What do the eyes tell us about sexual preferences according to the age and sex of the stimuli? Connecting attention and eye movements to pedophilia

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Abstract

Attention plays a central role in current theories about the processing of sexual information. Attention paradigms, such as eye tracking, have been used to study sexual preferences for men (androphilia) or women (gynephilia). More recently, eye tracking has also been used to study the atypical sexual preference of pedophilia, which represents sexual attraction to prepubescent children. The aim of this review is to apply a conceptual model of attentional processing in sexual response, the information processing model, and show how eye-tracking is a useful indirect measure of both typical sexual preferences such as androphilia and gynephilia and atypical preferences such as pedophilia. Implications for research are discussed in terms of recognizing the value, scope, and limitations of eye-tracking paradigms in the study of pedophilia, and hypothesis generation using this type of indirect measures of human sexual response.

Keywords: Eye-tracking, attentional processes, typical sexual preferences, atypical sexual preferences, Pedophilia.

Introduction

The use of eye-tracking technology in sexuality research is relatively new and has become popular in the last decade as a tool to examine cognitive processes underlying the processing of sexual information (Duchowski, 2017; Wenzlaff et al., 2016). Eye-tracking is a low cost, non-invasive technique, less susceptible to manipulation than other techniques, that facilitates free participation with lower restrictions in studies of sexuality. Because of this, it is a promising methodology for the evaluation of both typical and atypical sexual preferences (Snowden et al., 2011).

In contrast to other recent empirical reviews of eye-tracking research (Carvalho et al., 2020; Wenzlaff et al., 2016), the aim of this article to apply a conceptual model of attentional processes in sexual response, the information processing model, and show how eye-tracking is a useful indirect measure of both typical sexual preferences such as androphilia (referring to teleiophilic androphilia, or attraction to men) and gynephilia (teleiophilic gynephilia, or attraction to women) and atypical preferences such as pedophilia (attraction to prepubescent children) and perhaps other chronophilias (see Seto, 2017). These constructs (automatic and controlled processes, early and late attention, implicit and explicit memory, first and duration of fixations), which explain the relationship between sexual preferences and eye movements, are specified and both theoretically and empirically documented, based on what is known about the cognitive mechanisms that underlie typical (e.g. gender differences in preferences towards adults the opposite sex), as well as atypical sexual preferences, both deviated, according to the age of the stimulus (e.g. pedophilia) and not deviated, according to the sex of the stimulus (e.g. preferences for adults of the same sex), using indirect cognitive measures of human sexual response such as eye-tracking.

Cognitive-motivational model of sexual arousal: the role of visual attention

Sexual arousal is made up of subjective and objective arousal. The former refers to the evaluation and categorization of the stimulus as sexually preferred (Janssen et al., 2000; Stoleru et al., 1999), and

the latter to the physiological response, which includes changes in cardiovascular, respiratory and genital activity, as well as vaginal vasocongestion and lubrication in women, and penile erection in men (de Jong, 2009; Janssen et al., 2000). The interaction of both components gives rise to sexual behaviors of approach or avoidance of a stimulus (Geer & Bellard, 1996).

In the cascade of excitation produced by a stimulus, physiological sexual arousal, by itself, is not enough to trigger subjective sexual arousal. The variation in this experience will depend on the awareness and classification of this response as sexual (Janssen & Everaerd, 1993). Thus, a stimulus becomes sexual from the interaction between cognitive and physiological processes that give rise to a particular subjective sexual response in the presence of the stimulus (Spiering & Everaerd, 2007). In turn, this interaction may be the result of biological, neurochemical, hormonal, and psychological factors that contribute to the construction of the cognitive assessment of the stimulus.

The two most prominent cognitive models of sexual response are the information processing model developed by Spiering and Everaerd (2007) and the incentive motivation model developed by Toates (2009; 2017), that integrate cognitive, motivational, and behavioral factors. They obviously differ on emphasis and some elements, but they have much in common, especially the importance of pre-conscious then conscious attention following the presentation of a sexual stimulus.

In this paper, we link eye-tracking research findings to these cognitive models of sexual response, and propose how this methodology can be used to illuminate not only typical preferences for men or women or both, but also atypical preferences for prepubescent children.

The extended model from Barlow (1986) proposes that affective mechanisms impact attention, which then contributes or detracts from sexual arousal, and potentially further amplifies the initial affective reaction (de Jong, 2009; Janssen, 2011; Samson & Janssen, 2014). The identification of aversive and appetitive stimuli is essential for survival and adaptation, and therefore it is a function of attention (Krupp, 2008). Sexual stimuli are appetitive stimuli that offer information about the sexual

maturity, reproductive potential, fecundity, healthiness, and genetic quality, perceived as the sexual attractiveness of a potential partner, so that attention has a relevant role to obtain that information through the perceptible signals of sexual stimuli (Dixson et al., 2015; Feinberg, 2008; Nettle, 2002; Salska et al., 2008; Suschinsky et al., 2007).

The information processing model of sexual response (Spiering et al., 2003; Spiering & Everaerd, 2007) explains the interaction between the physiological and subjective mechanisms that give rise to the sexual response, based on the integration of top-down (automatic) and bottom-up (controlled) processes (Janssen et al., 2000; Laan & Janssen, 2007). The connecting bridge between these processes and sexual arousal is attention, and eye movements are a manifestation of the cognitive mechanisms that underlie this link. Similarly, the incentive motivation model developed by Toates (2009) views attention as a connecting bridge between presentation of a potentially sexual stimulus and sexual response.

Typically, when a sexual stimulus in front of the observer signals possible sexual reward, the conspicuous biological characteristics (e.g. prominent breasts in women or broad shoulders in men) generate a non-conscious pre-attentional orientation towards the stimulus. This is because of the activation of implicit memory, which stores relevant information about the stimulus related to innate reflexes and/or conditioned responses (Spiering & Everaerd, 2007), as well as history of sexual reward, largely dependent on the history and learning experience of each individual (Toates, 2009; Toates et al., 2017). A non-conscious initial genital response is given if the global features attended coincide with the information of the implicit memory, which is known as physiological sexual arousal (Spiering et al., 2002; Spiering & Everaerd, 2007).

The awareness of genital arousal leads to the activation of a controlled mechanism of conscious attention of the specific features of the stimulus. If they correspond to the content stored in the explicit memory in the form of sexual scripts, memories, attitudes, fantasies, and expectations of reward or

cost, they induce a more prominent and conscious physiological sexual arousal, and a cognitive evaluation that results in the experience of subjective sexual arousal (Spiering et al., 2004), in which a closer approach or contact with the sexually desired stimulus is sought (Smid & Wever, 2019). More suitable sexual stimulation will result in greater sexual arousal, which in turn increases the likelihood of engaging in behavior (Both et al., 2004). If approaching the stimulus is reinforced, excitation will increase and inhibition will decrease (Smid & Wever, 2019). At this moment, behavior is not only under the control of external stimuli, but there is also a goal-oriented executive control that moderates the approach behavior towards the stimulus (Toates et al., 2017). Thus, a complete sexual response that integrates mechanisms of attention, memory, and self-regulation emerges (Spiering et al., 2003; Spiering & Everaerd, 2007).

Therefore, the pre-conscious and conscious attention processes that are activated by a sexually preferred stimulus function as indirect indicators of sexual arousal. Early or pre-conscious attention can be an indicator of genital physiological response, while late or conscious attention is an indicator of subjective sexual response (Dawson & Chivers, 2016; Huberman et al., 2015). Thus, the attentional patterns can function as predictors of excitation patterns according to the stimuli (e.g. sex and age) and according to the characteristics of the observer (e.g. sex, sexual preferences).

If a stimulus is or has become sexually relevant, it turns into a stimulus capable of triggering sexual arousal and activating automatic and controlled processes that will influence the decision to avoid or approach the stimulus (de Jong, 2009; Krupp, 2008). Thus, there must be a relevant stimulus that activates physiological and subjective sexual arousal for sexual behavior to occur (Both et al., 2007).

The information processing model continues to be the main basis for research, both on typical (e.g. Dawson et al., 2017; Handy et al., 2020; Huberman & Chivers, 2020; Timmers & Chivers, 2018) and atypical deviant sexual arousal (Fromberger et al., 2013; Jordan, Wieser, et al., 2018; Vásquez-

Amézquita, Leongómez, Seto, & Salvador, 2019). It has been supported through neurobiological evidence (Mokros et al., 2016; Poeppl et al., 2016), and has been integrated into the most recent explanatory models of sexual violence, such as the Incentive-Motivation and Hierarchical Control Model. This model integrates pre-conscious and conscious components of sexual stimulus processing, from its early phases, in which motivational processes triggered by incentives and/or cognitive representations of incentives are involved, to its late phases, in which a slow conscious executive control is involved, which allows delaying gratification and regulating behavior (Toates et al., 2017).

Linking eye movements into the arousal information processing model

Eye movements reflect attention, and indirectly allow access to cognitive processes underlying sexual responses (Duchowski, 2017; Wenzlaff et al., 2016). Eye tracking methods have been used to understand the perception of visual scenes (Henderson et al., 1999, e.g. 2007) or negative biases towards emotional stimuli in clinical settings (Armstrong et al., 2012; Holzman, 1974). Its use in the evaluation of typical and atypical sexual preferences is, however, relatively new (Dawson & Chivers, 2019; Fromberger, Jordan, von Herder, et al., 2012; Jordan, Fromberger, et al., 2018; Rupp & Wallen, 2007; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019).

Eye movements are not simple reflex actions; they are influenced both by bottom-up processes guided by external stimuli, and top-down processes involving higher-order functions of the brain (Duchowski, 2017; Land, 2006). Thus, the gaze is directed at places relevant to the organization of the action and achievement of individual goals (Land, 2006).

Eye-tracking uses fixations and saccades as indirect measures of sexual preference. Fixations are intervals between saccades that bring stimuli of interest to the fovea, and saccades are ballistic changes in the position of the eyes, which allow moving from one position to another (Le Meur & Liu, 2015). Fixations and saccades allow researchers to access the interaction between early and late attention

processes, to be used as indicators of sexual arousal towards sexually preferred stimuli, according to the age and sex of the stimulus (Fromberger, Jordan, von Herder, et al., 2012; Janssen et al., 2000).

The metrics used as indirect indicators of early and late attention to stimuli are the first fixations and the total duration and amount of fixations, respectively (Fromberger, Jordan, von Herder, et al., 2012). First fixations are relatively automatic, controlled by exogenous stimuli; this is, they are addressed by the salient characteristics of relevant stimulus that competes for the attention of the subject with others stimuli when they are presented simultaneously. Therefore, when two or more stimuli simultaneously appear in extrafoveal vision, they compete with each other; the latency of first fixation (in the case of emotional stimuli within the first 500 ms; see Calvo et al., 2008; Le Meur & Liu, 2015; Nummenmaa et al., 2006) to one of these competing stimuli is a measure of early attentional capture by relevant characteristics of the stimulus (Carretié, 2014; Fernández-Martín et al., 2017). The dorsal and ventral circuits are mechanisms underlying exogenous attention (Carretié, 2014).

The measurement of early attention is only possible when, in the same scene, two or more stimuli compete for the observer's cognitive resources. The most relevant stimulus characteristics will capture attention faster compared to the non-relevant stimuli. Hence, attention to a stimulus will depend on the stimulus with which it is competing (Nummenmaa et al., 2006).

The total duration and number of fixations from when a stimulus appears until it disappears (from 650 to 700ms; Calvo et al., 2008; Calvo & Lang, 2004; Nummenmaa et al., 2006) is a parameter of late attention measurement. Duration and number of total fixations are controlled because the person looks at what is most interesting to them, so this later attention is influenced by schemas, mood, and other cognitive factors. In this process, the relevant characteristics of the stimuli that coincide with the information stored in the explicit memory will maintain attention for a longer time and more frequently when they coincide with the observer’s interests or preferences (Henderson et al., 1999). Fixations of 200 to 300ms are sufficient for obtaining and processing conscious information of a stimulus or area of

relevant interest. The total duration is usually related to the number of fixations on a stimulus or specific area of interest, and both are commonly taken as indicators of conscious processing and level of interest in relevant information (Wenzlaff et al., 2016). We integrate eye movements into an information processing model of sexual arousal, based on both the Information Processing Model and the Incentive Motivation Model in Figure 1.

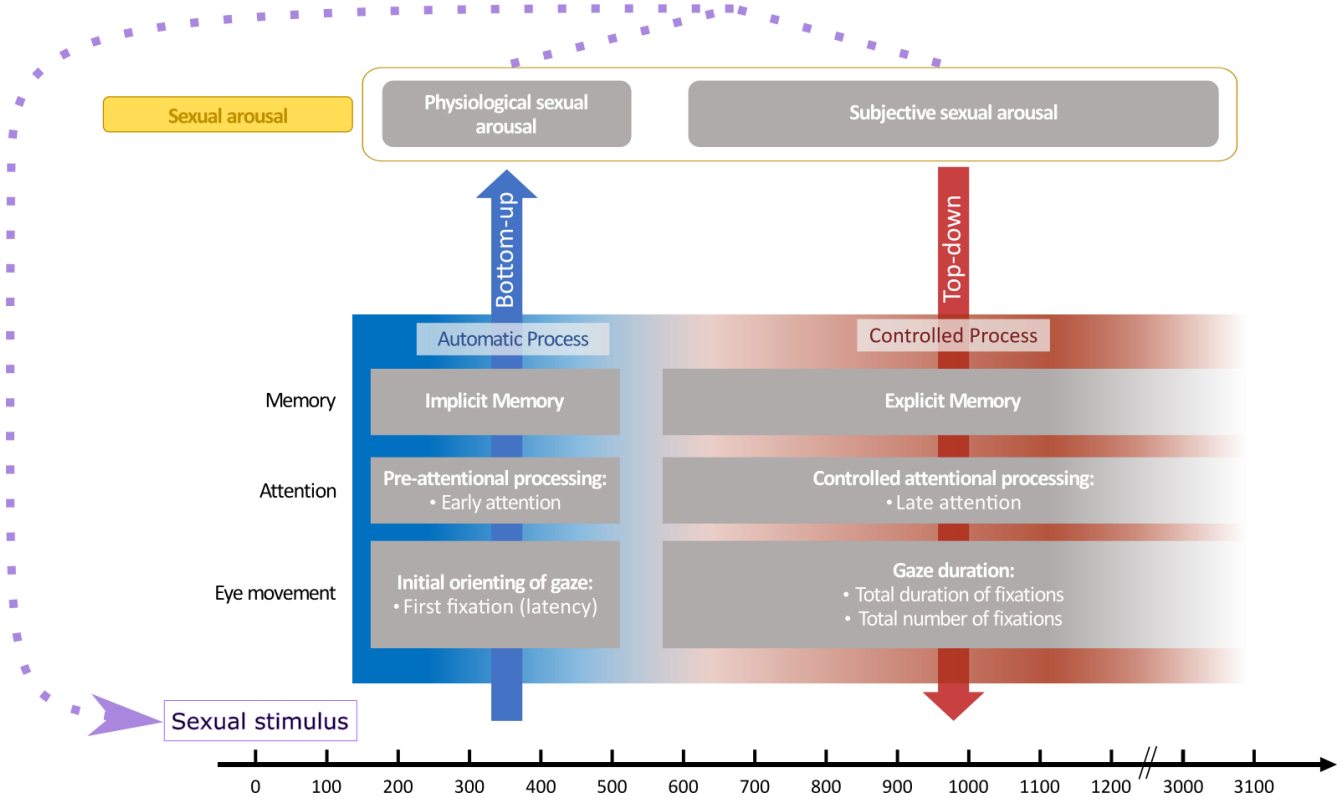

Figure 1. Integrative model of eye movements in the sexual arousal information processing system. The horizontal blocks represent the cognitive processes underlying the eye movements towards sexually relevant stimuli that give rise to the sexual arousal. The horizontal panels represent: in blue, the automatic bottom-up processes, which give rise to the beginning of the physiological sexual arousal; and in red, the controlled top-down processes, which give rise to the subjective sexual arousal. The x-axis represents a timeline of the hypothetical course of automatic and controlled processes, from the appearance of the stimulus, through the beginning of the pre-attention process, advancing to the controlled processing of sexual information. The purple arrow represents the cycle of the complete sexual response, which occurs when automatic and controlled processes interact, increasing the physiological arousal and increasing attention on the visual stimulus or relevant regions that maintains the expectation of reward.

Eye tracking is a non-invasive method that allows access to multiple cognitive processes, including perception, attention, memory, executive control and language. It is especially useful in the study of motivational processes in response to different types of incentives and potential rewards at the socio-emotional level. A well-conducted eye-tracking study allows solid inferences about behavior related to preferred or prioritized stimuli. Likewise, eye-tracking makes it possible to measure variables that are difficult to measure through other methods, like the precise location of attention on an area of interest in both static and dynamic stimuli, and the cognitive resources invested at different moments of the presentation of a stimulus and according to the demand of the task. Finally, since the neural correlates of eye movements are well established, recording eye movements allows inferences about how the brain processes information (Karatekin, 2007).

Another advantage of eye tracking over other direct or indirect measures is that it provides information about the body regions that cue both sex and age of the sexually relevant stimulus, thus offering important information to identify sexual preferences according to these characteristics.

Eye tracking and Atypical sexual preferences

Atypical sexual preferences according to sex of stimuli: Gynephilia and Androphilia

Sexual preferences according to the sex of stimuli within the gynephilic (attraction to women) - androphilic (attraction to men; Huberman et al., 2015; Huberman & Chivers, 2015; Vasey & VanderLaan, 2014) continuum can be typical or atypical. Sexual preferences for women by men and for men by women are species-typical, whereas same-sex preferences are atypical, involving a small minority of the population (Pillard & Bailey, 1998). Typicality as we refer to it here refers only to statistical rarity. Same-sex sexual preferences can be called non-paraphilic atypical sexual preferences (Rahman, 2005) because they are not sexual disorders and do not include paraphilic atypical sexual

preferences that involve sexually immature persons, objects, or unusual activities (e.g. sex or sexual intrusive and persistent fantasies by coercive sex or sex with children; Pullman & Seto, 2012).

Regarding sexual preferences according to sex, extensive empirical evidence has shown that gynephilic or androphilic men without paraphilic sexual interests show a specific sexual response pattern to women or men, respectively, and this manifests itself in both the early and late attentional patterns (Dawson et al., 2017; Lykins et al., 2008; Rupp & Wallen, 2007; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019). This has been shown using different methods, such as genital measures (Chivers et al., 2007, 2010; Spape et al., 2014; Suschinsky et al., 2009), subjective self-report (Chivers et al., 2004; Rupp & Wallen, 2007, 2008; Spape et al., 2014), and attentional paradigms (Ebsworth & Lalumière, 2012; Rieger et al., 2015; Rieger & Savin-Williams, 2012) and specifically with eye tracking (Lippa et al., 2010; Rupp & Wallen, 2007; Vásquez-Amézquita et al., 2018; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019).

In women, the response pattern is different. Early studies revealed that women, regardless of their gynephilic or androphilic sexual preferences, showed a similar genital response pattern towards stimuli of both sexes, or a non-specific category sexual arousal pattern (Chivers, 2005; Chivers et al., 2004; Jones, 2013; Lippa et al., 2010; Suschinsky et al., 2009). A non-specific sexual response, frequent in human females, is defined as a pattern of similar sexual response to both sexually preferred and non-preferred stimuli, in which there is lower congruence between physiological and subjective sexual arousal (Chivers et al., 2010).

In short, through the use of eye tracking, it was found that the early attention pattern of men tends to be gender-specific, while the pattern of women tends to be non-specific. This can be contrasted to the late attention pattern that was gender-specific in gynephilic men and androphilic women, although with weaker effects in women (Dawson & Chivers, 2016, 2018).

These findings have been consistent with previous studies using genital measurements and that have separately analyzed exclusively androphilic women and women with some degree of gynephilia, finding that only exclusively androphilic women showed a non-specific genital response to their self-reported preferred sex, inconsistent with their self-reported sexual arousal (Bouchard et al., 2015; Chivers et al., 2007, 2015), while gynephilic women showed a category-specific sexual response, similar to that observed in men (Chivers et al., 2007; Rullo et al., 2010).

These findings indicate that sexual preferences can be explored through the visual attention patterns to sexually relevant stimuli, since some aspects of visual attention seem to be guided by the observer's sexual interests. Thus, the attentional processing of sexual stimuli may vary depending on the stage at which the information is processed (early or late) and thus provide information on the underlying mechanisms (automatic or controlled) of atypical sexual preferences.

Atypical sexual preferences according to age of stimuli: Chronophilias

It has recently been proposed that sexual preferences can also be categorized according to the age of sexually preferred stimulus, or *chronophilias* (Seto, 2017). This concept comes from a forensic need to classify men with atypical sexual preferences for sexually immature stimuli (Imhoff et al., 2017). Chronophilia categories include nepiophilia (babies and children up to two years old), pedophilia (prepubescent, typically between 3 and 10 years old), hebephilia (pubescent, typically between 11 and 14 years old), ephebophilia (teenagers, typically between 15 and 17 years old) teleiophilia (young and sexually mature adults, typically between 18 and 30 years old), mesophilia (middle-aged adults, typically between 40 and 50 years old) and gerontophilia (elderly adults, typically over 60 years old) are labelled to classify sexual preferences according to the age of the stimulus (Seto, 2017). Teleiophilia is the species-typical sexual preference for sexually mature young adults.

We propose a hypothetical model of typical and atypical sexual preferences that integrates both the age and sex dimensions of the stimuli (Figure 2). The distribution along the typical-atypical

continuum according to the age and sex of the stimuli is hypothetical, estimated, and constitutes a starting point for research. The typicality according to the age of the stimulus, is estimated from what is known about the frequency of chronophilias in men, given the indirect evidence of mainly teleiophilic preferences among women and few cases of pedohebephilia (for review, see Seto, 2017). Seto (2017) speculated that men would show a bias towards younger age categories, whereas women would show a bias towards older age categories, given normative data on age preferences in dating and marriage. Likewise, for the typicality according to the sex of the stimulus, indirect evidence suggests that the frequency of non-exclusively androphilic women may be higher than that of non-exclusively gynephilic men, taking into account the specificity of men's sexual response and the non-specificity of androphilic women's sexual response (Chivers, 2017; Chivers et al., 2015; Spape et al., 2014).

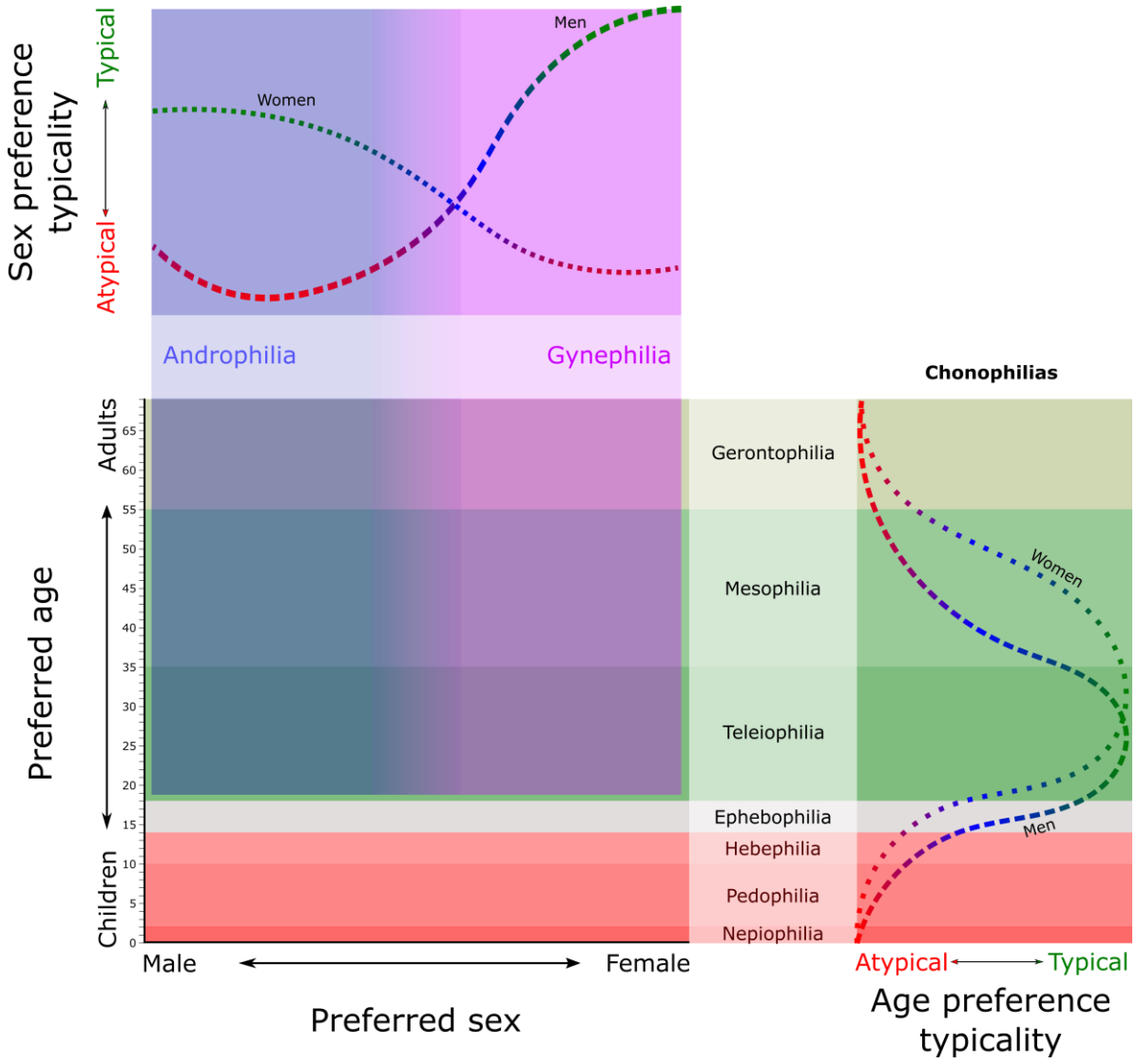

Figure 2. Hypothetical model of the variations in the typical and atypical sexual preferences according to the age and sex of the preferred stimulus and representation of the distribution of the typicality according to age and sex of the stimuli, estimated from indirect evidence (Chivers, 2017; Chivers et al., 2015; Imhoff et al., 2010; Seto, 2017; Spape et al., 2014). In typicality according to the age of the stimulus, paraphilic chronophilias are represented in red, and in green tones those that are not considered paraphilias. In typicality according to the sex of the stimulus, the bands, blue (Androphilia) and purple (Gynephilia), represent sexual preferences for sexually mature men and women.

The available evidence using eye tracking, and even any other direct or indirect measure of sexual arousal, is limited to the distinction of sexual preferences by prepubescent and pubescent children (Tanner Stages 1 to 3), postpubescent adolescents (Tanner Stage 4) and adults (Tanner Stage 5) to

study pedohebephilic atypical sexual preferences (Attard-Johnson et al., 2016, 2017; Fromberger et al., 2013; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019). However, there is no evidence for other non-paraphilic chronophilias, either typical or atypical, like mesophilia or gerontophilia.

Category-specific sexual response: gender differences

We summarize the evidence on category-specific sexual response in this section for two reasons. First, to highlight that most of the information available about these atypical sexual preferences such as pedophilia and hebephilia comes from research in men, and it is clear that atypical age preferences are more common in men than in women (Seto, 2008). And second, because paradigms based on the visualization of stimuli using eye tracking, have been consistent in showing a low sensitivity to detect effects, especially those of sex on the pattern of visual attention, and are therefore insufficient to identify typical and atypical sexual preferences in women, given the unspecific female sexual response, especially in exclusively androphilic women (Dawson et al., 2017; Dawson & Chivers, 2014, 2019; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019).

The evidence on the category-specific sexual response among male has led to the use of direct and/or indirect measurements of sexual arousal as indicators of specific sexual preferences according to the sex and age of the stimuli, proving useful in cases in which men may fear revealing or are interested in denying their atypical, either paraphilic or non-paraphilic, sexual preferences (Chivers et al., 2004; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019).

Given the non-specificity of the female sexual response according to the sex of the stimulus and the low proportion of pedophilic women (Chivers, 2017; Knack et al., 2015), it is not easy to rely on either direct or indirect sexual arousal measures to assess the sexual preferences of women according to the age of the stimulus even though, more or less consistently, it has been found that gynephilic and androphilic men and women, without paraphilic sexual interests, show an attentional pattern consistent

with their subjective sexual arousal towards sexually mature adults (Tanner Stage V; Attard-Johnson et al., 2017; Ebsworth & Lalumière, 2012; Fromberger, Jordan, von Herder, et al., 2012; Imhoff et al., 2010; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019). This is why the assessment of deviant atypical sexual preferences, such as pedophilia, focuses mainly on men, and there is scarce evidence available and no valid measures to assess interest according to the age of the preferred stimulus in women (Bouchard et al., 2019).

Atypical age sexual preferences and eye-tracking

Although research with gynephilic and androphilic men has shown that there is a pattern of specific early and late attention to adult stimuli of the preferred sex (Fromberger, Jordan, von Herder, et al., 2012; Hall et al., 2011; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019), only three laboratory groups, in Germany, (Fromberger et al., 2013; Fromberger, Jordan, Steinkrauss, von Herder, Witzel, Stolpmann, Kröner-Herwig, Müller, et al., 2012; Jordan et al., 2016), United Kingdom (Hall et al., 2015) and Colombia in Latin America (Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019) has used eye-tracking as a measure of pedophilic sexual interest with forensic samples.

Results, nevertheless, have been mixed, initially showing that men with pedophilic sexual interests show early and late attention bias towards children, compared to groups of offenders without sexual offenses or men in the general population without pedophilic sexual interests (Fromberger, Jordan, Steinkrauss, von Herder, Witzel, Stolpmann, Kröner-Herwig, Müller, et al., 2012). However, more recent studies with pedophiles and sexual offenders against children, could not verify the pattern of late attention, but only the early attention bias towards children (Fromberger et al., 2013; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019), and greater late attention on areas that signal sexual maturity such as the chest (Hall et al., 2015; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019), contrary to previous evidence that reported more engagement attention on the pelvic region of children in pedophiles compared to control groups (Fromberger et al., 2013).

Recently, there has been experimentation with eye tracking and implicit viewing paradigms using sexual stimuli as distractors, to look for evidence about top-down control problems in the child stimuli viewing in pedophiles compared to non-pedophiles (Jordan et al., 2016; Jordan, Fromberger, et al., 2018; Jordan, Wieser, et al., 2018).

Jordan et al (2016) found that pedophilic men show less attention control when the sexual stimulus is a child distractor, compared to two non-pedophilic control groups (men who had nonsexually offended and nonoffending community men), evidencing faster first fixations and longer duration of fixations on child distractors. This study showed good levels of discrimination between pedophilic and nonpedophilic men. However, it presented as limitations the complexity of the task and the motivational factor to respond to a complex cognitive task. The authors highlight that individual motivation to solve a task can modulate the processing of a distractor. For this reason, in these tasks with distractors, it may be necessary to explicitly evaluate motivation. Likewise, the researchers find it necessary to individually adapt the difficulty of the task to control for its effects on motivation to solve it. Finally, non-sexual control distractors were not included to validate the effect of sexual distractors on attentional control.

In a second study Jordan, et al (2018) compared non-forensic and forensic pedophilic men, finding that non-forensic men showed better attention control than forensic patients on child stimuli. However, this difference did not reach statistical significance and the sample size was small.

Limitations of Eye-tracking in sexual preferences research

All methods for the evaluation of atypical sexual preferences include strengths and limitations, including eye-tracking paradigms (see Carvalho et al., 2020).First, experimental paradigms using indirect measures, such as eye-tracking, although based on a solid conceptual framework, ignore some of its key components, like the value of triggering incentives. Studies with experimental stimulus visualization paradigms should include, in their analysis of response to sexually atypical stimuli, the

history of incentives through the evaluation of the self-reported intensity of sexual attraction towards pre-pubertal children, in the case of pedophilia, among those who admit having pedophilic sexual preferences, use of child pornography and sexual contact with children.

Second, most studies use stimuli without sufficient validation to show that they approximate the idiosyncratic preferences of those evaluated. For someone who is sexually attracted to young men, for example, their response may be affected by the muscularity of the depicted individuals, with some more attracted to highly muscularized men and others attracted to slim, non-muscular women. Other characteristics that could influence sexual responses include height, hair color, and skin tone. Therefore, the selection of stimuli is key in designing an experimental paradigm to measure sexual preferences according to the age of the stimuli (e.g. Fromberger et al., 2013; Hall et al., 2015; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019).

And third, studies ought to be replicated and expand the research to establish the psychometric properties of test-retest reliability, as well as convergent and discriminant validity as a measure of typical and atypical sexual preferences, of which there is limited knowledge (Fromberger, Jordan, Steinkrauss, von Herder, Witzel, Stolpmann, Kröner-Herwig, & Müller, 2012). The design of experimental paradigms of parallel forms is necessary to measure test-retest reliability. Studying the discriminant validity of the attribute categories that configure the experimental paradigms in relation to the type of stimuli, will allow to discriminate the effects of relevant and non-relevant sexual stimuli, sexual and non-sexual, explicit and non-explicit, with and without context, as well as those that measure preferences according to sex and/or age of the stimulus, and distinguish between men with and without pedophile sexual interests. Convergent validity studies are necessary to define the usefulness of different types of experimental paradigms; for example, those of free visualization versus those of forced choice. The latter have been questioned due to the possibility of involving delay processes based on the evaluation of characteristics of the stimulus, which can be faster to discard stimuli that do not

belong to a category (i.e stimuli evaluated as non-sexual Imhoff et al., 2012), compared to paradigms visualization that does not involve restricting the natural response to the stimulus.

A strategy to increase the reliability and validity of indirect measurements using eye tracking is the triangulation with other direct and indirect methods that offer information about typical and atypical sexual preferences, and that have reported good psychometric properties such as the Revised Screening Scale for Pedophilic Interests (e.g. Seto et al., 2017) and with other indirect measures with a good level of discriminant and convergent validity such as the Implicit Association Test (IAT) or viewing time (Babchishin et al., 2013, 2014).

A relevant technical aspect in the use of eye-tracking to reliably measure typical and atypical sexual preferences, has been the lack of consistency in the upper limit lattency for first fixations. That is, to what extent to consider a first fixation as early attention; this leads to inconsistencies in the findings regarding this variable as a measure of early attention towards stimuli of sexual relevance (e.g. Fromberger et al., 2013; Fromberger, Jordan, Steinkrauss, von Herder, Witzel, Stolpmann, Kröner-Herwig, Müller, et al., 2012; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019).

This is important, since, for example, Imhoff et al. (2010) showed that the psychometric properties of visualization times during the evaluation of the sexual attractiveness of the stimuli, of a sexually preferred category, were better under conditions of presentation of time-restricted stimuli (<1000ms), which demand for a rapid response. This has a double importance. First, because the time restrictions and the demand for quick responses can be better indicators of automatic sexual responses towards sexually preferred stimuli, so the duration of the stimulus and the task is very important to increase validity of an experimental paradigm. But, also, because the precise delimitation of the time to consider a response as automatic or controlled, is part of the factors that must be evaluated to consider as valid a measure of sexual preferences through eye tracking (Imhoff et al., 2019).

A new experimental attentional paradigm using eye-tracking have recently been proposed to measure non-conscious cognitive processes that underlie the processing of sexual information in early stages (Oberlader et al., 2017), attempting to overcome the limitations of free-viewing and forced choice paradigms, which report evidence about uncontrolled processes from latencies of the initial fixation on the sexually relevant stimulus, which has been recently criticized (Imhoff et al., 2019), because although it is a response that is not influenced by the introspection of the individual, it cannot be considered entirely an automatic processes response or measure, at least, without setting a maximum response latency threshold that can really be considered automatic. Experimental tasks such as the cued pro– and antisaccade paradigms that measure saccades (a rapid movement of the eye between fixation points) approaching the sexually relevant or irrelevant stimulus (prosaccades), and saccades moving away from the sexually relevant or irrelevant stimulus (antisaccades), have shown potential to be used as an indirect measure to explore initial attentional processes based on sexual interest (Oberlader et al., 2017).

This paradigm has an advantage in the validity and reliability of the task to measure early attentional processes. Compared with previous studies using the first fixations (e.g. Fromberger et al., 2013; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019), this task using sexual stimuli is based on the saccades that occur before the first fixation and that offer more precise information on earlier stages of the localization of attention, in addition to help understanding the conflict between automatic and controlled processes in the generation of a saccade (Hutton & Ettinger, 2006; Oberlader et al., 2017). Evidence of its usefulness has been proven in studies on attentional biases towards emotional stimuli in clinical disorders (e.g. Aichert et al., 2013; Llamas-Alonso et al., 2020; Mueller et al., 2012; Yep et al., 2018). It has been tested with sexual stimuli in a recent study (Oberlader et al., 2017), and its usefulness in samples of men with pedophile sexual interests is being investigated (In press Pezzoli et al., 2019).

Finally, another significant limitation is that the majority of studies are concentrated in non-clinical groups with typical sexual preferences (Lykins et al., 2008; Rupp & Wallen, 2007), and much more recently in groups of men and women with non-paraphilic (Dawson et al., 2017; Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019) and paraphilic (Fromberger et al., 2013; Jordan et al., 2016; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019) atypical sexual preferences with very limited evidence in clinical and forensic samples with paraphilic atypical sexual preferences. It is hoped this review spurs interest in conducting further research on atypical sexual preferences, including paraphilias such as pedophilia and other chronophilias.

Future Directions and Conclusions

The literature reviewed reveals important contributions of eye tracking during the last decade to the understanding of the cognitive mechanisms underlying typical and atypical sexual preferences, but it also shows the obstacles (e.g. insufficient evidence at the moment with clinical and forensic samples; lack of precision on psychometric properties of experimental sexual stimuli visualization paradigms) for concluding its usefulness in this field.

Despite this, eye-tracking is less expensive and invasive than genital measures in sexuality studies and, especially, in the evaluation of atypical sexual preferences, taking into account the barriers to sexuality research participation (Plaud et al., 1999), but especially clinical and forensic samples, given the social prejudice that certain sexual topics, such as pedophilia, represent (Jahnke et al., 2015; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019).

Eye-tracking has become a key method to test the theories of sexual arousal that give a central role to both the attention, and the interaction between automatic and controlled cognitive processes that give rise to the human sexual response (Janssen et al., 2000; Spiering et al., 2004; Toates et al., 2017). This, in addition to being an alternative technique to self-report (given how easy it is to lie or manipulate what is reported) to test cognitive theories about pedophilia and child sexual offenses

(Ward & Beech, 2006), that share the common notion that there are underlying cognitive mechanisms that could lead to attentional biases towards atypical sexual stimuli (e.g. prepubescent, and/or pubescent children). It can even be useful for testing newer integrative models, both for understanding sexual preferences according to sex and according to age, including the entire spectrum of chronophilias (Imhoff et al., 2017; Smid & Wever, 2019).

The idea of an early attention bias towards child stimuli suggests the existence of mechanisms related to implicit memory, in which atypical non-conscious associations can occur between concepts related to sex and the sexually immature bodies of children. This could offer gratification or reduce discomfort, reinforcing attention biases towards children as an object of desire, and mediating the motivation to approach or not, which would eventually lead to the decision to move from fantasy to the search for sexual contact with a minor (Smid & Wever, 2019). The mechanisms that explain the motivation to act are beyond the scope of these indirect measures which can only be considered useful as indirect indicators of sexual preferences.

Regarding late attention processes, the evidence about pedophilia and sexual offending is inconclusive. Since the measurement of this process is much more susceptible to the conscious control of the subject, leading to inconsistencies in the investigation that, on the one hand, show that there would be no differences between pedophiles and not pedophiles in the amount of conscious attention that is devoted to child stimulation (Fromberger et al., 2013). However, eye tracking has allowed the identification of a differential pattern in specific regions of the sexually immature body such as the chest (Hall et al., 2011; Vásquez-Amézquita, Leongómez, Seto, & Salvador, 2019) and pelvis (Fromberger et al., 2013). This is information that is not provided by other indirect measures, and highlights the importance of replicating and refining attention paradigms using eye-tracking.

Eye-tracking research should continue, with larger general samples, clinical and non-forensic samples with pedophilic sexual interests, and forensic samples that differentiate child sexual offenders

with and without pedophilic sexual interests, since not all sex offenders have pedophilia and not all people with pedophilia have sexually offended (Seto, 2009). Additionally, the full spectrum of chronophilias should be included in the research of sexual preferences according to age, just as the full spectrum of the gynephilia-androphilia continuum has been included in the study of sexual preferences according to sex.

Eye tracking studies differentiating pedophilic from non-pedophilic child sex offenders, and pedophilic men who have offended from those who have not, could have clinical and forensic applications because eye tracking, as the technology becomes more affordable, could be useful in the clinical assessment of pedophilic sexual interests when more intrusive measures such as phallometric assessment of penile responses is not available or would be refused. Because eye-tracking can distinguish automatic from controlled attention, it could be used to monitor the impact of cognitive-behavioral treatments designed to increase self-regulation of sexual arousal on controlled attention specifically. Longitudinal follow-up research could determine if eye tracking results can predict sexual recidivism, as phallometric testing and visual reaction time measures can (see Seto, 2018).

Likewise, a new line of investigation is possible in forensic samples of women who have sexually offended against children and who may have pedophilic sexual interests. Eye-tracking can help in exploring these new hypotheses since nonoffenidng women have shown age-specific sexual interest in eye tracking (e.g. Vásquez-Amézquita, Leongómez, Seto, Bonilla, et al., 2019) and other indirect measures (Attard-Johnson et al., 2016; Ebsworth & Lalumière, 2012; Rieger et al., 2015). New perspectives support the idea that indirect measures, including eye-tracking, may be promising in assessing atypical sexual preferences in women (Bouchard et al., 2019).

Although we are far from being able to use eye-tracking and attentional paradigms as clinical diagnostic tools, research is the main way to find its usefulness and reliability as an indirect measure of sexual preferences, and as a potential complementary tool in clinical and forensic settings. This work is

an invitation to continue doing research using this technique and to extend its application range to the clinical-forensic field, supported by solid theoretical models on sexual information processing as well as typical and atypical sexual preferences according to age and sex.

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