Using virtual reality and eye-tracking with child sexual offenders: Assessing deviant sexual interests

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Sexual interests and sexual offending against children

In the area of sexual offending, the presence of deviant sexual interests is a central feature of both clinical and theoretical understandings. At the theoretical level, many influential theories of sexual offending consider the presence of deviant sexual interests as a key element in explaining both sexual offending behaviors onset and reoffending (Finkelhor, 1984; Hall & Hirschman, 1992; McGuire, Carlisle, & Young, 1965; Singer, 1984; Ward & Beech, 2006; Ward & Siegert, 2002).

The Integrated Theory of Sexual Offending (ITSO) (Ward & Beech, 2006), which incorporate and articulate most of the notions suggested in other theories has gained considerable popularity over the past decade. According to the ITSO, sexual offending results from the constant interactions of three types of factors: (1) biological factors, (2) ecological factors and (3) neuropsychological factors. Clinical indications of deviant sexual behaviors, including deviant sexual interests, are thought to result from these factors' dynamic interaction. Precisely, ITSO highlights how interactions between biological and ecological vulnerabilities may impact neuropsychological functions directly linked to action and behaviors, through three systems: (a) motivation and emotion, (b) perception and memory, and (c) action selection and inhibition. In sum, the way all components interact with each other and translate into behavior is highly specific to each offender and represent risk factors.

In addition to factors that are specific to the individual, ITSO suggests that deviant sexual behaviors are fundamentally situated. Precisely, sex offending would result from the actualization of individual risk factors by contextual and ecological triggers. Thus, both individual

predispositions and precise environmental conditions need to be present in order for sexual deviant behavior to take place. Therefore, it becomes essential to not only understand the risk factors but also determine how they emerge and interact in a specific situation in order for a person to commit a sexual assault.

Understanding sex offending through ITSO has concrete implications on a practical level. First, sexual interests assessment requires that the necessary ecological conditions be present to trigger sexual arousal. Second, the assessment procedure should identify risk factors by combining measures on different dimensions of sexual interests. Finally, the procedure should provide information on how sex offenders regulate their continuous interactions with a given environment in the light of their specific risk factors (Benbouriche, Nolet, Trottier, & Renaud, 2014; Carver & Scheier, 2011; Kingston, Yates, & Firestone, 2012; Ward, Hudson, & Keenan, 1998).

In clinical settings, the presence of deviant sexual interests is the cornerstone of decision making surrounding diagnosis, treatment and supervision recommendations. Actually, one of the essential criteria of the diagnostic category is the presence of «any intense and persistent sexual interest other than sexual interest in genital stimulation or preparatory fondling with phenotypically normal, physically mature, consenting human partners» (American Psychiatric Association, 2013, p. 685). In addition, a robust body of research argues that deviant sexual interests are one of the most important risk factors linked to sexual recidivism (Hanson & Bussière, 1998; Hanson & Morton-Bourgon, 2005). That being said, the Risk-Need-Responsivity intervention model, an empirically validated treatment models for offenders, highlight the importance of targetting risk factors specifically associated to offending (Andrews & Bonta, 2010; Andrews, Bonta, & Wormith, 2011; Hanson, Bourgon, Helmus, & Hodgson, 2009).

Therefore, the accurate assessment and characterization of deviant sexual interests bear significant importance when working with child sexual offenders.

Sexual interests assessment

Several sources of information are taken into consideration when conducting deviant sexual interests assessment, such as clinical interviews and self-administered questionnaires. Although essential to the assessment process, these sources of information are contingent to the participant's willingness to remain trustful throughout the assessment process, which can be a challenge when dealing with clients facing legal repercussions and social stigma. Furthermore, it requires a certain level of insight and self-awareness from the individual, who needs to remember, acknowledge and share specific details on sexual interests without reference to the environmental context in which they occur.

In order to obtain objective data on sexual interests, many specialized clinics use penile plethysmography. Penile plethysmography is an assessment method that measures changes in penile circumference, or volume, during the presentation of stimuli generally containing age- and coercion-related elements (Marshall & Fernandez, 2003b). To date, sex offender's assessment methods relying on penile plethysmography have received vast empirical support (Harris, Rice, Quinsey, & Chaplin, 1994; Howes, 1998; Malcolm, Andrews, & Quinsey, 1993; Quinsey & Chaplin, 1988a, 1988b). Overall, these methods allow to discriminate child sex offenders from nonoffenders (Harris et al.,1994; Howes, 1998; Serin, Malcolm, Khanna, & Barbaree, 1994). Results from the procedure are also specifically linked to sexual recidivism (Hanson & Bussière, 1998; Hanson & Morton-Bourgon, 2005).

Penile plethysmography assessments have relied on either visual or audio stimuli presentation; each of theses modalities having their advantages and weaknesses. Visual stimuli consist of a series of pictures depicting individuals from different genders and age groups.

Despite being valid (Proulx, 1989), these stimuli are hardly standardizable, and the presentation of stimuli depicting actual children and adults to elicit sexual arousal have raised ethical and legal concerns (Card & Olsen, 1996). Given the constraints, visual stimuli were progressively forgone in favor of the auditory modality. The auditory modality consists of a serie of narrated scenarios describing interactions between an adult and either another adult or child while they are involved in varying degrees of physical and sexual coercion. One concern surrounding auditory stimuli is their limited ability to reproduce the ecological conditions that trigger deviant sexual arousal responses in real life situations (Blader & Marshall, 1989; Marshall, Anderson, & Fernandez, 1999). In fact, many influential researchers acknowledge that improvements to the ecological validity of the assessment procedure are in order (Haynes, 2001; Konopasky & Konopasky, 2000; Marshall & Fernandez, 2003a; O'Donohue & Letourneau, 1992).

Whether using auditory or visual stimuli, another concern surrounding the penile plethysmography procedure is its vulnerability to voluntary control of the erectile response by participants (Golde, Strassberg, & Turner, 2000; Howes, 1998; Howitt, 1995; Lalumière & Earls, 1992; Looman, Abracen, Maillet, & Difazio, 1998; Mahoney & Strassberg, 1991). Over the years, researchers have tried to develop methods and protocols to address this issue (Golde et al. 2000; Henson & Rubin, 1971; Laws & Rubin, 1969; Mahoney & Strassberg, 1991; Malcolm Davidson, & Marshall, 1985; Marshall, 2004; Proulx, Coté, & Achilles, 1993; Quinsey & Chaplin, 1988b), but none have proven to be entirely satisfactory in detecting or preventing voluntary control of the erectile responses.

In sum, assessment procedures using penile plethysmography could benefit from improvements surrounding the ecological validity of stimuli that trigger the sexual response. The development of methods to identify and prevent result tempering by erectile control would also be beneficial in terms of internal validity. Furthermore, the ecologically situated understanding of

sexual aggression offered by influential theories imply the development of methods, for both clinical and research purposes, that allow the simulation of clinically significant environments, with its immediate stimuli, whether physical, social or emotional (Barbaree & Marshall, 1991; Beauregard, Leclerc, & Lussier, 2012; Bouffard, 2002; Bouffard, 2011; Exum & Zachowics, 2014; Gannon, 2009; Spokes, Hine, Quain, Marks, & Lykins, 2014; Ward, 2009).

Possible contributions of virtual reality

It can be expected that virtual reality's ability to generate specific environments, virtual characters, and provide high experimental control may help overcome some limitations in the assessment of deviant sexual interests. Indeed, virtual reality provides assessment conditions that closely respect the ecological properties of real-life circumstances. This is of paramount importance given the fact that precise environmental conditions need to be present in order for individual risk factors to be triggered and sexual deviant behavior to take place (Ward & Beech, 2006). Virtual reality also appears to be a relevant method to grasp and understand the underlying mechanisms involved in sexual offending.

Possible contribution of eye-tracking

One of the instruments that also provide new perspectives on sexual functioning and more specifically on the mechanisms surrounding sexual interests is eye-tracking. This device, which can easily combined with immersive technologies, allows gaze recognition and grants access to the visual information retrieval process through an infrared camera pointed at the fovea. Research based on such technologies suggests that visual attention is kept for longer periods on stimuli in resonance with sexual preferences, and that specific eye movement patterns are related to sexual interests (Alexander & Charles, 2009; Dixon, Grimshaw, Linklater, & Dixon, 2011; Fromberger et al., 2012a; Hall, Hogue, & Guo, 2011; Lykins, Meana, & Kambe, 2006; Lykins, Meana, & Strauss, 2008; Rupp & Wallen, 2007).

Furthermore, eye-tracking research has uncovered that cognitive processes modulate eye movements (Engbert & Kliegl, 2003; Hafed & Clark, 2002; Laubrock, Engbert, & Kliegl, 2005; Yarbus 1965, 1967). Specifically, studies have shown that exploration patterns for the same image change according to participants' objective during the stimuli presentation (Yarbus 1965, 1967). Considering the important role cognitive strategies play in the control of the erectile response (de Jong, 2009; Henson & Rubin, 1971; Laws & Holmen, 1978; Laws & Rubin, 1969), the identification of interfering cognitive processes responsible for erectile inhibition during plethysmographic assessment could significantly improving the internal validity of the instrument. Thus, it could prove relevant to combine eye-tracking with immersive technologies for sexual interests assessments.

While virtual reality (Glantz, Rizzo, & Graap, 2003; Gregg & Tarrier, 2007) and eye-tracking (Rayner, 1998; Rosh & Vogel-Walcutt, 2013) have been used for several years to study an array of biological and behavioral phenomena, the uses of these methods with sexual offenders is fairly recent. To our knowledge, no literature review has so far been conducted on the use of virtual reality and eye-tracking to assess child sexual offenders.

A search was conducted on PsycINFO using the following words: sexual offenders OR sex offenders OR sex offenses OR pedophilia AND virtual reality OR (eye-tracking OR fixation OR gaze) on June 1st, 2015. Conference proceedings, and paper sessions retrieved online were also considered. All studies included had to pertain specifically to sexual interests assessment with child sex offenders, provide quantitative results and clearly emphasize on methodological choices surrounding stimuli and physiological indicators. In the next section, a narrative review of eight studies using virtual reality or eye-tracking in combination to virtual reality for sexual interests assessments will be conducted, with studies being grouped among those essentially addressing procedure validation and those combining physiological indicators.

Using virtual reality or eye-tracking to assess child sex offenders

Validation studies

Since early 2000, Renaud and colleagues (2002) have developed a research program based on virtual reality and eye-tracking for the assessment of deviant sexual interests. First, a serie of animated 3D stimuli was developed and standardized. In contrast to other series of modified images used for sexual interests assessment (Dombert, Mokros, Brückner, Schlegl, Antfolk, et al, 2013; Fromberger, Meyer, Kempf, Jordan, & Müller, 2015), these stimuli are animated. Movements performed by all characters were generated by motion capture system and express nonsexual neutral affects. Physiological properties of the stimuli were given particular attention and all accurately represent the morphological characteristics associated with Tanner's development stages (1978). In total, nine animated computer-generated stimuli (ACGS) representing both genders through various stages of development were created, as well as a neutral stimulus.

A first study aimed to establish face validity for the ACGS (Goyette, Renaud, Rouleau, & Proulx, 2008). One hundred and forty undergraduate students (mean age = 22.3 years) were presented with all nine ACGS. Each stimulus was presented for 90-sec. For each stimulus, participants had to indicate perceived age as well as rate the stimulus overall realism and ability to generate sexual arousal.

Average perceived age was significantly different according to developmental stages: children (7.63-years-old), prepubertal (11.79-years-old), puberty (15.92-year-old), adult (23.78-year-old). Statistically equivalent means were obtained in a subsequent study conducted with sex offenders (Goyette, Trottier, Rouleau, Renaud & Longpré, 2011). Sexual arousal ratings for ACGS fluctuated according to participant's sexual orientation, with significantly greater sexual arousal reported to the sexually preferred adult ACGS than all other stimuli. Reported magnitude

of sexual arousal to the sexually preferred ACGS was low to moderate. In addition, the mean overall realism rating for the ACGS was 5.39 (SD = 1.94) on a scale ranging from 1 (not at all realistic) to 10 (similar to a human).

Results suggest satisfactory face validity for all ACGS. Findings also highlight the necessity to consider realism and graphic quality as important variables in the context of human sexuality, specifically when performing sexual interests assessment. In fact, levels of realism and graphic quality required for studies of sexuality remains an important issue to consider when developing tasks and virtual environment.

To that effect, Fromberger et al. (2015) made an attempt to determine the optimal level of immersive technological necessary to generate sexual arousal in one of their projects. Essentially, Fromberger and colleagues conducted a series of studies combining eye-tracking and visual reaction time to assess sexual interests (2012a, 2012b, 2013, 2015). Visual reaction time is an assessment method, which consists of inconspicuously recording the time a participant spends exploring the sexual attributes of a stimulus, while he is asked to perform an associated task, such as assessing stimuli attractiveness. A body of research suggests that visual reaction time is associated with sexual interests and is longer when an observer is exposed to a category of sexual stimuli corresponding to his sexual interests (Abel, Lawry, Karlstrom, Osborn, & Gillespie, 1994; Lykins et al., 2008).

For this particular study (Fromberger et al., 2015), twenty-five heterosexual males and twenty homosexual males from the community were presented with 20 fixed computer-generated stimuli representing nude adults from both genders modeled and designed at the University of Göttingen. Stimuli presentation took place in three different immersive conditions: (1) monoscopic flat-screen with no head-tracking, (2) stereoscopic head-mounted display and head-tracking, and (3) stereoscopic head-mounted display with head-tracking and turnable view. While

participants were requested to evaluate the level of attractiveness and realism of the stimuli, visual reaction time was used as a measure of sexual interest. Subjective ratings of attractiveness and realism, visual reaction time as well feeling of presence were gathered for analysis.

Overall, results suggest that the two stereoscopic conditions generated significantly higher subjective ratings of stimuli realism, sexual attractiveness and feeling of presence than the monoscopic condition. Level of immersion did not however have an impact on the capacity to identify preferred sexual stimuli, as viewing time was invariably longer when exploring stimuli corresponding to sexual interests in all three viewing condition. Findings also suggest differential scanning patterns when participants were allowed to turn around the stimuli. In this particular condition, participants circulated significantly more often around the stimuli corresponding to their sexual preference. Thereby, level of interactivity appears to be an important variable to consider when assessing sexual interests.

These results suggest that stereoscopic technologies perform better on subjective measures associated with sexual attractiveness, realism and presence than monoscopic technologies, while level of immersion seems to have little impact on objective measures allowing sexual interests assessment. Findings in regards to scanning patterns and body positioning also emphasize the relevance of focusing on psychophysiological indicators other than erectile response when assessing sexual interests.

A third study focused on establishing the validity of virtual reality and ACGS as a presentation modality for the plethysmographic procedure. Specifically, Trottier et al. (2014b) aimed to establish the immersive procedure's ability to generate sexual arousal profile representative of sexual interests, as well as its diagnostic accuracy. For this research, 22 child sex offenders and 42 non-deviant male participants were recruited and presented with five ACGS developed by Renaud et al. (2002) on a stereoscopic head-mounted display. For each trial,

erectile responses were standardized in order to to minimize inter-individual variability inherent to penile response (Blanchard, Klassen, Dickey, Kuban, & Blak, 2001). Deviant differentials, an index of relative preference between normative and deviant stimuli, were also calculated (Harris, Rice, Quinsey, Chaplin & Earls, 1992; Seto, Cantor, & Blanchard, 2006; Seto, Harris, Rice, & Barbaree, 2004).

Results suggest that stereoscopic presentation of ACGS yielded significant erectile responses representative of sexual interests that allowed group discrimination. Precisely, child sex offenders had greater sexual arousal to children stimuli than adult stimuli, whereas the control group had greater sexual arousal to adult stimuli than children stimuli. Results pertaining to diagnostic accuracy were obtained through Receiver Operating Characteristic (ROC) analysis. ROC analyzes establish the ability of a test to discriminate between two groups (Streiner & Cairney, 2007). The Area Under the Curve (AUC) represents, in this particular instance, the probability that the stimuli modality used will produce a higher deviance differential for a randomly selected sex offender than for a randomly selected control individual. The AUC values can range from 0 to 1. A value of 0.5 indicates a diagnostic capacity at the level of chance whereas higher values indicate better performance (Streiner & Cairney, 2007). ACGS yielded a significantly greater diagnostic accuracy (AUC= .90) than chance. Similar diagnostic accuracy (AUC= .85) was obtained in a research using the same protocol on a flat panel display (Goyette, 2012). that the stereoscopic presentation of ACGS appears to be a valid presentation modality for penile plethysmography assessment, generating satisfactory discriminant validity and excellent classification accuracy.

Overall, the published literature provides empirical support for the use of monoscopic and stereoscopic technologies as well as the presentation of computer-generated stimuli for sexual interests assessment. It now becomes appropriate to question the possibility of combining virtual

reality to other instruments, such as eye-tracking, to obtain additional information regarding sexual interests.

Studies using combined physiological indicators

The objective of this research was to determine if certain eye-movement patterns recorded during the monoscopic exploration of ACGS could be linked to sexual interest towards children (Goyette, Trottier, & Renaud, 2010). Twenty-two child sex offenders and 36 adult males from the community were presented with the nine ACGS developed by Renaud et al. (2002) on a flat panel display. Eye-movement data was recorded using an infrared camera measuring corneal reflection that was installed on a motorized tray and subsequently standardized.

For data analysis, three mutually exclusive body areas of identical dimensions were circumscribed: the head, chest, and genital area (including hips). The creation of distinct body areas allowed considering fixations and saccades in relation to the spatiotemporal changes in and between the identified body areas. Fixation number and duration as well gaze directional changes between areas of references were considered for analysis.

Results suggest that ocular dynamics associated with sexual interest are characterized by shorter mean fixation duration, greater time spent exploring the genital area, significantly greater number of fixations in the genital area as well as a greater number of transitions of eye-gaze toward the chest and genital areas. These ocular behaviors were found in child sex offenders when exploring children stimuli and in men of the community when exploring adult stimuli. Similar results were obtained in a research using the same protocol with the stereoscopic presentation of the ACGS (Trottier, Goyette, Rouleau, Marshall-Lévesque & Renaud, 2014a). Findings support eye-tracking technologies ability to provide relevant information pertaining to sexual interests, which allow group discrimination according to sexual offending history.

Fromberger and colleagues (2012a; 2013) also studied eye movements for sexual interests assessment. Specifically, two studies based on the same research protocol were conducted using monoscopic presentation of fixed computer-generated stimuli, originating from the Not Real People set of stimuli (Mokros, Butz, Dombert, Santtila, Bäuml, & Osterheider, 2011). The selected subset consists of 128 computer-modified photographs of naked and clothed people representing both genders and two developmental stages: stage 1 and 2 (pre-pubescent) and stage 4 and 5 (pubescent and post-pubescent). Both studies were conducted on the same sample composed of 22 child sex offenders, 8 sex offenders of adult women and 52 men from the general population.

The protocol consisted in presenting a pair of stimuli for 5000 ms and then asking which of the stimulus is most attractive. Each set of two stimuli was composed of people from the same gender, but different developmental stages. Eye movements were recorded during stimuli presentation. Following this task, participants were asked to assess subjective sexual arousal for each stimulus at their own pace while viewing time was recorded without their knowledge.

In the first study using this protocol, Fromberger and colleagues (2013) wanted to test the assumption that stimuli in resonance with sexual interests are automatically selected by the viewer and will retain focal attention. Results obtained were in line with the assumption, with child sex offenders recording shorter entry time on child stimuli, whereas men from the community and sexual offenders of adult women, recorded shorter entry time on adult stimuli.

Findings are also coherent with results from the second study (Fromberger et al., 2012a), in which the authors compared the initial orientation, relative fixation time and viewing time according to group. In fact, findings suggest that initial orientation, which represents automatic attentional mechanisms, was faster for child sex offenders when facing children stimuli compared to sex offenders of adult women and men of the community. Similarly, for child sex offenders,

relative fixation duration was significantly longer when facing children stimuli and shorter when viewing adult stimuli in comparison with offenders of adult women and men from the community.

Furthermore, the ability of initial orientation and relative fixation time to classify men accurately according to sexual preference towards adult or children was assessed with ROC analysis. Classification capacity for initial orientation (AUC = .90), relative fixing time (AUC = .83), and visual reaction time (AUC = .76) all recorded good stability and perform significantly better than chance. All three variables' classification accuracy were statistically equivalent. Findings from both researches bring further support to the use of eye-tracking technologies for sexual interests assessment.

The goal of this research (Trottier, Rouleau, Renaud & Goyette, 2014c) was to address penile plethysmography's vulnerability to faking attempts by participants. Precisely, this research evaluated the possibility of detecting, with eye-tracking, the use of cognitive strategies to exert voluntary control on the erectile response during the plethysmographic assessment. Since, eye-tracking research had demonstrated that cognitive processes modulate eye-movement (Engbert & Kliegl, 2003; Hafed & Clark, 2002; Laubrock, Engbert, & Kliegl, 2005; Yarbus 1965, 1967), it was hypothesized that faking attempts resulting from the use of a cognitive strategy would be detected.

To test that hypothesis, the eye movements and erectile responses of 20 men were recorded during the stereoscopic presentation of ACGS. Men had to explore stimuli in three distinct viewing conditions: (1) Free visual exploration of a stimulus corresponding to sexual interest, (2) Free exploration of a stimuli neutral stimulus, and (3) Exploration of a stimulus corresponding to sexual interest while attempting to suppress erectile response. In the third condition, participants were specifically asked to try to inhibit their erectile response by thinking

of a disgusting image previously shown to them. For analysis, areas of interest were computed into three zones: (1) the erogenous zone, which regrouped the chest and genital areas, (2) the non-erogenous zone, which regrouped the head and feet areas, and (3) the exterior zone.

Results suggest that when attempts are made to suppress the erectile response to a stimulus corresponding to sexual interest, eye movement patterns are significantly different compared to the free visual exploration of either a sexually preferred stimulus or a neutral stimulus. Exploration patterns associated with erectile suppression are characterized by subdued stimuli exploration, long and infrequent fixations, and avoidance of the erogenous zone. Thereby, the combination of eye-tracking, immersive technologies, and penile plethysmography allowed the identification of gaze pattern specific to the presence of cognitive strategies used for erectile inhibition. The identification of interfering cognitive processes responsible for erectile inhibition during plethysmographic assessment could significantly improve the internal validity of the assessment process.

A study was conducted to demonstrate the feasibility of immersive "role playing" with a sex offender as an intervention toward recidivism prevention (Renaud, Dufresne, Dassylva, Nicole & Goyette, 2009). The scene was designed based on the participant’s sexual offending history and created by certified clinicians. A clinician enacted the 5-minute real-time interaction with the offender in distinct rooms. A child female ACGS was presented to him through a stereoscopic head-mounted display. A speech recognition system allowed to modulate the lip movements of the animated female child character according to the words used by the clinician in charge. The ACGS was animated through a joystick, which further allowed manipulations of both body movements and facial expressions. Erectile responses were also recorded in real time throughout the role play and allowed the clinician to modulated verbal interactions, body movements and facial expressions of the ACGS.

As the role play unfolded, the participant recorded significant erectile tumescence in response to the ACGS's movements, became increasingly involved in the verbal exchange with the character and expressed cognitive distortions related to sexual offending. This case study introduces the use of immersive technologies to the realm of intervention with child sexual offenders. Role play also allows the direct observation of many risk factor indicators as they unfold in real time such as cognitive distortions, social skills, affect regulation and decision-making skills. It then becomes possible to not only identify the presence of deviant sexual interests but also to understand how individual risk factors emerge and interact in a specific situation towards the commission of a sexual assault. These observations are all the more promising for assessment and treatment purposes when considering the recent development of custom-made ACGS (Dennis, Rouleau, Renaud, Nolet & Saumur, 2014).

Discussion

Some general findings emerge from these different studies. First, the introduction of virtual humans, whether animated (Renaud et al., 2002) or static (Dombert et al., 2013; Fromberger et al., 2015; Mokros et al., 2011), is an important progression for sexual interest assessment. In addition to being standardizable, they allow accurate group discrimination and diagnostic accuracy (Fromberger et al., 2012a, 2013; Goyette, 2012, Goyette et al., 2010; Trottier et al., 2014b) and their ability to elicit physical or attentional responses linked to sexual interests is maintained throughout immersive conditions (Fromberger et al., 2015). Thus, it appears all immersive conditions allow sufficient ecological validity for individual risk factors to be triggered and sexual deviant arousal to take place (Goyette et al., 2010; Fromberger et al., 2012a, 2013; Renaud et al, 2009; Trottier et al., 2014b), which is paramount for both our clinical (Andrews & Bonta, 2010; Andrews, Bonta, & Wormith, 2011; Hanson, Bourgon, Helmus, & Hodgson, 2009) and theoretical (Ward & Beech, 2006) understanding of the phenomenon. This

conclusion supports the implementation of immersive technologies and ACGS as new modalities of assessments in clinical and research settings.

Furthermore, the use of visual stimuli for the penile plethysmographic procedure facilitates the inclusion of additional devices, such as eye-tracking, towards an integrated sexual interests assessment. In that sense, it is becoming evident that many ocular variables are associated with sexual interests (Fromberger et al., 2012a, 2013, 2015; Goyette et al, 2010; Trottier et al., 2014c) and that eye-tracking not only allows a direct access to these exploration patterns but also to underlying attentional and cognitive processes directly involved in the sexual arousal process or its inhibition (Engbert & Kliegl, 2003, 2005; Fromberger, 2012a, 2013; Hafed & Clark, 2002; Laubrock et al., 2005; Trottier et al., 2014c; Yarbus 1965, 1967). Beyond sexual interests assessment, the combined use of eye-tracking and virtual reality could contribute greatly to our understanding of sexual abuse by granting access to perceptual-motor as well as the attentional, self-regulation and decision-making processes associated with sexual arousal and sexual offending behaviours.

However, much more empirical and clinical researches are needed. Eye-tracking applications are very recent in sexual interest assessment. Although an important and necessary starting point, most research protocols to date have been based on exploratory experimental or quasi-experimental designs. Often, working assumptions, selected ocular indicators, and data analysis strategies implemented were also exploratory. Most research protocols have limited the participant's mobility in the virtual space and focused on tracking head movements (3 degrees of freedom). Since increasing interactivity between the participant and the ACGS has proven to enhance subjective ratings of realism and sexual arousal (Fromberger et al., 2015), tracking 6 degree of freedom and allowing the individual to move across the virtual environment and around

the ACGS could further improve the procedure's ecological validity and our understanding of approach behaviors leading to sexual offending.

The use of virtual reality and eye-tracking remains a complex endeavor that requires proper training in the handling of the instruments and as well as in software operation. Furthermore, the staggering number of raw data emerging from each trial requires various transformations before it can be analysed and interpreted. These challenges are further increased by the use of several instruments simultaneously. Now equipped with a decade worth of insight, integrating skills and knowledge from different areas through the composition of multidisciplinary teams should be a priority.

Future research efforts should be devoted to the development of assessments and treatments protocols supported by virtual reality and eye-tracking to appreciate the full potential of these novel tools in the field of sexual aggression. In this regard, the flexibility of the stimuli in terms of physical appearance and emotional expression could allow the development of assessment protocol targeting adult rape perpetrators as well as other types of paraphilias and paraphilic disorders (Hogue & Perskins, 2011; Perkins & Hogue, 2011). Moreover, the possibility to use idiosyncratic characters and environments allow the reproduction of risk situations that are specific to the individual and pave the way to the use of virtual reality for broader assessments and even treatments of sexual offenders (Renaud et al, 2009). It could, for example, be possible to produce a virtual situation in which a participant has to move across a public setting such as a schoolyard or a public swimming pool filled with child ACGS.

On one hand, these protocols could be used to promote the use of self-regulation processes and be used in combination with traditional cognitive-behavioral intervention strategies such as roleplay (Renaud et al, 2009). Such a procedure could possibly be integrated into treatment programs and allow patients to consolidate their knowledge in dealing with their risk

situations in a controlled environment with the assistance of the therapist. It could also allow the therapist to adjust the difficulty of the situation, stop the process at any time to identify cognitive distortions and propose more adapted thoughts or to assist a client having problems with its self-regulation. On the other hand, use of such role plays post treatment could help make decisions in terms of recommendations for monitoring conditions or further treatment, by allowing in-vivo access to a client's abilities to apply behavioral skills acquired during treatment.

If such applications seem particularly attractive, virtual reality and eye-tracking in sexual offending are still for now mostly restricted to the assessment of deviant sexual interests. While more proof-of-concept, as well as clinical randomized trials, are required, other aspects need to be addressed. Environments should be able to offer much more dynamical features than those currently available and to take into account a given patient's reactions. This idea refers directly to notions of interactivity and coupling in virtual environments (Bevacqua, Stankovic, Maatallaoui, Nedelec, & De Loor, 2014).

If the general aim of virtual reality is to simulate an environment closer to reality, a critical feature remains feedback loops by which any action leads to retroaction in a continuous manner. For example, virtual environments should be able to take into account and to evolve according to specific reactions. Imagine an interaction with a virtual character. If a sexual response is detected above a given threshold during a given amount of time, virtual character could morph into a facial expression of fear or disgust. A clinical relevant information could be found in patient's following reactions to this dynamic and continuous "update", directly related to self-regulation processes.

In sum, virtual reality and eye-tracking appear to be promising methods towards the resolution of some of the issues hindering penile plethysmography and a better understanding of the interacting factors related to sexual aggression as they may unfold in natural settings.

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