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Video-Based Eye Tracking in Sex Research: A Systematic Literature Review

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Although eye tracking has been used for decades, it has gained popularity in the area of sex research only recently. The aim of this article is to examine the potential merits of eye tracking for this field. We present a systematic review of the current use of video-based eye-tracking technology in this area, evaluate the findings, and identify future research opportunities. A total of 34 relevant studies published between 2006 and 2014 were identified for inclusion by means of online databases and other methods. We grouped them into three main areas of research: body perception and attractiveness, forensic research, and sexual orientation. Despite the methodological and theoretical differences across the studies, eye tracking has been shown to be a promising tool for sex research. The article suggests there is much potential for further studies to employ this technique because it is noninvasive and yet still allows for the assessment of both conscious and unconscious perceptional processes. Furthermore, eye tracking can be implemented in investigations of various theoretical backgrounds, ranging from biology to the social sciences.

Eye-tracking technology has already been used in a variety of research fields, such as scene perception (Henderson & Hollingworth, 1999) and clinical research (Toh, Rossell, & Castle, 2011), to measure participants' visual behavior and to gain insight into attentional processes (for a review, see Duchowski, 2002). In sex research, however, its use is relatively new and has gained popularity only in the past decade. The eye trackers most commonly applied are video-based optical measures that use reflections of the eye without direct contact (for different techniques, see Duchowski, 2007). In addition to assessing eye movements, these programs allow pupil dilation to be measured. The continual improvement of measurement quality and accessibility in recent years has resulted in increased application of this technique (Schütz, Braun, & Gegenfurtner, 2011).

Although various eye movements are possible (Kowler, 2011), the most commonly investigated in applied eye-tracking research are saccades and fixations. Saccades are voluntary or reflexive short (30 to 80 milliseconds [ms]) and rapid movements of the eyes. Fixations are periods of time (200 to 300 ms) during which the fixation on a specific characteristic of the visual environment is relatively stable, allowing information to be extracted and processed (Holmqvist et al., 2011). The total amount of time a participant spends looking at one position is measured through the fixation time, gaze time, or dwell time. The number of fixations on a scene region is also commonly assessed. In the course of scene viewing, total gaze time is correlated with the total number of fixations in that region. Fixations that are longer and occur more frequently are commonly taken to be an indication of interest or of a greater level of relevant information, as it seems logical that we would spend more time looking at regions that capture our interest (Henderson & Hollingworth, 1999). While total gaze time could be manipulated by the participant, the first fixation and the first fixation duration after presentation of the stimulus are considered to be related to early attentional processes, which cannot be controlled consciously (Spiering & Everaerd, 2007). Notably, such early viewing measures are largely influenced by the visual features of the stimulus as opposed to its content (Findlay & Gilchrist, 2003).

Another reaction of the eye that is linked to attention, or in particular sexual interest, is pupil dilation, which refers to changes in pupil size (for an overview, see Laeng, Sirois, & Gredeback, 2012). Observers' level of interest in and attention to a visual stimulus as well as their level of physical pleasure are related proportionally to pupillary diameter, with enlarged pupils being interpreted as indicating increased attention or greater sexual arousal (Rieger et al., 2015). While pupil dilation is linked to the autonomic nervous system and is hence difficult to control consciously (Bradley, Miccoli, Escrig, & Lang, 2008), the relationship between eye movements and attention is not

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that straightforward. Despite visual attention and visual extraction of information being two distinct concepts, they are intimately linked (Nobre & Kastner, 2013). The general idea is that visual attention is directed to the part of the visual field on which the eye is fixating (Just & Carpenter, 1976). One exception to this assumption would be having the eyes on a certain spot without consciously paying attention but rather thinking about something else (Posner, Snyder, & Davidson, 1980).

The different outcome measures are generally understood to represent some degree of visual interest. However, eye-tracking data alone does not explain *why* the visual interest occurs. It does not inform us about higher-order processing, and the interpretation of the meaning of visual attention remains relatively unclear (for a review, see Schütz et al., 2011). Still, influences originating from the task (Borji & Itti, 2014) or various other cognitive and emotional processes have been demonstrated (Hayhoe & Ballard, 2005; Nummenmaa, Hyönä, & Calvo, 2006). Unsurprisingly, attentional processes and cognitive biases play an important role in theories of sexual arousal as well (Akerman & Beech, 2012; Barlow, 1986; De Jong, 2009; Dekker & Everaerd, 1989). Sexual stimuli have been proposed as being processed in a manner comparable to other stimuli and interpreted as "evolutionarily meaningful," therefore eliciting an attentional bias and more attentional engagement (Spiering & Everaerd, 2007).

The aim of this article is to examine the potential merits of eye-tracking technology for sex research. This review is divided into three main parts: First, we describe the method employed in this review and introduce search strategies and inclusion criteria. The results, with a particular focus on the potential benefit of eye tracking for sex research, are presented in the second part. Finally, we summarize the findings and limitations of the studies and propose further research directions.

Method

Search Strategy

We conducted an exploratory search with Google Scholar to create the search terms that were applied to identify studies for inclusion in this review. We then checked the electronic databases Web of Science (all databases) and Ovid (including PsycINFO and EMBASE) using the search terms "eye track*, eye movement* OR pupil dilation," and "sex*, attraction, nudity, porn* OR mate choice." The two results were combined by the AND operator so all studies included at least one word from either group. No topic, field, time, language, or design restrictions were made for the search in the databases. Nonetheless, due to the search terms it is unlikely that studies without English abstracts or keywords were found. We added more current references during the review of the papers and checked all articles for additional studies that also matched the inclusion criteria. The search was carried out in August 2014 and produced a list of 3,541 unique citations published between 2006 and 2014.

Inclusion and Exclusion Criteria

To be included, studies must have (a) used a video-based eye-tracking technique; (b) been published in a peer-reviewed journal; (c) been empirically based; (d) reported original research findings; and (e) been conducted about a topic relating to sex research (e.g., body perception). We excluded studies that (a) used other techniques to assess eye movements, (b) focused on gender differences not related to sex research (e.g., anatomical differences), or (c) exclusively used faces as stimulus material. Faces are considered to be special cues that are processed somewhat differently from other cues (Minnebusch & Daum, 2009). There is a large research field face perception that is beyond the scope of this review (see Bruce & Young, 2012). Although some studies investigated gender biases or beauty, the research questions were usually not directly linked to sex research (for reviews, see Herlitz & Lovén, 2013; Palermo & Rhodes, 2007; Rhodes, 2006; Thornhill & Gangestad, 1999).

Data Extraction and Search Results

After duplicates were removed, the first author checked the titles and abstracts of all the citations to determine which studies met the review's inclusion criteria. The excluded studies either did not use eye tracking or were focused on methodological questions. Others were disregarded for various reasons, including the investigation of general perceptual processes or viewing behavior of patient groups (e.g., autism). The search of titles and abstracts revealed a total of 64 articles that required a full-text review before a decision about inclusion or exclusion could be made. All studies under consideration were summarized by the first author. All three authors discussed whether the studies met the criteria and decided on the 34 articles to be included. Most of the excluded studies investigated other forms of visual evaluation (e.g., viewing time). In some cases, eye tracking was applied only to ensure that the stimuli were fixated upon but not as a measurement itself. Other studies investigated gender differences not directly linked to sex research (e.g., mental rotation) or showed stimuli that were unrelated (e.g., flick of hair). The majority of the reviewed studies were conducted in the United States, the United Kingdom, or Germany. They were diverse in their research foci and approaches, and we hence thematically grouped them to facilitate reading and comparison.

Eye Tracking and Sex Research: Results

As mentioned, eye tracking allows visual attention to be analyzed. In sex research up until now, this capacity has

chiefly been used in three areas. Most of the research we found focused on viewing behavior with regard to bodies, especially concentrating on attractiveness. A second group of articles addressed forensic questions, predominantly in the context of pedophilia. The third group was concerned with questions about sexual orientation. Consequently, we present the research in three thematically organized sections covering the areas of body perception and attractiveness, forensic research, and sexual orientation.

Body Perception and Attractiveness

The largest group of studies presented in this review focused on body perception and perception of attractiveness. This is not surprising, because the assessment of human beauty standards and attractiveness are linked to the human body and have attracted researchers' attention for centuries (Douglas & Shepard, 1998; Langlois et al., 2000; Lindell & Lindell, 2014). The added value of eye tracking in this line of research is the possibility of showing precisely where and how participants look when perceiving bodies.

To explore what they consider "natural" gaze behavior, many researchers ask their participants to freely look at a stimulus (free exploration). Other researchers investigate eye movements during specific tasks (e.g., attractiveness ratings), as a general influence of the task on viewing behavior is well-known.

Free Exploration. Lykins, Meana, and Kambe (2006) were the first to study viewing patterns in response to erotic and nonerotic stimuli using eye tracking. Participants fixated more and longer on erotic photos than on nonerotic photos. With pictures of models in casual clothing, participants tended to look at faces first (Hall, Hogue, & Guo, 2011, 2014; Hewig, Trippe, Hecht, Straube, & Miltner, 2008; Nummenmaa, Hietanen, Santtila, & Hyönä, 2012). This corresponds to research on the importance of faces for mate choice and social interaction (Hari & Kujala, 2009; Minnebusch & Daum, 2009). However, participants inspected nude bodies more thoroughly, and fixations were biased away from the face and toward the chest and pelvic regions. Fixating on these regions was also associated with elevated physiological arousal, which was measured by pupillometric responses and self-report (Nummenmaa et al., 2012). Lykins, Meana, and Strauss (2008) described a similar bias for stimuli that were dressed but posing in a sexual manner.

Several studies found gender differences in viewing behavior regarding dressed (Hall et al., 2011; Hewig et al., 2008; Lykins et al., 2008) as well as undressed figures (Nummenmaa et al., 2012). For erotic and nonerotic images of heterosexual couples, men gave greater visual attention to opposite-sex models, whereas women divided their attention more evenly between opposite- and same-sex models (Lykins et al., 2008). More specifically, Hall and colleagues (2011) reported that heterosexual men dedicated more fixations and for longer durations to the upper body and waist only for females of their preferred age. No comparable consistency in patterns was found for women, and it was hence considered unlikely that eye tracking directly mirrors their sexual interest. Results are often interpreted as a reflection of selective attention to signals relevant to choosing a sexual partner suitable for reproduction. A greater specificity for men is in line with results obtained from other measures, such as physical arousal (Chivers, 2010) and viewing time differences (Israel & Strassberg, 2009), which have already demonstrated a greater "nonspecificity" of sexual arousal in women. However, based on their results using video material with different levels of explicitness, Tsujimura and colleagues (2009) speculated that men and women may display similar visual attention patterns if the sexual stimuli are sufficiently explicit.

Differences have been reported not only between genders but also within each gender. Men who scored high on sexual compulsivity directed more gaze to the waist-hip ratio (WHR) of women and of their preferred age (Hall et al., 2014), while men with a high degree of social introversion had a tendency to view sexual regions for a shorter duration (Tsujimura et al., 2010). Concerning dilation, pupils of both men and women dilated more to sexual than to other auditory stimuli, but pupils of men with low testosterone levels dilated for shorter durations (Dabbs, 1997). Rupp and Wallen (2007) reported hormonal influences for females as well. When seeing heterosexual couples involved in sexual acts women taking oral contraceptives spent more time looking at female bodies, clothing, and background. In contrast, women with a normal cycle looked more at the genitals of both sexes than at any other scene region. A clinical group of women reporting painful intercourse showed a comparable pattern to those taking oral contraceptives (Lykins, Meana, & Minimi, 2011). The authors concluded that these women were either distracted from the sexual aspects of the picture or avoided these sexual regions. They further suggested exploring the potential of eye tracking in the multidisciplinary treatment of sexual dysfunctions similar to its use in treatment of other psychological symptoms (see Discussion section that follows).

Attractiveness Ratings. What influences the perception of attractiveness is subject to a large debate in which a wide range of factors such as body shape or personality are being discussed (for a review, see Langlois et al., 2000). Eye tracking could contribute relevant information to at least some of these questions. In all the studies presented in this section, participants were asked to rate the attractiveness of the presented stimulus while their eye movements were being recorded. In particular, men's viewing behavior regarding women, as well as gender differences in viewing behavior, have been investigated.

Fromberger, Jordan, von Herder, and colleagues (2012) established the idea of reliable attentional biases for sexually relevant stimuli. Heterosexual men showed longer fixation durations and more first fixations to the sexually relevant stimulus (woman) when simultaneously presented with a

sexually irrelevant stimulus (girl, boy, man). Eye tracking has also added to research on the importance of female body shapes, especially the WHR, for male evaluation (for a review, see Marani & Koch, 2014). Men fixate more and longer on images of women with a lower WHR and also select them as more attractive (Suschinsky, Elias, & Krupp, 2007). Similar results were obtained from a Turkish study but only for the male and not for the female participants (Dural, Cetinkaya, & Guelbetekin, 2008). Dixson, Grimshaw, Linklater, and Dixson (2010) further specified that for back-posed images of women, men attended more to the midriff and the buttocks, while for front-posed images the female breasts were especially relevant. However, there is a growing amount of literature suggesting that body mass index (BMI) rather than WHR per se is relevant in rating female attractiveness (Cornelissen, Tovée, & Bateson, 2009). Addressing this issue with eye tracking resulted in very similar fixation patterns for groups rating attractiveness or estimating BMI. Fixations clustered in the central and upper abdomen as well as on the chest. In contrast, another group estimating WHR looked less at the center of the torso but more on the edge of the waist and upper hips. The authors interpreted this as demonstrating different processes underlying WHR estimation compared to BMI or attractiveness ratings (Cornelissen, Hancock, Kiviniemi, George, & Tovée, 2009).

Notably, Melnyk, McCord, and Vaske (2014) further stressed the individual differences in male gazing patterns. In their pilot data, they found consistent gaze patterns within a given male, which may override characteristics of fixation points evoked by the stimulus itself. Statistical analysis revealed two systematic clusters of individual differences: Both groups exhibited a strong orientation toward the face, but one group distributed their time much more evenly among other areas of interest.

Instead of evaluating whole body images, some studies also focused on the importance of single signals. Investigating the relationship between WHR and breast size, Dixson, Grimshaw, Linklater, and Dixson (2011b) showed images of naked women that were digitally altered in WHR and breast size. Men looked at breasts more often and for longer, irrespective of WHR. No differences in eye movements were found for specific features of female breasts (breast size, areola pigmentation), although attractiveness ratings differed (Dixson, Grimshaw, Linklater, & Dixson, 2011a). Comparing individual preferences for either breasts or buttocks, Dagnino, Navajas, and Sigman (2012) reported a bimodal distribution of preferences in Argentinian men. Their participants fixated the preferred body part first and last in the decision-making process.

Other Tasks. Questions concerning partner choice that go beyond attractiveness ratings have also been addressed using eye tracking. From a rather evolutionary perspective Dixson, Grimshaw, Ormsby, and Dixson (2014) asked women to judge different men's back-posed bodies for the potential of a short- or long-term relationship. Unlike in other studies (Little, Connely, Feinberg, Jones, & Roberts, 2011), neither attractiveness ratings nor eye movements differed according to short-term or long-term evaluation. Concerning somatotypes, only heavy-set men evoked specific eye movements, with the lower back instead of the upper back capturing most attention. Notably, the authors stated that the effect could either be due to the information obtained from this specific region or to the uniqueness in heavy-set men relative to the other somatotypes.

Investigating the relationship between social status and attraction, Maner, DeWall, and Gailliot (2008) presented evidence suggesting that observers selectively attend to male, but not female, targets who display signs of social dominance. For female targets, signs of physical attractiveness were focused on more (DeWall & Maner, 2008).

Different intentions have also been studied with regard to a more social context. When making decisions about romantic love, Bolmont, Cacioppo, and Cacioppo (2014) found that their participants were more likely to fixate on and look longer at faces. In contrast, when showing sexual interest, their gaze was more frequently directed at the body and longer in duration. Interestingly, no gender effects could be observed. Furthermore, objectification theory suggests that the focus is shifted from face to body, and especially to sexual body parts, when people objectify women (Fredrickson & Roberts, 1997). Gervais, Holland, and Dodd (2013) presented empirical evidence regarding the nature of this so-called objectifying gaze. Men who were asked to focus on appearance revealed an increased tendency to initially exhibit the objectifying gaze compared to men who were asked to focus on the women's personality.

Summary. Summarizing the use of eye tracking in research on body perception and attractiveness, we can conclude that the method contributes detailed information to a variety of fields of study. In particular, the question as to where exactly people direct their visual attention can be answered. A comparison of the studies' findings provides insight into the effects of different intentions, as well as of gender differences in viewing behavior. Overall, there was a tendency to look at the face when presented with a whole body image across studies. However, this varied as a result of different factors, such as stimulus explicitness or task. Men's viewing behavior seems to be more stimulus specific, while women tend to disperse their attention more evenly. This difference in specificity coincides with other physical measures (Chivers, 2010; Israel & Strassberg, 2009). Further research is needed concerning the suggested harmonization of male and female viewing patterns due to explicitness of stimulus material, especially because such a finding would differ from results obtained with other measures. On a different note, it should be taken into consideration that many different influences on an individual level, such as personality, sexual cognition, and hormonal status, modify eye movements in a complex way. The use of

different participant groups would be helpful when seeking to clarify such variation.

It should be noted that most of the research conducted in the field of visual attention and body perception has been conceptualized within a theoretical framework of evolutionary psychology. Papers focusing on the social conditions of visual perception are currently in the minority. A greater theoretical diversity of studies would be desirable, at least to further develop the utilization of eye-tracking methodology in a diversified context.

Forensic Research

Studies associated with forensic research mainly center around pedophilic sexual interest. Recurrent sexual interest in prepubescent children is one of the strongest single predictors for recidivism in child sexual abuse (Hanson & Morton-Bourgon, 2005); thus, the valid and reliable diagnosis of this preference is of particular importance. In North America penile plethysmography (PPG) is still considered to be the gold standard in the assessment of sexual preferences and is widely used in both research and clinical settings (for a review of measures of deviant sexual interest and arousal, see Akerman & Beech, 2012). Although PPG has gained some recognition, it has been criticized repeatedly for various flaws, including its vulnerability to faking (Laws, 2009). This is relevant in forensic settings, where PPG results have an influence on risk appraisal or even release approval. However, the criticism about potential faking could be addressed by combining PPG with eye tracking: Preliminary results by Trottier, Rouleau, Renaud, and Goyette (2013) demonstrated how eye tracking could help improve the internal validity of PPG. Their results suggest that attempts to control erectile responses generated specific eye-movement variations. The exploration process was slowed down and the exploration of the erogenous zone was limited. These findings indicate that recording eye movements can provide relevant information about the presence of competing covert processes responsible for erectile inhibition.

Fromberger and colleagues (2013) assessed automatic and controlled attention for men with pedophilic interest compared to nonpedophile individuals. Pedophile men looked significantly faster at child than at adult stimuli. Notably, relative fixation durations, which can be consciously manipulated, were longer on adult stimuli than on child stimuli. This result is interpreted as a confirmation of the hypothesis that pedophile men automatically select sexually relevant stimuli (children). Furthermore, pedophile men looked first and longest at the faces and pubic regions of children, whereas nonpedophile men focused on faces and breasts of adults. Following the idea of developing a method to distinguish pedophilic from nonpedophilic men via eye-tracking data, Fromberger, Jordan, Steinkrauss, and colleagues (2012) evaluated the diagnostic accuracy of eye-movement parameters. Their method, based on fixation latency, discriminated between pedophilic and nonpedophilic subjects with a sensitivity of 86.4% and a specificity of 90.0%. Cross-validation also demonstrated good validity of eye-movement parameters with equal or better results for the classifier compared with other measures (e.g., viewing time, Implicit Association Test results, PPG results). The authors hence concluded that eye tracking is a promising approach when assessing pedophilic interest. Nevertheless, as with other physiological measures, the differences obtainable on group levels should not be used for individual diagnosis.

With regard to the evaluation of antiandrogen therapy (ADT) for pedophilic men, Jordan, Fromberger, Laubinger, Dechent, and Müller (2014) examined the effectiveness of a new eye-tracking and functional magnetic resonance imaging (fMRI) design based on the case of one exclusively pedophilic forensic inpatient. Before ADT the patient showed a significantly higher relative fixation time for images of girls compared to images of women. After four months of ADT, this pattern was reversed. He fixated on images of girls for a shorter amount of time but longer on images of women. The authors interpreted this change in attentional processes as either reflecting an increased ability of the patient to avoid deviant sexual stimuli or a lowered need to look at it due to potentially reduced sexual drive caused by ADT. An improved ability to manipulate answers in a socially desirable manner may serve as another explanation. More research is needed to shed light upon this question. Automatic attentional processes, which the authors consider as representing sexual preference, remained mostly unchanged. They consequently reasoned that the ADT had no impact on the pedophilic preference of the patient.

Beyond research on pedophilia, eye tracking has been used to investigate the influences of cognitive biases on rape cases and on dating violence survivors. Süssenbach, Bohner, and Eyssel (2012) studied the schematic influences of rape myth acceptance (Burt, 1980) on visual information processing. People with high rape myth acceptance endorse stereotypes about victims and perpetrators in the contexts of assaults (Bohner, Eyssel, Pina, Siebler, & Viki, 2009). After reading a short text on a rape case, students viewed an alleged police photograph of the room in which the rape supposedly happened. The picture contained two potentially rape-myth-consistent cues, one expected (wine bottle) and one unexpected (poster of a nude torso). Generally, higher acceptance of rape myths was related to more victim blame and less perpetrator blame as well as to more lenient verdicts. Eye tracking further revealed differences due to the expectedness of the cues. Participants with higher rape myth acceptance fixated the expected cue earlier and more briefly but had longer initial fixations on the unexpected cue. The differences in encoding were equally strong but inversely correlated with the overall case evaluation. Because the manipulation of participants' level of rape myth acceptance in a second study affected eye movements, the authors interpreted rape myth acceptance as a cognitive bias actively guiding visual information processing. Future studies should focus on the conditions when schema-related stimuli

become so highly expected that they are detected faster and encoded more efficiently.

Concerning the victims of rape, Lee and Lee (2012) investigated the time-course characteristics of attentional bias toward violent stimuli in two groups, one of dating violence survivors and one of individuals without such experiences. Results showed that the survivors spent more time on dysphoric stimuli and less time on happy stimuli. The authors suggest that the type of attentional differences could thus form the basis for trainings on shifts of attention. This is related to clinical research on anxiety in which eye tracking helped shed light on the processes of maintaining versus avoiding attention (Armstrong & Olatunji, 2012).

Summary. The results presented in this section underline the potential usefulness of eye tracking within forensic contexts, and specifically for the assessment of automatic processes, which are supposedly not consciously controllable. In particular, eye tracking demonstrated similar or better accuracy in the classification of pedophilic interest when compared to other methods for diagnostic assessment. However, individual diagnosis should not be based solely on eye-tracking assessment, because additional information is always necessary to meet the complexity and requirements of diagnosing deviant sexual preferences. The influences of the cognitive bias of rape myth acceptance as well as the effects on viewing behavior of dating violence victims have also been presented. In this context, eye tracking was also suggested as a potential tool for the development of behavioral trainings, which could be an interesting subject for further research (see the Discussion section). Other forensic questions that go beyond these examples remain uninvestigated with eye tracking (e.g., other forms of sexual deviance besides pedophilia).

Sexual Orientation

Investigation of the differences between heterosexual and nonheterosexual people has a long tradition in sex research. Although no universal definition of sexual orientation exists (van Anders, 2015), it is often understood as the orientation toward the preferred sexual stimulus in research with psychophysiological measures (Bailey, 2009). The use of pupillometry to determine a subject's sexual preference dates back to the 1960s (Hess, Seltzer, & Shlien, 1965) but has been criticized for poor methodology and statistical errors (Aboyoun & Dabbs, 1998; Zuckerman, 1971).

However, Rieger and Savin-Williams (2012) recently resumed this line of research. Converging evidence from areas of sexual psychophysiology, visual attention, and brain response suggests that men's response is specific to preferred sexual stimuli while women's response appears to be nonspecific (Chivers, 2010). Self-defined hetero-, homo-, and bisexual men as well as homosexual women exhibited greatest pupil dilation with regard to their erotic target, whereas bisexual and heterosexual women exhibited less category-specific patterns. Also, substantial dilation to both sexes was most common in heterosexual women and bisexual men. Following these findings, Rieger and colleagues (2015) simultaneously assessed genital and subjective arousal in addition to pupil dilation. The measures were both associated with each other and with self-reported sexual orientation, albeit stronger in men than in women. The more specific (male-typical) pattern of homosexual women compared to other women and the more unspecific (female-typical) pattern of bisexual men compared to other men are considered gender atypical. Because the differences in specificity remained across methods, they could not be explained solely by measurement artifacts. The authors therefore suggested the existence of gender-reversed patterns for specific groups. The only eye-movement analysis concerning sexual orientation conducted to date demonstrated a bias for sexually preferred stimuli in homosexual men (Fromberger et al., 2013). Fixation time was longer and first fixations were more often directed toward the preferred sexual stimulus (a man for homosexual men) compared to the non–sexually preferred stimulus.

Summary. Eye-tracking research on sexual orientation is relatively new and its methodology is not yet fully developed. The research presented in this section suggests that viewing patterns and pupil dilations vary for different groups of nonheterosexual participants. In summary, it can be said that up to now results are in line with research using other methods. This consistency, however, indicates similarity for a psychophysiologically operationalized understanding of sexual orientation. Questions that arise in relation to the concept of sexual orientation itself may still persist. From a constructivist point of view, the concept can be understood as a heterogeneous social construct rather than a uniform phenomenon with a biological foundation. From this perspective, the objective measurement of a supposedly uniform sexual orientation could at least be called into question. Eye tracking could, however, be used in further studies on diversity to investigate how self-categorization and other influences connected to sexual preferences and identity interact (van Anders, 2015).

Discussion

The literature reviewed here has demonstrated a variety of different applications for eye tracking in sex research. However, it has also revealed how difficult aggregation and comparison of the presented results are due to the small number of similar studies conducted so far. The research presented differed in terms of theoretical basis, methodological procedures, stimulus material, and tasks, as well as in terms of participant groups. It is because of this versatility that we regard eye tracking to be a powerful tool. In the following section, we discuss the value eye tracking has to offer for sex research. We summarize the information on methodological and theoretical aspects gathered from the

articles reviewed and make recommendations for future research.

The Value of Eye Tracking for Sex Research

Eye tracking allows for the direct assessment of eye movements, which are closely linked to visual attention. According to the model of the process of sexual arousal presented by Singer (1984), eye movements correspond to the first of three stages. Hence, they are measurable earlier, and fewer assumptions about the process are needed than for the third stage of genital arousal. This close link to visual attention also causes the high level of face validity that eye tracking has for testing sociocognitive functions. Unlike vignette techniques, showing a picture is not that well structured and thus reduces demand effects while increasing the potential of subjective interpretations by participants. By capturing image perception, eye tracking further bypasses written and spoken language, thereby eliminating language biases. This makes it more attractive for cross-cultural studies. In contrast to data from self-reports, eye tracking supposedly captures behavioral information that can be out of reach of conscious control and manipulation (e.g., covert processes of attention). This is of particular concern in some areas of sex research (e.g., clinical or forensic contexts), where participants are motivated to answer in a certain way. Because fixation latency is considered to be an indicator of early attentional processes, faking or socially desirable behavior might be detected and consequently diminished using eye tracking. Still, the assumed immunity of automatic processes to faking should be further tested so as to be based on solid empirical ground. Compared to other physiological measures (e.g., fMRI, electroencephalogram [EEG]), eye tracking is easily applicable. Preparation, measurement, and limited analysis can be done fairly quickly, in particular when using commercial systems. Although high-end systems are still fairly expensive, prices are decreasing (Goldberg & Wichansky, 2003) and low-cost systems of acceptable quality are emerging (Mantiuk, Kowalik, Nowosielski, & Bazyluk, 2012).

Unlike genital arousal measures, eye tracking is not invasive and hence less likely to attract special participant groups (Strassberg & Lowe, 1995). Eye tracking functions by means of the same organ for both sexes and therefore permits direct comparisons (Rieger & Savin-Williams, 2012). Advantages of viewing time and reaction time measures include, among others, the exact evaluation of the regions looked at (Armstrong & Olatunji, 2012).

Theoretical Perspectives and Applications

Eye tracking offers a comprehensive method for recording eye movements, allowing for an indirect examination of visual attention. The reasons why specific eye movements have occurred can be interpreted from different theoretical perspectives. In the field of sex research, however, eye tracking has mainly been used from rather "essentialist" perspectives (e.g., for biological, evolutionary, or cognitive psychological and medical studies), while "constructionist" approaches are clearly underrepresented (DeLamater & Hyde, 1998). Nevertheless, various theoretical backgrounds could make use of the technology in the future, including those with sociocultural perspectives. These perspectives comprise but are not limited to different social constructionist approaches to sexuality (e.g., sexual scripting approach; Gagnon & Simon, 1973), feminist and queer theories, and intersectional approaches (for a review of theories, see Tolman & Diamond, 2014). Because the use of true-to-life stimulus material is possible, eye tracking could, for example, be used to assess the perception of complex sexual scenes in the context of participants' different intrapsychic and interpersonal scripts.

Eye tracking is already providing new information in the disambiguation of body cues relevant for the evaluation of aspects such as attractiveness, health, and fertility. However, additional comparative studies are needed to disentangle how biological, cognitive, and more sociocultural influences might interact. While cognitive influences have so far been investigated on a rather basic research level, such influences might also be of practical use with clinical and forensic subjects. This might eventually help in (sex) therapy, for example, by increasing the reliability of the diagnosis, for measuring therapeutic outcomes, or for developing cognitive trainings. Such trainings for attentional shifts based on eye-tracking results are already under investigation with pedophile men in a virtual-reality context (Renaud et al., 2005). Meta-analysis revealed consistent positive effects of comparable cognitive bias modifications on anxiety and potentially on depression (Hakamata et al., 2010; Hallion & Ruscio, 2011). Specific influences of eye movements on the effectiveness of these attention trainings are discussed (Armstrong & Olatunji, 2012). Also, the assessment of time courses in viewing is considered important for advances in theoretical models (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007).

Eye tracking is a much appreciated tool for the evaluation of websites (Nielsen & Pernice, 2010) and offers new fields of application in the context of online content (e.g., seeking sexual health information, online dating). Moreover, new mobile eye-tracking devices that permit measurement in real-world settings and in the context of natural action (e.g., dating situations) could be interesting from a variety of theoretical perspectives. However, influences of the awareness of eye-movement measurement on participants' looking behavior need to be considered (Risko & Kingstone, 2010).

Methodological Aspects

In the studies reviewed, static eye trackers and fixation-based outcome measures were most often used. For future research, additional and more recently developed outcome measures (e.g., saccades, blinks, scanpath) and the emerging

portable trackers (e.g., goggles) should be examined (Holmqvist et al., 2011).

Procedures varied on different levels (e.g., number of stimuli, presentation duration). Generally, stimuli were presented individually or in small groups for purpose of comparison while the common tasks were free exploration or attractiveness ratings. Depending on the design and the research question, each method of presentation and each task entails advantages as well as disadvantages. Eye movements are basically influenced by the visual stimulus, the intent, and the person investigated (Ma, Sim, & Kankanhalli, 2013). Different kinds of contextual factors (e.g., task order, length) and complex interactions among them influence eye-movement data (Goldberg & Wichansky, 2003) and hence need to be evaluated for every study. The procedure and stimuli used, as well as the eye-tracking system best suited for measurement, depend largely on the research question. Hence, no standard procedure can be recommended for data collection (Holmqvist et al., 2011). Consequently, meta-analytic aggregation is very challenging. Although multiple authors report similar-sounding values (e.g., number of fixations on the face), the specific details (e.g., how the face region is defined) differ greatly. Findings should therefore be presented in sufficient detail for the subsequent aggregation and interpretation.

Eye tracking can be used for (cross-)validation in combination with other psychophysiological measures (e.g., fMRI, genital plethysmography), as well as with subjective responses. Initial evidence indicates a high level of concordance between genital arousal measures and pupil dilation (Rieger et al., 2015). Further determining how the different measures (e.g., eye movements and blood flow) are linked seems valuable to improve external validity and gain additional insight into the processes mediating viewing behavior and sexual arousal.

Stimulus Material

With regard to stimulus material most studies used images of real or computer-generated human figures, which varied from fully clothed to completely naked. The majority of the stimulus material was retrieved either from freely available Internet or magazine sources. Alternatively, photographs were taken according to the specific purposes of the study. In some cases, stimuli were digitally altered to enable comparisons of specific aspects. It is important to take into consideration that digital alterations might lead to uncommon appearances. These might draw attention due to novelty rather than due to attraction (Bateson, Cornelissen, & Tovée, 2007). In this context, different types of lower-level (e.g., contrast, luminance, color) and higher-level features (e.g., perceived attractiveness) are additionally expected to alter viewing behavior and need to be considered (Findlay & Gilchrist, 2003). There was little variation in age and ethnicity in the stimuli presented. However, age, gender, and ethnicity have been shown to influence perception as well as stereotypes about sexuality (Lai & Hynie, 2011; Petersen & Hyde, 2010). Related aspects of social inequality could be investigated from an intersectional perspective (Kim, Puri, & Kim-Puri, 2005).

Sexually explicit material has been used in only a few studies. Because results indicate a decrease in gender differences for more explicit material, future research should include variations in the degree of explicitness to test this hypothesis. Body poses, movements, and interactions with facial features—especially for attractiveness—also need further investigation (De Gelder, 2009; Fink, Weege, Neave, Pham, & Shackelford, 2015).

Databases with images that can be used to induce specific psychophysiological states have been built up in other contexts (e.g., the International Affective Picture System [IAPS]; Lang, Bradley, & Cuthbert, 1999). Unfortunately, doing something similar in sex research appears difficult due to the variation in (sexual) preferences and research questions, which limit the comparability across different studies. Importantly, the use of photographic images portraying real models is a difficult topic that raises legal and ethical concerns, particularly regarding the assessment of pedophilic interest (Laws & Gress, 2004). Most studies in this context therefore used computer-generated stimuli or (standard) sets that do not display images of real people and that meet contemporary legal and ethical requirements. Almost all studies used still images. However, some researchers argue that static stimuli are not ecologically valid (Fisher & Voracek, 2006). Videos have been demonstrated to evoke the highest levels of physiological and subjective arousal (Julien & Over, 1988) and are considered to be more representative of real-life human interaction. Video material may therefore elicit more authentic patterns of visual attention in sexual situations.

Participants

As far as the participants are concerned, mostly young, heterosexual students from Western societies have been investigated. So far, little variety exists in terms of participant age, cultural background, personal attitudes, or sexual preferences. Studies that directly compare such potential individual influences are needed. From other research it is known that preferences change during maturation (Connolly, Slaughter, & Mealey, 2004). Such impacts of age and interactions with stimulus age should also be subject to further investigation. So far, only a few studies have investigated non-Western participants, and cross-cultural comparison is lacking. Because eye movements have already been shown to differ across cultures for face perception (Blais et al., 2008) further research seems relevant. Concerning broader participant diversity, some research has been conducted with groups in forensic contexts (e.g., men with pedophilic interests), and one study involved a clinical group (women with pain during intercourse). Other participant groups (e.g., patients with sexual dysfunctions) could help shed light on differences in attentional processes

that might be helpful for a better understanding of the underlying processes. Comparing viewing behavior might also help to understand changes in sexual preferences. Such changes have been frequently reported by transsexual persons (Auer et al., 2014). Assessing eye movements might also help comprehend when and how such changes occur. To do this, additional designs, such as longitudinal studies, would need to be realized. One explanation for such changes, but also for other variations, may be the influence of sex hormones (e.g., oxytocin, testosterone). Very few studies thus far have addressed hormonal influences on eye movements in sex research, but effects have been revealed, for example, when processing faces (Anderson et al., 2010; Gamer, Zurowski, & Büchel, 2010; Guastella, Mitchell, & Dadds, 2008). Furthermore, eye tracking has already been used successfully in one single-case study of hormonal therapy (Jordan et al., 2014).

Limitations of the Review

Our conclusions are based on the selected set of research publications that we were able to identify for inclusion in our review. Studies that are neither indexed nor published in peer-reviewed journals have therefore been disregarded. Due to the scope of this review, studies of face perception have not been taken into account. Because eye tracking has been used extensively in this field, these results should be taken into consideration when conducting research that involves faces.

Conclusions

Summarizing this review, it is obvious that the potential applications of eye tracking are immense and that many valid results in line with other measures have been obtained. The technology offers several methodological advantages for sex research because it is noninvasive but still allows for the assessment of both conscious and unconscious processes. The diverse findings clearly demonstrate that visual attentional processes play an important role in human sexuality. However, it is essential to keep in mind that eye tracking primarily allows for the assessment of visual attention. Influences on various levels, ranging from stimulus presentation to cultural differences, can alter viewing behavior with regard to the research question. Consequently, design and analysis of the experiments should always be conducted with caution to allow for interpretation of the data. In addition, possible effects of unintended contextual influences need to be controlled for and reported. Because availability, usability, and accuracy of commercially distributed eye-tracking systems are increasing, while handling difficulties and prices are decreasing, it is very likely that their use in sex research will expand. The different application areas have so far only been touched upon and could, for example, be extended to attentional trainings or mobile tracking. For a higher level of contribution of eye tracking to sex research, we additionally recommend using this technique for investigation from different theoretical backgrounds, especially from a sociocultural perspective. We are curious to see how the use of eye tracking will develop in the coming years.

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