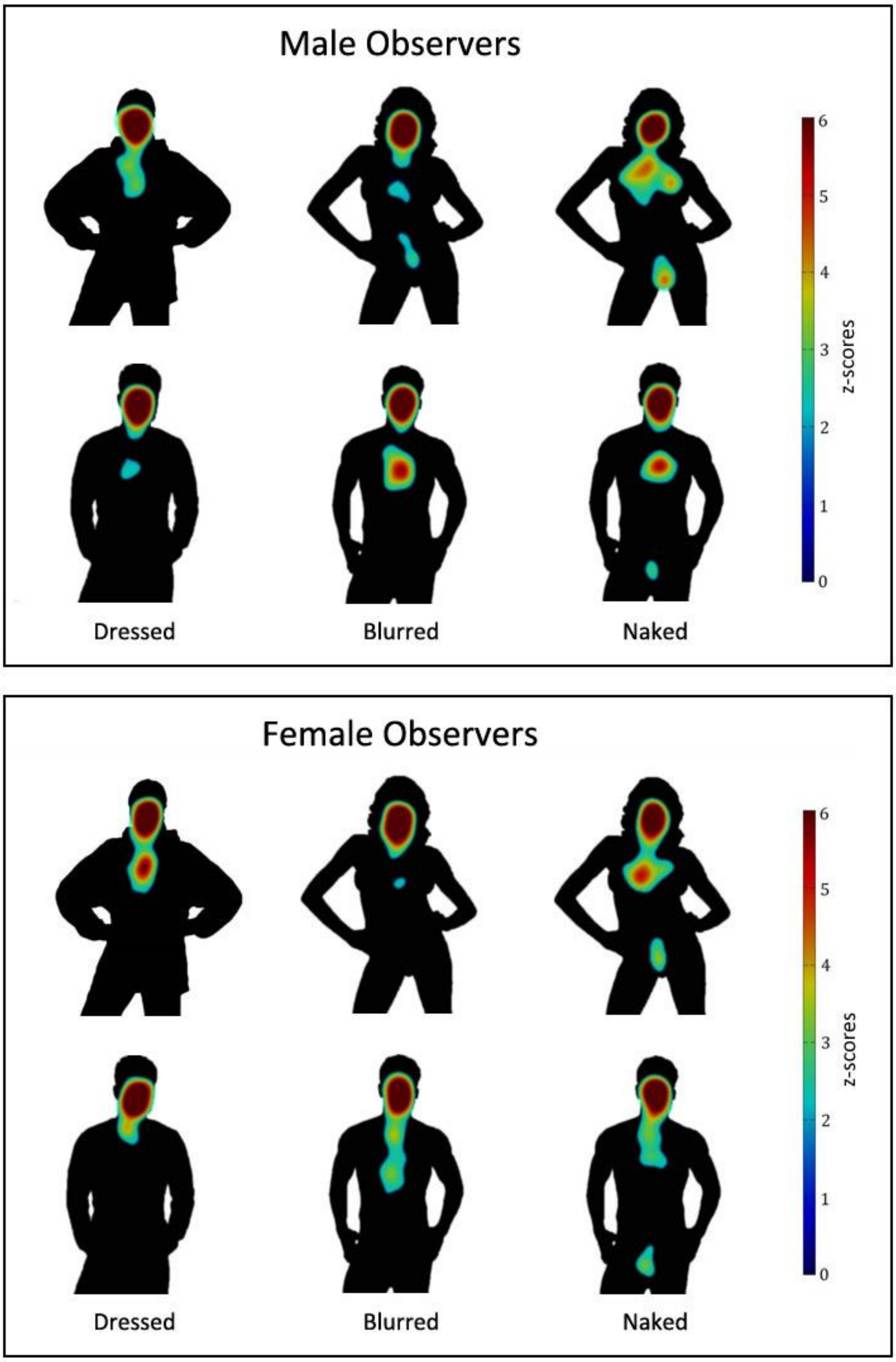

Figure 4.3 Distribution of fixations for a female (top) and a male (bottom) target in the dressed, blurred and naked exposure conditions (respectively, from left to right) for male and female observers.

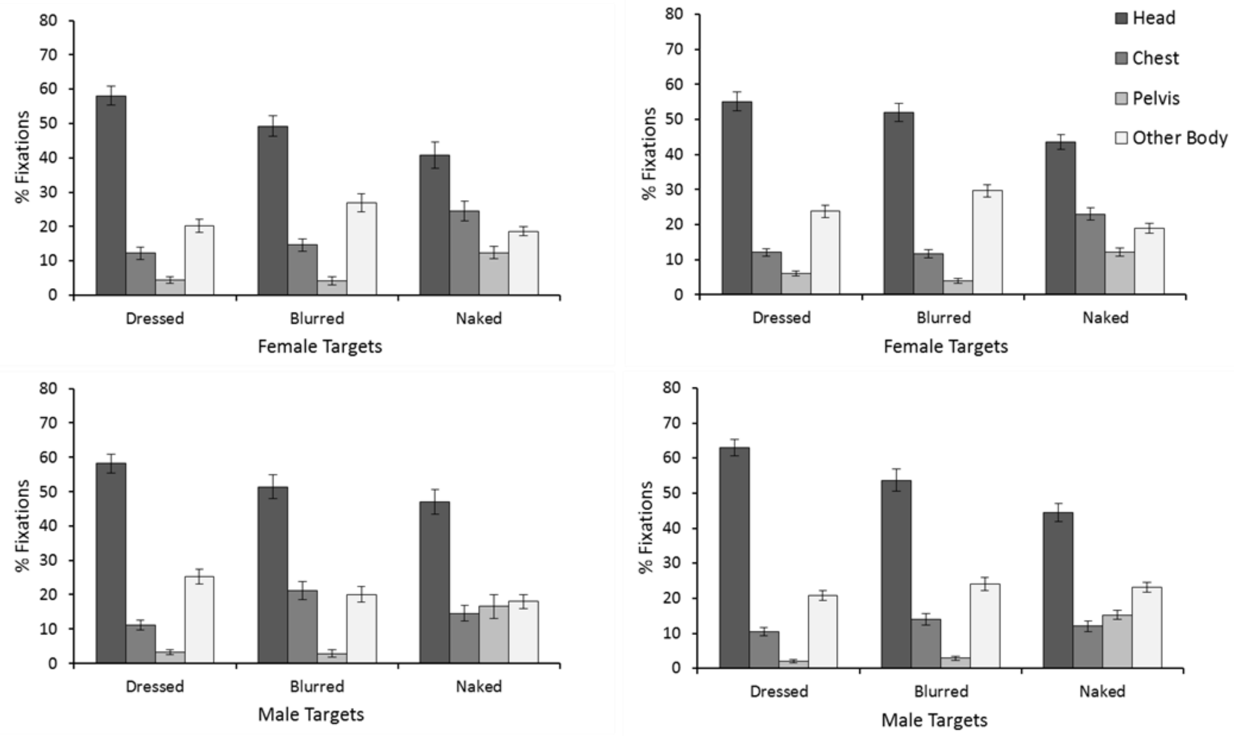

Figure 4.4 Mean percentage fixations to the head, chest, pelvis and other body regions (arms, legs, and abdomen) for male (left) and female (right) observers. Lines represent standard errors of the means.

Heterosexual Male Observers

For male observers, this analysis showed main effects of ROI, $F(3, 54) = 91.64$, $p < 0.001$, partial $\eta^2 = 0.84$, but not for exposure, $F(2, 36) = 0.64$, $p = 0.53$, partial $\eta^2 = 0.03$, and stimulus category, $F(1, 18) = 0.62$, $p = 0.44$, partial $\eta^2 = 0.03$. This analysis also revealed an interaction between exposure and ROI, $F(6, 108) = 17.85$, $p < 0.001$, partial $\eta^2 = 0.50$. A three-way interaction was also found, $F(6, 108) = 4.45$, $p < 0.001$, partial $\eta^2 = 0.20$. No other interactions were revealed, all Fs ≤ 1.59, all ps ≥ 0.20, partial η^2s ≤ 0.08.

To explore the three-way interaction, Bonferroni-adjusted pairwise comparisons of the stimulus categories were conducted for each ROI. For female targets, more fixations were directed at the head region in dressed (57%)

compared to blurred images (48%), which were both greater than the naked condition (39%), all $ps < 0.05$. Fixations for the chest in dressed (12%) and blurred images (15%) did not differ from each other, $p > 0.74$, but both showed fewer fixations to this region than nakeds (25%), both $ps < 0.01$. Percentage fixations to the pelvis did not differ for dressed (4%) and blurred images (4%), $p = 0.10$, but were greater for naked images (13%), both $ps < 0.001$. Fixations for other body regions in naked (19%) and dressed images (21%) did not differ, p = 0.85. Blurred (27%) stimuli elicited more fixations to the body regions than naked stimuli, $p < 0.05$, and did not differ from blurred stimuli, $p = 0.08$.

For male targets, the head was fixated on more in dressed (58%) compared to naked (47%) images, $p < 0.05$, and both did not differ from fixations to the head in the blurred condition (51%), both $ps \geq 0.07$. More fixations were directed at the chest in the blurred images (20%) compared to the dressed (11%), $p < 0.001$, but not naked images (15%), $p < 0.05$, but the latter conditions did not differ, $p = 0.44$. A greater number of fixations were directed at the pelvic region in the naked condition (17%), compared to the dressed (3%) and blurred images (3%), both $ps < 0.01$. Fixations for this region in the dressed and blurred images did not differ, $p = 1.00$. More fixations were directed at other body regions in the dressed condition (26%) compared to the naked (18%) images, $p < 0.01$, but not the blurred (21%), $p = 0.36$. Fixations for other body regions did not differ for the blurred and naked conditions, $p = 0.51$.

In summary, male observers directed more fixations to the face regions in the dressed and blurred condition, whereas when naked targets were viewed, attention was directed away from the face and shifted onto the chest and pelvic regions.

Heterosexual Female Observers

The equivalent analysis for female observers showed main effects of stimulus category, $F(1, 24) = 17.5$, $p < 0.001$, partial $\eta^2 = 0.42$, and ROI, $F(3, 72) = 95.75$, $p < 0.001$, partial $\eta^2 = 0.80$, but not for exposure, $F(2, 48) = 0.58$, $p = 0.56$, partial $\eta^2 = 0.02$. This analysis also revealed interactions between exposure and ROI, $F(6, 144) = 17.75$, $p < 0.001$, partial $\eta^2 = 0.43$, and stimulus category and ROI, $F(3, 72) = 4.74$, $p = 0.005$, partial $\eta^2 = 0.17$, but not for exposure and stimulus category, $F(2, 48) = 2.66$, $p = 0.08$, partial $\eta^2 = 0.10$. An interaction between all three factors was also found, $F(6, 144) = 7.11$, $p < 0.001$, partial $\eta^2 = 0.23$.

To explore the three-way interaction, Bonferroni-adjusted pairwise comparisons of the stimulus categories were conducted for each ROI. For female targets, fewer fixations were directed at the head region in naked images (44%) compared to dressed (55%) and blurred images (both 52%), both *p*s < 0.05. Fixations for the chest in dressed and blurred images (both 12%) did not differ from each other, $p = 1.00$, but were both less than fixations to this region for naked targets (23%), both *p*s < 0.001. Percentage fixations to the pelvis was greater for naked (12%) compared to dressed images (6%), and blurred targets (4%), all *p*s < 0.01, the latter categories did not differ, $p = 0.26$. Fixations directed at other body regions did not differ for dressed (24%) and naked targets (19%), $p = 0.37$, and the latter was fewer than blurred targets (28%), $p = 0.09$.

For male targets, the head was fixated on more in dressed (63%) compared to blurred (54%) images, and both were greater than for naked images (44%), all *p*s ≤ 0.01. Fixations to the chest region did not differ for the dressed (11%), blurred (14%) and naked targets (12%), all *p*s ≥ 0.16. A greater number of fixations were directed at the pelvic region when viewing naked males (15%) compared to blurred (3%) and dressed (3%) males, both *p*s < 0.001. Fixations to the pelvic regions for the latter two conditions did not differ, $p = 1.00$. No differences were found for other body regions, all *p*s ≥ 0.36.

Overall, fixations to the face region were greater when viewing dressed and blurred targets, in contrast when viewing naked stimuli attention shifted towards the chest and pelvic region.

Pupillary responses

Pupillary responses were analysed in two ways. First, these pupillary responses were compared for male and female observers across all conditions (see Figure 5). A 2 (observer sex) x 2 (stimulus sex) x 3 (exposure condition) mixed-factor ANOVA of this data revealed an interaction of stimulus sex and observer sex, $F(1, 43) = 21.72$, $p < 0.001$, partial $\eta^2 = 0.34$. Bonferroni-corrected pairwise comparisons showed that male observers' pupils were larger whilst viewing women than men, $p < 0.01$, whereas female observers displayed the opposite effect, $p < 0.01$. No other main effects or interactions were found, all *F*s ≤ 1.01, *p*s ≥ 0.37, partial η^2s ≤ 0.02. In addition, a 2 (observer sex) x 2 (stimulus sex) x 3 (exposure condition) mixed-factor ANOVA was also conducted for the control images (see Figure 5). This revealed no main effects or interactions, all *F*s ≤ 2.11, *p*s ≥ 0.13, partial η^2s ≤ 0.05.

In the second analysis, pupillary responses were compared with a baseline that reflects the mean pupil size during the viewing of all stimuli via a series of one-sample *t* tests (with *alpha* corrected at $p < 0.004$ for multiple comparisons). The pupils of male observers were larger than baseline during the viewing of dressed, and naked women, $t(19) = 3.64$, $p < 0.004$, $d = 1.67$, and $t(19) = 4.07$, $p < 0.004$, $d = 1.87$, respectively. A similar trend was observed for blurred women, but this did not reach significance, $t(19) = 2.72$, $p = 0.014$, $d = 1.25$. In contrast, pupil size did not differ from baseline for dressed, $t(19) = 1.25$, $p = 0.23$, $d = 0.57$, blurred, $t(19) = 0.52$, $p = 0.61$, $d = 0.24$, and naked men, $t(19) = 0.04$, $p = 0.97$, $d = 0.02$. Pupillary responses to control scenes were consistently below baseline but these differences were not reliable, all ts ≤ 3.05, ps ≥ 0.007, ds ≤ 1.40, except for blurred men, $t(19) = 4.73$, $p < 0.004$, $d = 2.17$.

In female observers, dressed and naked men elicited pupil sizes above baseline, $t(24) = 3.45$, $p < 0.004$, $d = 1.41$ and $t(19) = 4.32$, $p < 0.001$, $d = 1.76$, respectively. Blurred men produced a similar but non-significant effect, $t(24) = 2.98$, $p = 0.006$, $d = 1.22$. By contrast, pupil sizes did not differ reliably from baseline for dressed, $t(24) = 0.93$, $p = 0.36$, $d = 0.38$, blurred, $t(24) = 0.33$, $p = 0.75$, $d = 0.13$, and naked women, $t(24) = 0.95$, $p = 0.35$, $d = 0.39$. Finally, pupil sizes for the control images were consistently smaller than baseline across conditions but these effects were not significant, all ts ≤ 2.93, ps ≥ 0.007, ds ≤ 1.20, except for blurred women, $t(24) = 3.75$, $p < 0.004$, $d = 1.53$.

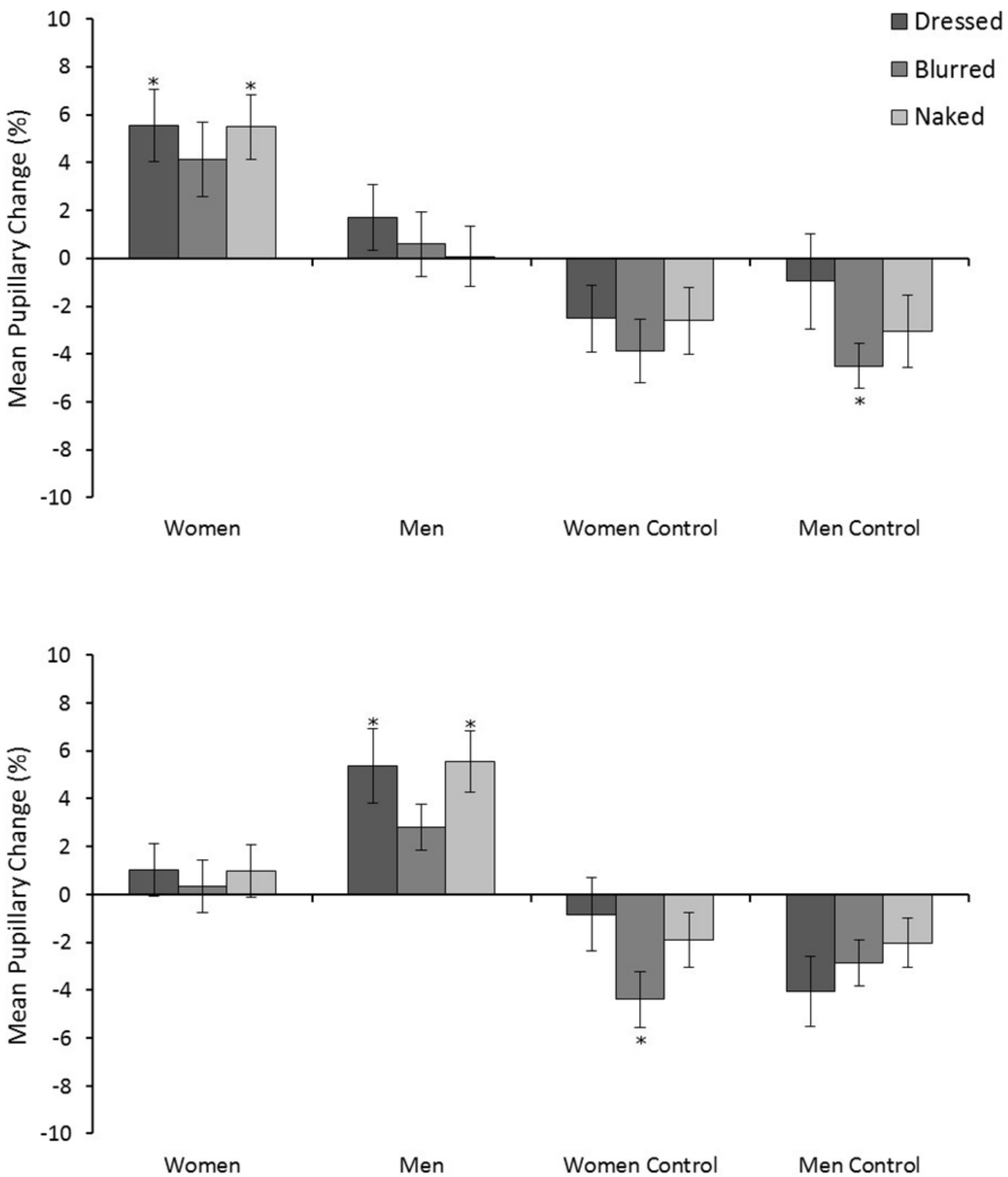

Figure 4.5 Percentage pupillary change for all stimulus categories for male (top) and female (bottom) observers. Error bars represent standard error of the means. *Note:* * represents $p < 0.004$ in the one-sample t-tests (*alpha* corrected for multiple comparisons).

Correlation of sexual appeal and pupillary responses

Sexual appeal ratings were also correlated with mean pupillary change (see Figure 4.6). For this analysis, the control conditions were excluded and the data for male and female targets was combined. The distribution of sexual appeal ratings was skewed. Therefore, non-parametric Spearman's correlations are reported. For male observers, positive correlations between pupillary change and sexual appeal ratings were found for dressed, $r_s(38) = 0.33$, $p < 0.05$, and naked stimuli, $r_s(38) = 0.49$, $p < 0.01$, but not for blurred stimuli, $r_s(38) = 0.26$, $p = 0.11$. For female observers, a correlation was not found for dressed, $r_s(48) = 0.19$, $p = 0.18$, and naked stimuli, $r_s(48) = 0.18$, $p = 0.20$, but was correlated for blurred person photographs, $r_s(48) = 0.28$ $p = 0.05$.

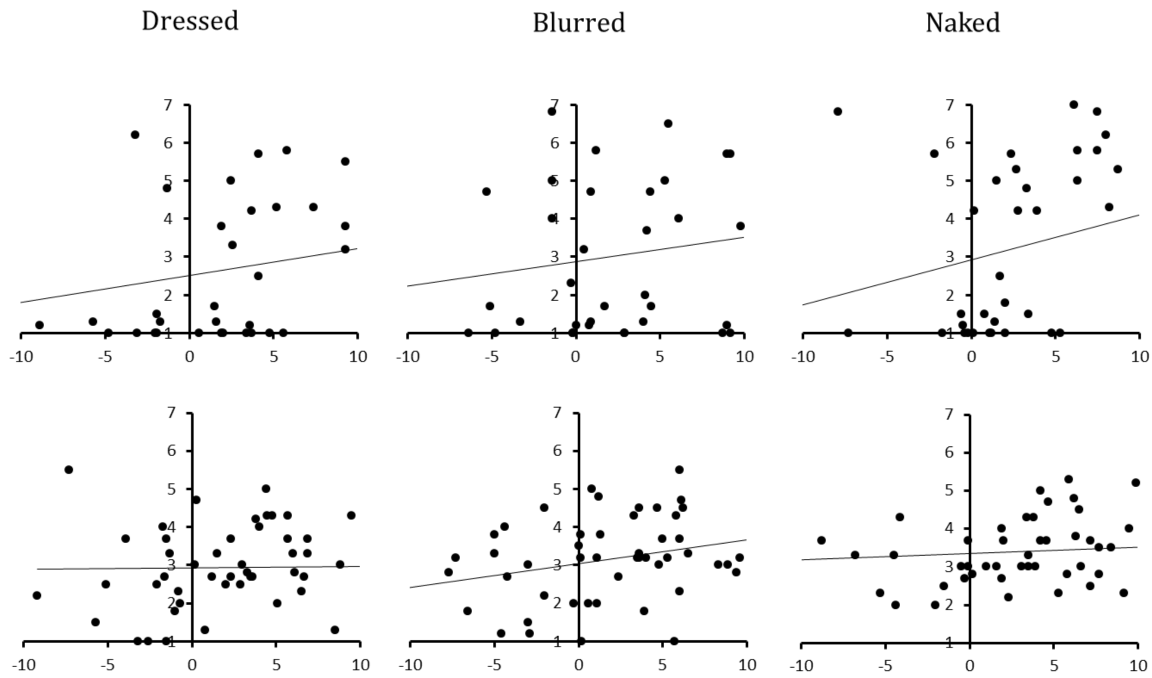

Figure 4.6 Correlations between the mean pupillary change (%) (on x-axis) and the sexual appeal ratings (on y-axis) for male (top) and female (bottom) observers.

Discussion

This study examined whether pupillary responses to the visual presentation of men and women are influenced by different levels of sexual exposure. More specifically, we sought to determine whether one of these conditions (dressed, partially naked or naked) provides a clearer index of sexual interest, and whether this interacts with observer sex. This experiment showed pupillary responses that were consistent with observer's self-reported sexual preferences. Thus, pictures of women elicited a clear pupillary dilation in heterosexual male observers that was not present when viewing men or control images. In contrast, pupil size was largest in heterosexual female observers during the viewing of men compared to women and control images.

When pupillary responses were broken down by exposure condition, strong dilation patterns for both dressed and naked persons emerged. Only a small set of studies have directly compared pupillary responses to such images, with inconsistent results. One study assessed pupillary responses of heterosexual female observers and found enhanced dilation for naked male images (Hamel, 1974). However, a later study revealed a generalized dilation response for naked stimuli of both sexes in heterosexual males and females (Aboyoun & Dabbs, 1998).

Several reasons could account for these discrepancies. For example, such a discrepancy in findings might reflect the use of different eye-tracking methods for measuring pupil size, which range from elementary pupillometry systems that record pupil diameter only every minute (Hamel, 1974), or every 0.5 seconds (Aboyoun & Dabbs, 1998), to state-of-the-art equipment with millisecond precision (Watts et al., in press). Furthermore, it is unclear whether these studies controlled for stimulus factors such as identity, colour and pose. Aboyoun and Dabbs (1998), for example, intermixed images of Caucasian and African American men and women, and different identities were presented in the naked and dressed conditions. Strong differences in colour tone arising from such a mixture of identities and races could have interfered with pupillary responses to the sexual content of these images (Kohn & Clynes, 1996; Labato-Rincón et al., 2014). Similarly, Watts et al. (in press) compared responses to people in pornographic footage with recordings of other people discussing weather, leaving open the possibility that results might reflect differences in identity or scene content. The current study improves on these previous attempts by using sophisticated contemporary eye-tracking technology in combination with highly controlled stimuli. Under these conditions, pupillary responses to images of men and women appear to be sex-specific but not sensitive to the sexual explicitness of the materials.

Naked images of people have been shown to elicit a stronger recording of arousal than dressed images when this is measured with other physiological measures, such as genital response and skin conductance (Abel et al., 1981; Kuban et al., 1999; Malcolm et al., 1993). It is unclear why a similar pattern is not found with pupillary responses. Pupil dilation is an instantaneous response (Zuckerman, 1971), so it is possible that a change in pupil size is elicited with lower levels of sexual arousal than is necessary for other physiological measures. As such, images of dressed people may provide sufficient arousal for eliciting a similarly strong dilation response to naked images.

The responses of male observers to stimuli depicting women converge with previous research, which has also shown increases in pupil size to such content (Hess et al., 1965; Rieger & Savin-Williams, 2012; Rieger et al., 2015). In the current study, female observers also showed stronger dilation for photographs depicting the opposite-sex. In the sex literature, there is conflicting evidence with regard to the response patterns of heterosexual women. Some studies have revealed pupil dilation in female observers that is indistinguishable to sexual content of men and women (Rieger & Savin-Williams, 2012; Rieger et al., 2015) or stronger for the opposite sex (Hamel, 1974; Hess & Polt, 1960; Laeng & Falkenberg, 2007; Watts et al., in press). In light of these differences, the current study also investigated whether nudity influences the pupillary responses of *heterosexual females* by enhancing (Hamel, 1974) or diminishing any sexual preference effects (Aboyoun & Dabbs, 1998). In this experiment, these observers recorded clear dilation patterns for images depicting the person of the opposite sex, consistent with their sexual orientation. More importantly, this pattern was strong for naked *and* dressed images. This suggests that image nudity cannot explain the inconsistent dilation patterns that have been recorded across studies in heterosexual females.

As with previous studies, these pupil responses also correlated for male observers with the sexual appeal ratings that were provided for these photographs, which indicates a direct link between sexual interest and pupil size (Attard-Johnson et al., 2016, Rieger & Savin-Williams, 2012; Rieger et al., 2015). In male observers this was found for naked and dressed image conditions in male observers, but not for blurred stimuli. This could be due to the weaker pupillary responses to these images, and is discussed in more detail below. In line with previous research, these correlations were weaker or not present in female observers whose responses only correlated for the blurred condition (Rieger & Savin-Williams, 2012; Rieger et al., 2015). In these observers, the differences in sexual appeal ratings of male and female targets were smaller than those obtained for male observers. This could therefore account for the lack of a reliable correlation between sexual appeal ratings and pupil size in female observers.

This experiment also included a third condition in which the sexual regions of the targets were blurred to provide a partially naked condition. Pupillary responses to these blurred images also showed dilation for the preferred target sex, but this effect was weaker in comparison to the dressed and naked stimuli. It is unclear why this is the case. However, one possible explanation could be that the blurred image regions interfered with pupillary responses. When a viewer's eye is directed from a distant to a nearby object the image becomes 'out-of-focus', consequently an accommodation response is triggered and the pupils constrict to increase depth of focus and improve image quality (Vanderah & Gould, 2015). It is possible that a similar reflex occurred here, whereby the partially blurred images were processed as 'out-of-focus' stimuli, thus triggering the accommodation reflex and consequently pupil constriction. This constriction may have counteracted pupil dilation that was elicited by the sexual interest of the blurred stimuli.

Chapter 5 Summary and Discussion

This thesis investigated the use of pupillary responses as a measure of sexual interests that is specific to adults' sexual preferences for sex categories (i.e., men versus women), and more importantly whether this can be extended to sexual age-preferences (i.e., adults versus children). The introduction evaluated current physiological and experimental methods for measuring age-specific sexual interests in child sex offenders. These approaches include direct recordings of sexual arousal with phallometric techniques and subjective ratings (Chivers et al., 2010; Laws et al., 2000), and more indirect measurements of sexual interest with attention-based approaches, such as visual response time (Ebsworth & Lalumiére, 2012; Israel & Strassberg, 2009; Lippa, 2012), Choice Reaction Time (Mokros et al., 2010; Ó Ciardha & Gormley, 2013) or eye-movements (Fromberger et al., 2012, 2013; Hall et al., 2011). However, the susceptibility of these measures to the observers' voluntary control over their responses is a shortcoming shared among these approaches. For example, it is possible to suppress genital arousal responses (Beck & Baldwin, 1994; Golde et al., 2000), to influence the outcome of a response based task by button-pressing in a nonsensical pattern, and to affect eye movements by diverting attention to other content (Bindemann et al., 2007). This is a problematic limitation when considering these methods for assessment with child sexual offenders, who may attempt to conceal their sexual interests (O'Donohue et al., 2000). As a result, the reliability and applicability of these measures is brought into question.

In light of this caveat, it is important to explore alternative measures that might be less susceptible to manipulation by the observer. Pupillary response is a potential approach that could provide an index of sex-specific sexual interests (Hess & Polt, 1960; Hess et al., 1965; Rieger & Savin-Williams, 2012; Rieger et al., 2015). Previous studies have reported dilation patterns that correspond with observers' self-reported sexual orientation and also with their genital responses (Reiger et al., 2015). However, the questions of whether this measure can be extended to distinguish adults' sexual interests in different age groups remains. This idea is appealing because pupil responses appear resistant to deliberate efforts to exert control over their size (see Heaver & Hutton, 2011; Laeng et al., 2012), which is an important characteristic when considering the use of this assessment in clinical and forensic settings. This thesis therefore explored pupillary responses as an alternative approach for measuring sex- and age-specific sexual interests over a series of seven experiments, by using eye-tracking for measuring eye movements and pupillary responses to images of adults and children.

5.1 Pupillary Responses

Chapter 2 examined whether pupillary responses to photographs of people can provide an indication of an observer's sexual interests, and specifically whether such responses are sensitive to images of adults or children. Across two experiments, heterosexual male and female observers were presented with images of beach scenes that comprised semi-clothed adults and children. Experiment 1 adopted a free-viewing paradigm whereby observers were asked to 'view the scenes as you naturally would' for a predetermined duration so as not to constrain spontaneous eye movements (e.g., Bindemann et al., 2009, Fromberger et al., 2013; Hall et al., 2011). By contrast, Experiment 2 explored more directly whether pupillary responses are linked to observers' sexual interest. For this experiment, observers were instructed to rate these target persons in terms of their sexual appeal. Both experiments generated similar results, such that the pupils of male observers dilated to photographs of women but not men, children, or neutral stimuli. These pupillary responses corresponded with observer's self-reported sexual interests and their sexual appeal ratings of the targets. Female observers showed pupil dilation to photographs of men and women, but not children. In women, pupillary responses also correlated poorly with sexual appeal ratings of these stimuli. The pupillary responses of heterosexual males and females to the sex categories (i.e., men versus women) are therefore consistent with previous research (Hess et al., 1965; Rieger & Savin-Williams, 2012; Rieger et al., 2015). Importantly, a clear age effect was also present such that no dilation was present when observers viewed images of children.

Although these findings are promising, these experiments are still limited in some respects. The pupil dilation patterns produced by heterosexual female observers were similar to those recorded by male observers (i.e., larger for women) and are inconsistent with their self-reported sexual orientation. This arousal pattern in heterosexual females is common in the wider sex literature, suggesting an underlying biological mechanism (e.g., Chivers et al., 2004; Lippa et al., 2010; Steinman et al., 1981), and I return to this point in a separate section (see *Sex Differences in Pupillary Responses* section). It was unclear in Chapter 2, however, whether this pattern of responding also applied to the pupillary responses obtained here, or whether these responses were driven by other unknown stimulus factors. Consequently, without a comparison for the male responses it was unresolved whether the pupillary responses of heterosexual male observers provide a reliable index of sexual interest, and whether these are truly age-specific.

Chapter 3 addressed this issue by comparing the pupillary responses of non-paedophilic men with hetero-, homo- and bisexual orientations to the same photographs. Only male participants were included in this experiment due to their high concordance between self-reported sexual orientation and phallometric measures of sexual interest (e.g., Chivers et al., 2010; Rieger et al., 2012, 2015). By including three male groups with diverse sexual orientations it was possible to circumvent the issue of equating low-level aspects of the stimuli that could not be identified. Therefore, if dilation is consistent with sexual orientation, then this would support the idea that the responses obtained in the preceding chapters reflect sexual interest. To this end, participants viewed the same beach scenes as in the previous experiments, the first was a free-viewing task (Experiment 3) and then a sexual appeal ratings task (Experiment 4).

In both experiments, dilation occurred for images of adults that matched observers sexually preferred sex (i.e., women for heterosexuals and men for homosexuals). Pupil dilation of bisexual men were indistinguishable to images of adult men and women in Experiment 3 but dilated more for adult women in Experiment 4. Importantly, images of children consistently produced either a constriction in pupil size or no change from baseline in all observers. These findings therefore support the notion that the pupillary responses obtained in Chapter 2 also reflect age-specific sexual preferences.

Although experiments 1-4 found distinct pupillary response patterns when observers viewed images of people representing different age groups (~ 5 and ~ 25 years of age), the question remained concerning the age sensitivity of these responses. Experiment 5 therefore examined pupillary responses to images of people at five different stages of sexual development, ranging from infancy to adulthood (Tanner, 1978). For this purpose, participants viewed images selected from the Not Real People (NRP) stimulus set (Pacific Psychological Association Corporation, 2004) and rated these images on their sexual appeal while their eye movements and pupillary responses were recorded. A pattern emerged with homosexual males, whereby pupil dilation was consistent with their sex-preferences. Specifically, reliable dilation occurred for images of pre-pubescent adolescent and adult males, whereas younger depictions of males did not evoke such a response. By contrast, images of women, regardless of age, did not evoke any dilation responses. Surprisingly, however, such clear responses were not obtained for heterosexual and bisexual males. In heterosexual males dilation occurred for images depicting females in early and intermediate pubescent stages, and post pubescent adolescents, but not for females in adulthood. For bisexuals, only intermediate pubescent females evoked a dilation.

Therefore, although these images produced pupillary responses that were sensitive to images depicting specific stages of sexual maturity in homosexual males, this was not clearly evident for heterosexual and bisexual males. While the reason for this is unclear, it is notable that the participant sample consisted of relatively young adults with a mean age of 22 years. It is therefore possible that the adolescent targets of Experiment 3 were also within an age range of sexual interest to these observers, for example, 20 year-old heterosexual men have previously reported being sexually interested in 18 year old women (Buunk et al., 2001). Alternatively, these responses might also reflect the age and composition of this stimulus set, which was not designed to provide sexually evocative content.

The issue of stimulus composition was addressed in Experiment 6, where participants viewed images of adult men and women of comparable attractiveness, composition, posture and facial expression. Only adult versions of these stimuli were available at the time, therefore this experiment did not include depictions of children and adolescents. The findings from Experiment 6 show the clearest pupil dilation pattern thus far, whereby heterosexual males dilated more when viewing women, homosexual men dilated more for men, and bisexual males showed indistinguishable responses for the two sexes. These responses also correlated with sexual appeal ratings for these images indicating that pupillary responses obtained in this experiment were directly linked to sexual interest. Although this experiment only employed images of adults, these findings lend credence to the pattern of effects that were observed in preceding experiments which employed less controlled stimuli.

Research into the assessment of sexual interests with pupillary responses vary widely in scene content, for example, these range from complex video footage (Rieger et al., 2012, 2015; Watts et al., in press), to static images of people in natural scenes (Experiments 1-4) or in the absence of scene background (Experiments 5-7; Hess et al., 1965). The findings from Chapter 3 suggest that clearer response patterns can be achieved by controlling for scene content. However, studies also differ in level of sexual explicitness in stimuli ranging from video footage depicting sexual acts (Rieger et al., 2012, 2015), static images of nude people (Hess et al., 1965) and partially dressed adults and children (Chapters 2 and 3). Only a small set of studies have directly compared pupillary responses for images depicting people at varying levels of nudity, with inconsistent results (Aboyoun & Dabbs, 1998; Hamel, 1974; Watts et al., in press). A number of reasons might account for this discrepancy, including variation in eye-tracking methods and poorly-controlled stimuli. As a consequence, the question remained of whether different levels of sexual exposure affect pupillary responses, which level of exposure provides the strongest index of sexual interest, and whether this interacts with observer sex.

Experiment 7 in Chapter 4 examined these questions by comparing pupillary responses to highly controlled photographs of dressed and nude adult models with contemporary eye-tracking methods. In this experiment, observers' pupils dilated to images of the opposite sex and these correlated with the sexual appeal ratings provided for these photographs. However, similar dilation responses were recorded both for nude and dressed stimuli. The findings from Experiment 7 therefore suggest that pupil size for measuring sexual interest may not be limited to sexually explicit stimuli, such as nude and partially nude images of people. Instead, patterns that distinguish sexually preferred from non-preferred persons can also be achieved with fully clothed portrayals of people. This widely increases the usability of this measure for assessing sexual preferences in a forensic context when use of sexually explicit stimuli is restricted due to ethical and legal constraints (Abel, Huffman, Warberg, & Holland, 1998; Kalmus & Beech, 2005).

5.2 Sex Differences in Pupillary Responses

5.2.1 MALE SEXUAL RESPONSE PATTERNS

The pupillary response patterns of male observers were generally consistent with sexual orientation and age-specific sexual interest for adults. Heterosexual men's pupils consistently dilated to images of women, and not to any other category, across all experiments. Furthermore, these responses corresponded strongly with observers' subjective sexual appeal ratings across categories. This pattern of responding converges with previous research in demonstrating high agreement between pupillary responses and sexual orientation (Hess et al., 1965; Rieger et al., 2012, 2015). This concordance is also consistently reported with other measures of sexual interest, including genital arousal (for meta-analysis, see Chivers et al., 2010) and viewing time studies (Quinsey et al., 1996). However, some research suggests that heterosexual men demonstrate sex-specific responses in studies that measure genital arousal because they are able to suppress responses to the non-preferred target, which could explain the non-specific arousal responses obtained in women (Chivers, 2005; Mahoney & Strassberg, 1991; Winters, Christoff, & Gorzalka, 2009). Considering that pupillary responses are automatic and difficult to inhibit (Laeng & Sulutvedt, 2013; Zuckerman, 1971), the consistent pupil dilation for images of women in heterosexual men obtained in this study suggest that control over physiological responses is an unlikely explanation for findings with other paradigms.

Homosexual men's pupils also predominantly dilated during the viewing of the preferred sex. However, the discrimination between pupillary responses for the same and opposite sex was not as strong and consistent across experiments. For example, in Experiments 3, 5 and 6, observers' pupils were reliably larger for adult men compared to baseline, but some dilation also occurred for women, though this was not statistically reliable. However, in Experiment 4 both types of adult targets elicited a reliable dilation. Similarly, in bisexual men, both adult male and female targets elicited dilation across experiments, but the level of arousal for each category appeared to vary.

In these experiments, sexual orientation is categorized into three distinct groups (hetero-, homo- and bisexual). However, some research also suggests that sexual orientation may be conceptualized more appropriately as a continuum (Savin-Williams, 2014; Savin-Williams, Cash, McCormack, & Rieger, 2016). Men who subjectively report bisexual attraction do not always show evidence of bisexual physiological arousal, but may be inclined more towards same- or other-sex targets (Rieger et al., 2005). In a recent eye-tracking investigation, men who reported their sexual orientation as 'bisexual men leaning gay', 'mostly gay', and 'completely gay' differed in their degrees of attention to women, with the former two categories reporting greater attraction to and focusing more on women, than the exclusively gay category (Savin-Williams et al., 2016). This leaves open the possibility that bisexual and homosexual men have the capacity to be sexually aroused by both sexes, but to different degrees. It is possible that this can explain the response patterns of homosexual and bisexual men that were obtained in Chapter 3.

5.2.2 FEMALE SEXUAL RESPONSE PATTERNS

Heterosexual female observers showed inconsistent pupillary response patterns, whereby dilation for same sex was observed in Experiment 1, for both sexes in Experiment 2, and strong dilation for the opposite sex in Experiment 7. Furthermore, in Chapters 2 and 4, pupillary responses only correlated weakly with the sexual appeal ratings that these observers provided for the person photographs. It is noteworthy, however, that although heterosexual females were inconsistent in sex-specificity of their response patterns, they consistently demonstrated an age-preference for adults. These findings suggest that pupillary responses are not as informative about women's sexual interests as they are in men, but may still be an index of sexual age-preferences in this group of observers.

Such inconsistency in sexual response patterns for females is not only a common occurrence in studies using pupil dilation but also for other measures of sexual interest, including genital arousal, viewing time measures and subjective ratings, in response to visual sexual stimuli (Bailey, 2009; Chivers, 2005; Rieger & Savin-Williams, 2012). The exact relationship between subjective and physical sexual arousal is complex and poorly understood, but is thought to involve multiple processes (see Rupp & Wallen, 2008). Theories suggest that subjective sexual arousal is a product of cognitive and peripheral physiological states (Basson, 2002; Janssen et al., 2000). Cognitive state involves the evaluation and categorization of stimulus as sexual and an affective response, and the physiological component comprises changes relating to respiration, cardiovascular function and genital arousal. It is thought that the inconsistency in sexual responding in women arises from a discordance between these two states (Chivers et al., 2004; Hall, Binik, & Di Tomasso, 1985).

Some research suggests that this discordance may arise due to measurement artefacts for physiological measurements such as genital arousal, whereby stronger correlations between thermography and subjective appeal ratings have been found compared to vaginal photoplethysmography (Chivers et al., 2010). A similar inconsistency in responding is also observed in viewing time measures and raises the question of whether longer response latencies reflects sexual interest for that target or other task- or stimulus-specific processes (Imhoff et al., 2010; Imhoff et al., 2012; Xu, Rahman, & Zheng, 2016). However, the inconsistent patterns of female responding obtained with pupil dilation in this thesis is typical of these other measures and suggests that sexual responses recorded are unlikely to be due to measurement artefact.

An alternative explanation is that female physiological responses are automatically activated by sexual stimuli and can occur in the absence of subjective sexual arousal, but the exact mechanisms underlying this are not well known (Chivers, 2005; Laan & Everaerd, 1995). It is possible, however, that discrepancies in female sexual responding across studies may be accounted for by difference between stimuli, whereby sexually explicit stimuli could enhance the physiological component of sexual responding and diminish any *specific* responses in women. Few studies have directly compared pupillary responses for stimuli that systematically vary in terms of their sexual explicitness (Aboyoun & Dabbs, 1998; Hamel, 1974; Watts et al., in press). These studies poorly controlled stimulus factors, such as identity, pose and scene content, and have yielded inconsistent results with regards to female responding. I return to this issue in section 5.3.

In light of these differences between previous studies, Experiment 7 investigated whether increases in nudity influence pupillary responses of heterosexual females by enhancing (Hamel, 1974) or reducing sexual preference effects (Aboyoun & Dabbs, 1998). In this experiment, female observers recorded clear dilation patterns for images depicting persons of the opposite sex. However, this pattern was present for nude *and* dressed images of people. This suggests that nudity is an unlikely explanation for the inconsistent dilation patterns in heterosexual females that were recorded across previous studies.

In Experiment 7, pupil dilation in women was strongly sex-specific and also matched reported sexual interest. This is surprising considering heterosexual women's tendency to respond physiologically to both sexes (for review see Chivers, 2010). Although women were shown nude images, these were not as sexually explicit as the pornographic video footage that has been used typically with genital arousal measures (for meta-analysis, see Chivers et al., 2010). One possibility is, therefore, that women's responding may be more sex-specific when sexual context is reduced, or even omitted completely, from visual stimuli. For example, heterosexual women's pupils dilate for faces of the opposite sex that they report being attracted to (i.e, their boyfriend or favourite actor), but not to other faces (i.e., other celebrities) (Laeng & Falkenberg, 2007). However, other cognitive factors such as recognition of familiar faces could have influenced dilation patterns in this study (Heaver & Hutton, 2011; Otero, Weekes, & Hutton, 2011). Furthermore, this does not explain the non-specific female responses found in Experiments 1 and 2 (in Chapter 2) which use partially nude images of people. Nonetheless, this is clearly an important avenue for further investigation.

5.3 Control for Stimulus Factors

Studies differ greatly in terms of the stimuli that have been used to measure pupillary responses to sexual stimuli, including, for example, variation in the degree of sexual explicitness (i.e., nude versus dressed targets) and scene content (i.e., pornographic video footage, photographs, artistic depictions etc.). A small set of studies have directly compared pupillary responses to sexually explicit and non-explicit stimuli with inconsistent results. For example, one study assessed pupillary responses of heterosexual female observers and found enhanced dilation for naked male images (Hamel, 1974). However, a later study revealed a generalized dilation response for naked stimuli of both sexes in heterosexual males and females (Aboyoun & Dabbs, 1998). The divergent findings make it difficult to assess the impact of nudity on pupillary responses and it is unclear whether these studies controlled for important stimulus factors, such as identity, colour and pose. Aboyoun and Dabbs (1998), for example, intermixed images of Caucasian and African American men and women, and different identities were presented in the naked and dressed conditions. Strong differences in colour tone could arise from this mixture of race and identity that could interfere with pupillary responses to the sexual content of these images

(Kohn & Clynes, 1996; Lobato-Rincón et al., 2014). More recently, Watts et al. (in press) also compared responses to people in pornographic footage with recordings of other people discussing the weather, again leaving open the possibility that their results might reflect differences in identity or scene content. Therefore, as an additional aim, this thesis sought to investigate the effects of low-level stimulus factors, such as luminance and colour, and scene content on pupillary responses to sexual stimuli.

5.3.1 IMAGE LUMINANCE AND COLOUR

One factor that may directly influence pupillary response is stimulus luminance (Bergamin & Kardon, 2003; Binda, Pereverzeva & Murray, 2013; Ellis, 1981). Experiment 1 examined how image luminance might interfere with pupillary responses to sexual stimuli. This was achieved by comparing responses for scene images in their original quality, or in an enhanced quality condition, with copies of the same stimuli in which mean luminance was equated across all stimulus categories. The results for each of these stimulus categories were highly comparable, which indicates that pupillary responses for the different person categories could not be explained simply by general variation in image luminance.

It is also possible that image colour can affect pupillary responses (Kohn & Clynes, 1996; Lobato-Rincón et al., 2014). This issue was explored in Experiments 2 and 7 by including a condition in which image content was randomized to create a control condition. In this condition, the location of all pixels of each image were randomized, so that the content of the scenes was no longer recognizable but the stimuli provided the same colour content. In both experiments, these control scenes failed to produce dilation patterns that corresponded with responses for the intact scenes (i.e., that matched the sexual interests of the observers). These findings therefore indicate that the pupillary responses that were obtained for the different person categories in the experiments here cannot be explained by the colour information of the photographs.

5.3.2 SCENE CONTENT

To provide a natural setting to display semi-nude people and increase ecological validity, Experiments 1 to 4 employed images that portrayed people in natural scenes. Although these stimuli were selected to be of similar composition and size, this approach resulted in variation of the person content in terms of body posture, facial expression, eye gaze of targets, and so forth. It is therefore possible that this variation could have affected eye fixations around the scenes and pupillary responses (Birmingham et al., 2008). Experiments 6 addressed this issue by comparing pupillary responses to highly-controlled stimuli in which all extraneous non-person content was eliminated and the person content was highly similar in composition, posture and facial expression. In addition to controlling for these factors, Experiment 7 compared pupillary responses for the *same* identities across three conditions (nude, partially nude, dressed). Both of these experiments yielded the clearest pupillary response patterns that are reported here, which were consistent with both male observers' (Experiments 6 and 7) and female observers' (Experiment 7) reported sexual orientation.

Taken together, these findings suggest that subtle variation in luminance, colour and scene content are not sufficient to diminish pupillary responses related to sexual interest. The robustness of this paradigm for measuring sex- and age-preferences is demonstrated further considering that this effect is present across different sexual orientations, and under different stimulus conditions (i.e., natural versus highly controlled scenes). However, the current experiments also suggest that even clearer dilation patterns might emerge when these factors are controlled for.

5.4 Future Directions

Taken together, the experiments in this thesis demonstrate that pupillary responses can provide an index of sexual interest that is sensitive to sexual orientation. More importantly, these experiments suggest that pupillary responses can also indicate adults' sexual interest in specific age groups. However, this research also raises many questions. For example, pupil dilation patterns were identical for sexually explicit and non-explicit stimuli in Experiment 7, and it is unclear why sexually explicit stimuli did not produce enhanced pupillary responses. One possibility is that observers avoided fixating the sexual body regions. To illustrate, heterosexual males only directed 14% of fixations towards the pelvic region of female targets, compared to 22% during the viewing of male targets. One way to address this issue is to record pupillary responses to images depicting only the specific body regions, such as the head, torso, and pelvis, which would require observers to fixate these directly.

Another question that emerges is whether it is possible to exert control over pupillary responses. A small set of studies suggest that the pupils appear resistant to top-down control, such that observers cannot willingly increase or decrease their pupil size (Laeng et al., 2012; Laeng & Sulutvedt, 2014). In these tasks, participants are simply instructed to attempt to dilate or constrict their pupils and are not provided with any specific strategies. However, it may be possible that observers can mentally distract themselves from the task with specific strategies, for example, by thinking of people that they find sexually unattractive. Such forms of distraction engage working memory, and a high working memory load has been shown to elicit pupil dilation (Granholm, Asarnow, & Sarkin, 1996; Kahnemann & Beatty, 1966). If such a strategy is applied during the measurement of sexual interests, then it may be possible to elicit a dilation response throughout, therefore attenuating any differences in responses for specific target categories. In contrast, it may also be possible to *suppress* pupillary responses by triggering executive control prior to the presentation of the stimuli. For example, participants' pupil sizes to aversive stimuli are reduced when these are preceded by an incongruent trial on flanker task (i.e., an arrow pointing in a different direction to other arrows in a display) but not by congruent flankers (i.e., all arrows pointing in same direction) (Cohen, Moyal, & Henik, 2015). In this experiment, incongruent flanker stimuli create a response conflict that requires executive control to resolve, which resulted in reduced emotional interference for subsequently-presented aversive stimuli. Future research should therefore assess pupillary responses to sexual images while observers engage their working memory and executive control.

Another aspect that requires further investigation concerns the emotional state underlying pupillary responses during the viewing of adults and children. Although sexual interest may be triggering pupillary responses for these images, it is also possible that other emotional states contribute to dilation responses. For example, the pupils also dilate during the viewing of positive emotional stimuli concerning people (Bradley et al., 2008). It is therefore possible that images of children might also produce a dilation response that reflects a positive emotional stage, such as affection, rather than sexual interest. Only a small set of studies have investigated the influence of affection on the autonomic nervous system, including cardiovascular, electro dermal and respiratory responses (for review, see Kreibig, 2010), but not with pupillary responses. Therefore, this is clearly an important avenue for further investigation, for example, by comparing pupillary responses for images of one's own children and those of others.

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