Using immersive virtual reality and anatomically correct computer-generated characters in the forensic assessment of deviant sexual preferences

Patrice Renaud · Dominique Trottier · Joanne-Lucine Rouleau · Mathieu Goyette · Chantal Saumur · Tarik Boukhalfi · Stéphane Bouchard

Abstract Penile plethysmography (PPG) is the gold standard for the assessment of sexual interests, especially among sex offenders of children. Nonetheless, this method faces some ethical limitations inherent to the nature of its stimuli and could benefit from the improvement of its ecological validity. The use of computer-generated characters (CGC) in virtual immersion for PPG assessment might help address these issues. A new application developed to design made-to-measure anatomically correct virtual characters compatible with the Tanner developmental stages is presented. The main purpose of this study was to determine how the virtual reality (VR) modality compares to the standard auditory modality on their capacity to generate sexual arousal profiles and deviance differentials indicative of sexual interests. The erectile responses of 22 sex offenders of children and 42 non-deviant adult males were recorded. While both stimulus modalities generated significantly different genital arousal profiles for sex offenders of children and non-deviant males, deviance differentials calculated from the VR modality allowed for significantly higher classification accuracy. Performing receiver operating characteristic analyses further assessed discriminant potential. Auditory modality yielded an area under the curve (AUC) of 0.79 (SE = 0.059) while CGC in VR yielded an AUC of 0.90 (SE = 0.052). Overall, results suggest that the VR modality allows significantly better group classification accuracy and discriminant validity than audio stimuli, which provide empirical support for the use of this new method for PPG assessment. Additionally, the potential use of VR in interventions pertaining to self-regulation of sexual offending is addressed in conclusion.

Keywords Immersive virtual reality · Pedophilia · Penile plethysmography · Made-to-measure virtual characters · Sexual self-regulation

P. Renaud
Psychology and Psychoeducation Department, Université du Québec en Outaouais, Gatineau, Canada

P. Renaud · M. Goyette · C. Saumur · T. Boukhalfi · S. Bouchard
Institut Philippe-Pinel de Montréal, Montreal, Canada

P. Renaud (✉)
Module de Psychologie, 283 Alexandre-Taché Boulevard, Room C2803, C.P. 1250 Succursale Hull, Gatineau J8X 3X7, Canada
e-mail: patrice.renaud@uqo.ca

D. Trottier · J.-L. Rouleau
Department of Psychology, Université de Montréal, Montreal, Canada

1 Introduction

Pedophilia is a sexual deviance commonly found among the paraphilias examined in forensic psychiatry. Although its prevalence is difficult to quantify, victims of pedophilia are numerous. For instance, in 2008, 43 cases of sexual assault per 100,000 children were recorded in Canada (Public Health Agency of Canada 2010). Psychological and financial costs of pedophilia are huge. For instance, a recent economic study on the costs of crime in Canada estimated that the total cost of sexual assault was of more than 44 billion dollars in moral damages for 2004 (Department of Justice Canada 2008). As more than half of sexual offenses are committed on minors, the cost of pedophilia is colossal, not only financially but also in terms of public health.

The diagnosis of pedophilia is currently based on three main criteria: (a) the recurrence over a period of at least

6 months of intense sexual fantasies, sexual urges, or behaviors involving sexual activity toward prepubescent children (generally under 13 years of age); (b) the presence of fantasies, sexual urges, or behaviors that cause significant psychological distress or personal difficulties to the patient in the accomplishment of his activities; (c) the requirement that the aggressor be at least 16 years old and at least 5 years older than the victim (APA 2000; 302.2).

The treatment of paraphilias in general, and of pedophilia in particular, is a difficult matter. The assessment of two major treatment programs based on cognitive behavioral therapy points toward results that can be qualified as thin at best (Barnoski 2006; Greenberg et al. 2002). These studies did not find a significant impact of treatment on survival analyses, i.e., on recidivism rate. As pointed out by Camilleri and Quinsey (2008), these disappointing results can be explained by the fact that no treatment can durably alter the central criminogenic need of sex offenders against children (SO), i.e., sexual preference for children. We also suggest that favoring a better integration and contextualization of what is learnt in therapy would help to consolidate and materialize the latter for patients. The feeling of presence and the involvement induced by the use of VR in cybertherapy might well become key ingredients for better results in this difficult field of rehabilitation (see Spagnolli et al. 2013, for a review on presence and cybertherapy). At the end of this article, we put forward that the use of VR might indeed be a good way to aim at these goals, especially in the development of a better sexual self-regulation capacity.

2 Deviant sexual interests and penile plethysmography

The presence of deviant sexual interests represents the strongest determining factor in recidivism among sexual offenders (Hanson and Bussière 1998; Hanson and Morton-Bourgon 2005). Over the years, many assessment methods have been developed to identify deviant sexual interest, such as the Abel Assessment for sexual interests (Abel et al. 1998), the Affinity project (Glasgow et al. 2003), the Sexual Deviance Card Sort (Laws et al. 2000), and the Choice Reaction Time (Wright and Adams 1994). Nevertheless, penile plethysmography (PPG), the measurement of penile tumescence, remains the gold standard in the assessment of sexual interests and is widely used in research and clinical settings (Blanchard et al. 2001).

Deviant sexual arousal assessment using PPG is based on the founding work of Freund in the 1950s, which gained increasing acceptance by the forensic scientific community in the 1960s (Freund 1963; Laws and Marshall 2003). Numerous researches have since established PPG's ability to discriminate sex offenders of children from a control

group (Barsetti et al. 1998; Blanchard et al. 2001; Freund 1965; Malcolm et al. 1993; Quinsey and Chaplin 1988b). To date, sexual arousal evidenced by a genital response expressed toward immature sexual objects or in the context of sexual violence during sexual assessment remains the central feature of our understanding of pedophilia and child molestation (Earls 1983; Kalmus and Beech 2005; Konopasky and Konopasky 2000; Marshall and Fernandez 2003).

2.1 Sexual stimulus modalities used in penile plethysmography

Diverse stimulus modalities have been associated with PPG, namely audio recordings, visual and audiovisual presentations, written scenarios, and sexual fantasy visualization. It is customary in both research and clinical settings to either use audio recordings or visual sexual stimuli. Visual stimuli usually comprise sorted picture sets categorized according to the victims' gender and age group. They are used to determine the offender's preferential gender and age in a sexual partner (Proulx 1989). The use of visual stimuli during PPG assessments to induce states of sexual arousal entails methodological limitations, notably the ethical and legal concerns inherent to the use of images depicting real individuals. In fact, the use of photographic images portraying real models to prompt either sexual arousal or deviant interest responses is a major shortcoming of sexual preference assessment procedures such as PPG and raises concerns surrounding the recurrent victimization of children whose images are repeatedly presented to sexual offenders to generate a sexual response (Laws and Gress 2004). Another limitation associated with the use of photographs is the lack of procedural standardization. Since most photographic stimuli sets come from seized pornographic material, there is no standardized stimulus content across assessment sites. Audio stimuli therefore usually offer more leeway from an ethical standpoint.

Audio stimuli are narrated scenarios describing various sexual acts committed with consenting or non-consenting adult partners and/or intra-familial and extra-familial children. These scenarios provide information on an individual's preferred sexual modes and are known for their sensitivity and specificity in forensic assessment of deviant sexual preferences. Nevertheless, researchers express concerns surrounding the scenarios' limited ability to portray the complex ecological conditions that trigger deviant arousal responses in sexual offenders (Blader and Marshall 1989; Marshall et al. 1999). In fact, environmental factors are getting increasingly recognized for their contribution toward the commitment of deviant acts (Ward and Beech 2004, 2006). Considering the contribution of multiple

factors in sexual offending, researchers are encouraging that modifications be made to improve the level of realism and possibly allow interaction between the participant and the stimuli (Marshall and Fernandez 2003; O'Donohue and Létourneau 1992; Renaud et al. 2002b). Recreating in laboratory settings the complexity and richness of natural environments in which the studied phenomena occurs would yield valuable information on other dimensions of sexual arousal and improve forensic assessment's ecological validity.

Although ecological validity and external validity are different construct (Brewer 2000), both types of validity are mutually linked, particularly when the phenomenon being measured involves perception and anticipation to act in specific contexts (Brunswick 1947; Hoc 2001; Rasmussen et al. 1994; Vincente and Rasmussen 1990). This is especially true where social interactions are concerned, since they involve elements such as emotional states and exploratory or preparatory behaviors. Therefore, stimuli presented during sexual interest assessment should be realistic stimuli made to correspond to individuals' specific criminogenic requirements (Andrews et al. 2006; Marshall et al. 1999; Renaud et al. 2010a; Ward and Gannon 2006) and as a result of prompt symptoms found in real sexual-offending contexts.

3 Virtual reality and computer-generated sexual characters

Researchers in the forensic field have been showing growing interest in virtual reality (VR) and computer-generated stimuli (Bailenson et al. 2008; Renaud 2004, 2007; Renaud et al. 2007a, b, 2009, 2010a). In fact, the presentation of animated computer-generated characters (CGC) in a virtual environment allows participants to be immersed in the presence of animated human-like stimuli, which may foster interactions that resemble reality outside of the laboratory. When addressing forensic issues such paraphilias and especially pedophilia, CGC have to simulate very specific anthropometric features.

4 New criteria for pedophilia and the use of Tanner stages in the design of CGC

Several changes of sexual disorders and sexual identity disorders have been suggested for the forthcoming edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-5*). Some of these changes concern the current pedophilia diagnosis included in the *DSM-IV-TR* (American Psychiatric Association 2000) which referred to recurrent, intense sexually arousing fantasies, sexual urges,

or behaviors involving sexual activity with prepubescent child or children (generally under 13 years old). Based on the last proposition available on the DSM-5 Web site, the current diagnosis will be replaced by *Pedophilic Disorder*, which refers to an equal or greater sexual arousal from prepubescent or early pubescent children than from physically mature persons, as manifested by fantasies, urges, or behaviors (APA 2012). In the forthcoming edition of the DSM, in addition to the specification of the preferred gender, clinicians will now have to specify between classic pedophilic (sexually attracted to prepubescent children: Tanner stage 1), hebephilic (sexually attracted to early pubescent children: Tanner stages 2–3), and pedohebephilic types (sexually attracted to both). This new formulation shows greater consistency with the *International Classification of Diseases-10th edition* (World Health Organization 2010), which defined pedophilia as a sexual preference for children, boys or girls or both, usually of prepubertal or early pubertal age. The proposed changes also take into account that men attracted to children in early puberty (i.e., hebephiles) represent a distinct group with respect to sexual preferences (Blanchard et al. 2009) and other characteristics, such as education, head injuries, etc. (Blanchard et al. 2003, 2007; Cantor et al. 2004, 2005, 2006, 2007). Furthermore, the new diagnostic considers that a significant number of men are pedohebephiles, that is to say, attracted both to prepubescent and pubescent children (Freund et al. 1972). The fact that the new diagnosis is based on the presence of a sexual preference for physical immaturity highlights the importance of objective measures of sexual interests in the evaluation process of sex offenders. These measures should not only be based on the age of the victims, but also on their physical development. The Tanner scale or Tanner staging is frequently used by physicians in order to assess abnormalities in the process of puberty. Indeed, it is an assessment of physical development or sexual maturation, based on primary and secondary sexual characteristics, such as the appearance of pubic hair, the development of breasts, as well as on the degree of testicular and penile development, regardless of chronological age. The different Tanner stages of pubertal development are listed from stage one (prepubertal stage) to stage five (adult stage: complete sexual maturation). The use of Tanner's stages (1973) in the evaluation process of sexual offenders will help to make the diagnosis more accurate by providing clear evaluation criterions based on the developmental characteristics of victims (e.g., a 13-year-old child could look much more or less mature than his age).

Since Tanner stages are based on standard norms, the latter can be used in the design of anatomically correct CGC. A modality combining immersive VR and anatomically correct CGC for PPG assessment could therefore

possibly provide increased sensitivity to ecological variables involved in sexual arousal. This combined modality would also address the ethical concerns surrounding the use of real models in PPG-based assessment of sexual preferences (Laws and Gress 2004; Renaud 2004, 2007; Renaud et al. 2002a, b, 2007a, 2010b). Consequently, the main purpose of this study was to determine how computer-generated stimuli presented in virtual immersion compare to the auditory modality currently used. Specifically, both modalities will be compared on their ability to generate (1) sexual arousal profiles representative of sexual interests and (2) deviance differentials characteristic of the presence of previous problematic sexual behavior. In addition, an application developed to design made-to-measure anatomically correct CGC compatible with the Tanner's stages will be presented in the Sect. 7.

5 Method

5.1 Participants

The clinical sample used in the present study was comprised of 22 male participants having admitted to engaging in inappropriate sexual conduct with minors. Participants were recruited from various community agencies dispensing treatment for sexual deviance throughout the Montréal metropolitan area. Men were either beginning treatment or were involved in presentencing assessment. 16 of them had previous accusations or convictions for sexual incidents involving various degrees of physical contact with children 14 years of age or less. 15 men had already completed at least one specialized treatment for sexual deviance. Criminal records as well as participants' accounts revealed that 18 of them had prepubescent female victim(s), three participants had male victim(s), and one participant had both male and female victims. Six participants in the clinical group attested to having a primary sexual interest toward children, among which two participants described an exclusive attraction to children. Of the remaining 16 participants, 15 described being primarily attracted to adults but also having an equal or lesser attraction to children, while one participant denied any sexual attraction toward prepubescent individuals and described himself as exclusively attracted to adults.

A total of 42 non-deviant (ND) male participants were recruited from newspaper ads to compose the control group. These individuals had no criminal record and attested to not having sexual interests toward children. 32 of these men identified being heterosexual, while 10 declared being of homosexual orientation.

Participants from both groups were matched according to age, education level, and socioeconomic status. The mean

age of the clinical group was 43.5 years (SD = 13.7) while the control group had a mean age of 40.7 years (SD = 11.5).

5.2 Materials

5.2.1 Stimuli

Audio stimuli consisted of 11 scenarios developed by Quinsey and Chaplin (1988a) and later translated and validated for French-speaking populations (Barsetti 1993). One neutral scenario and two scenarios each from five different categories of human interactions were presented: (1) consensual sex with adult partner, (2) nonviolent sexual contacts with a prepubescent child, (3) violent sexual contact with a prepubescent child, (4) rape with penetration of a prepubescent child, and (5) non-sexual assault of a prepubescent child. The mean duration of presentation was 121.8 s for each scenario. A mean score per category was calculated and subsequently used for analyses.

Computer-generated stimuli were 3D virtual characters depicting realistic naked human beings. They were designed, developed, and validated to simulate the Caucasian mesomorphic body type according to Tanner's developmental criteria (Renaud et al. 2010a; Tanner 1973). Because of anthropometric and legal requirements, it was decided to develop an in-house application for creating CGC adapted for use in forensic clinical settings.

This application allows the defining of the CGC's shape as well as its basic color in relation to various anthropomorphic characteristics. The face must be defined as well as primary characteristics such as gender, age, and ethnicity as well as secondary characteristics (eye color, hair color, haircut, etc.). Central to this application is the possibility to define body proportions according to Tanner stages. The application allows the modeling of the body, naked or dressed, with or without genitals (Fig. 1). The design of sexual features is also consistent with Tanner stages. The Tanner scales were integrated as a basis for the body proportions. Different techniques were assessed for varying body and genital features. The main focus was to provide an efficient way to give control over the results while maintaining the validity of body proportions and the genitalia sub-zones dimensions in relation to the Tanner scales. Different approaches were tested for controlling the body morphology and proportions from the use of blend shapes (a.k.a. morph targets), deformation bones and free-form deformation (FFD). It was found that the most efficient way was to decouple the morphology from the body proportions by controlling the body proportions by scaling deformation skeleton while the changes in morphology are done using blend shapes (i.e., slim vs. fat, muscular tonicity, etc.).Tanner scales were integrated as presets for the bones scales and the morphology blend-shapes values.
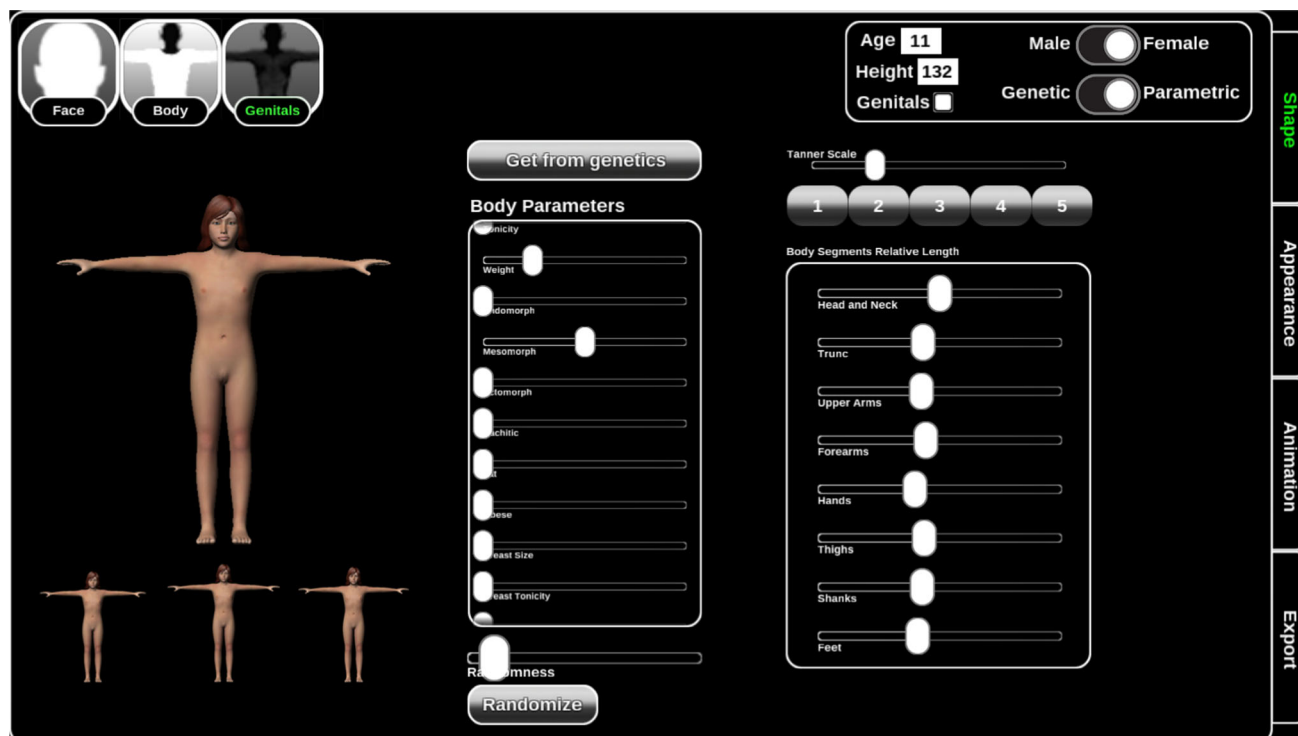
Fig. 1 Screenshot of the application's GUI to adjust Tanner's parameters (parametric mode)

This gives valid results and help getting greater control over the results, allowing interpolation between two Tanner scales to achieve intermediate results. To help achieving both valid and realistic results in accordance with Tanner scales, a series of genitalia blend shapes were modeled (11 for male character and 12 for female character). This allows precise control over the results. As for the body morphology, Tanner scales were integrated as presets of the blend-shapes values. This application could also be used in other studies requiring anthropometrically validated geometry of child characters (see for instance Schwebel et al. 2013).

A total of five CGC were presented: (1) adult male and (2) adult female characters having completed all five Tanner's stage of development (22 to 25 years old), (3) prepubescent male and (4) prepubescent female child at the end of Tanner's first stage of development (10 to 12 years old), as well as a (5) neutral stimulus. These characters were animated to simulate a neutral emotional attitude and subtle body movements and were each presented for a duration of 90 s.

5.2.2 Penile Plethysmography

Penile plethysmography (PPG) allows the measurement of blood flow variations in the penis during sexual arousal. For this study, PPG required that a mercury in rubber strain gauge be worn around the shaft of the penis during assessment. The gauge stretches as a result of the increase in blood flow in the penile shaft inducing variations in the electrical conductance of the mercury. These modifications were converted via polygraph (Limestone Technologies, DataPacUSM 16 bit acquisition instrument) and recorded through specific software (Limestone Technologies, Preftest Professional Suit Software). Raw scores for erectile responses were obtained by calculating the difference between the highest value obtained for a stimulus presentation and lowest preceding value from the start of the same trial. Raw scores were also converted into ipsative scores in an effort to minimize inter-individual variability inherent to penile tumescence (Blanchard et al. 2001). These intra-individual z-scores were subsequently used as dependent variable for statistical analyses.

5.2.3 Virtual reality system

This project utilized a head-mounted display to present dynamic 3D stimuli (NVis, NVisor SX model). The system also included an infrared ocular tracking system. The infrared system allowed pupil recognition and gaze direction analyzes, thereby granting real-time access to the exact gaze location of a participant while he explored the characteristics of a visual stimulus. It was therefore possible for the experimenter to ensure a participant's visual attention was kept on the stimulus throughout the presentation.

5.3 Procedure

After arriving at the Cyberpsychology Laboratory at the Philippe-Pinel Institute of Montréal, participants were briefed on the purpose of the study and on the manner in which data collected would be used. They then signed a consent form clearly attesting to the confidentiality of their participation and their freedom to withdraw from the study at any point. Participants also received a confirmation that their participation and/or results would not be used in any correctional or legal proceedings. Participants subsequently took part in a 20-min semi-structured interview, answering questions pertaining to their life situation, medical status, sexual orientation, and relational and sexual history as well as relevant criminal history when applicable. Following the semi-structured interview, the experimenter moved to an adjacent room to monitor the progress of the experiment. The two rooms were linked by an intercom system allowing two-way communication throughout the assessment procedure.

Participants were asked to attach the penile gauge and given a 5-min habituation period during which their erectile baseline was recorded. The complete translated set of 11 Quinsey and Chaplin (1988a) scenarios was presented to every participant. Erectile responses were recorded from the beginning of each scenario and ceased 30 s after each scenario ended. A return to baseline was required before a new scenario began. After all scenarios were presented, participants were allowed a resting period after which we started the second phase of the experiment.

Participants were then equipped with the head-mounted display and presented with a calibration screen, which allowed the experimenter to adjust the infrared ocular tracking system for gaze direction monitoring. Participants were then presented with a 5-min segment of an erotic film corresponding to their sexual orientation to assess erectile potential. A return to baseline was required in order to proceed with the experiment. Virtual characters were subsequently presented in preselected order: female adult, female child, male child, male adult, and neutral. Precisely, the order of presentation was randomly selected prior to beginning testing and stayed the same throughout the procedure with the exception of the neutral stimulus, which was presented last to avoid potential order effects on the perception of character realism. Virtual characters were each presented for 90 s during which erectile responses were recorded. Penile responses continued to be recorded for 30 s after each presentation. A return to baseline between stimuli presentations was required.

After all five CGC were presented, participants were asked to answer questions on the perceived age of each CGC as well as their perceived subjective sexual arousal to the CGC. They were also encouraged to give feedback on the entire procedure. Before leaving the laboratory, participants were screened for cybersickness symptoms; cybersickness is usually defined as motion sickness experienced by users of head-steered VR systems (McCauley and Sharkey 1992). The entire procedure was approximately 2 h in duration for which participants received a monetary compensation.

5.4 Statistical analysis

MANOVAs (Group × Stimuli) were first performed, and ANOVAs were subsequently executed in the context of significant multivariate effects. Deviance differentials were calculated for both stimulus types. Receiver operating characteristic (ROC) analyses and area under the curve (AUC) comparison were also carried out. An alpha level of 0.05 was used for all statistical analyses. All participants with complete data, including those having recorded low sexual responses, were included in the analyses.

6 Results

A MANOVA was conducted to investigate whether there were differences between groups based on sexual responses to the six different categories of human interactions presented as audio stimuli. Using Wilks' statistic, a significant effect of Group on erectile responses obtained to audio scenarios was found ($\Lambda = 0.80$; $F(6, 54) = 2.67$, $p < 0.05$). Separate ANOVAs on the outcome variables revealed significantly greater sexual arousal for the SO group compared to the ND group to three different scenario categories: (1) nonviolent sexual contacts with a prepubescent child ($F(1, 58) = 7.41$, $p < 0.01$), (2) violent sexual contact with a prepubescent child ($F(1, 58) = 5.81$, $p < 0.05$), and (3) rape with penetration of a prepubescent child ($F(1, 58) = 6.23$, $p < 0.05$). No significant differences were found for non-sexual assault of a prepubescent child, consensual sex with an adult partner, and neutral scenarios (see Fig. 2).

A MANOVA was also conducted to investigate whether there were differences between groups based on sexual responses recorded to the five different CGCs. Using Wilks' statistic, there was a significant effect of Group on erectile responses recorded to CGC in virtual immersion ($\Lambda = 0.21$; $F(5, 53) = 15.37$, $p < 0.001$). In addition, separate univariate ANOVAs indicated significant group differences for erectile responses elicited by four CGC: female adult ($F(1, 61) = 4.79$ $p < 0.05$) and male adult ($F(1, 61) = 11.50$, $p < 0.01$), as well as female child ($F(1, 60) = 9.52$, $p < 0.01$) and male child ($F(1, 60) = 8.68$, $p < 0.01$). No significant difference was found for the neutral stimulus. The SO group presented a distinct sexual
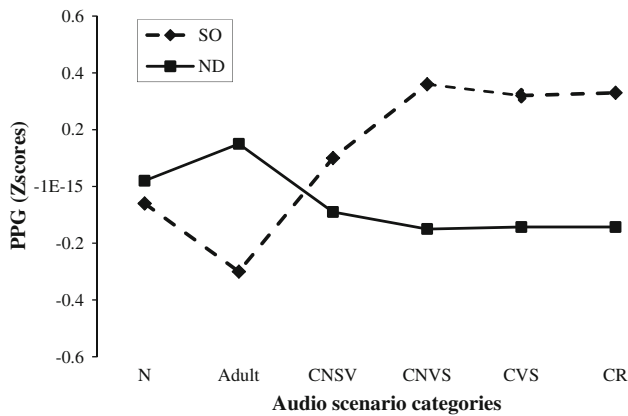
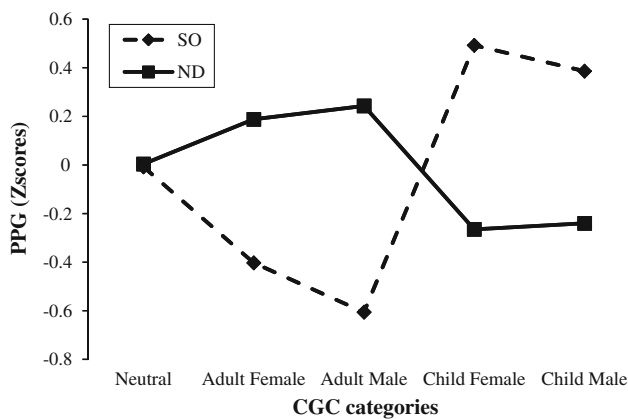Fig. 2 Sexual arousal profile recorded with audio scenarios

Fig. 3 Sexual arousal profile recorded with computer-generated characters

Table 1 Group classification accuracy for audio and CGC in VR immersion presentation modalities

| | | Computer-generated characters | | |
		Correctly classified	Incorrectly classified	Total
Audio scenarios	Correctly classified	40	4	44
	Incorrectly classified	14	2	16
	Total	54	6	60

The deviance differential cutoff point was 0.25

arousal profile, marked by pronounced erectile arousal in response to male and female child stimuli. On the other hand, ND group presented significantly greater sexual arousal to adult stimuli (see Fig. 3).

Deviance differentials were calculated for 60 participants in order to determine the classification accuracy of each instrument at a specific cutoff point. The cutoff point of 0.25 was chosen since it is recognized as the threshold after which individuals meet the diagnostic criteria for pedophilia (Blanchard et al. 2001; Freund 1990; Seto et al. 2006). Deviance differentials were calculated by subtracting the largest mean response obtained with adult stimuli from the largest mean response of the children stimuli (Harris et al. 1992; Seto et al. 2004, 2006). Individuals from the ND group scoring 0.25 or less and individuals from the SO group scoring 0.26 or more were deemed correctly classified, while individuals from the ND group scoring 0.26 or more and individuals from the SO group scoring 0.25 or less were labeled as incorrectly classified.

Deviance differential resulting from the virtual immersion modality allowed the accurate classification of fifty-

four participants compared to forty-four accurate classifications for the audio modality (see Table 1). A McNemar chi-square test (Sheskin 2004) was performed to determine whether the classification accuracy of both stimuli modalities was equivalent. Results suggest that classification accuracy for both stimuli presentation modality was statistically different, $\chi^2(1, N = 60) = 5.56$, $p < 0.05$, with the virtual immersion modality performing significantly better than the audio scenarios modality.

Receiver operating characteristic (ROC) analyses were performed to further compare the group discrimination performance of audio stimuli and CGC based on deviance differentials. ROC analyses help determine the ability of a test to discriminate between two groups looking at specificity and sensitivity of the latter (Streiner and Cairney 2007). Sensitivity (or true positive rate) measures the proportion of actual positives which are correctly identified as such (e.g., the percentage of participants who are correctly identified as being SO) while specificity measures the proportion of negatives which are correctly identified as such (e.g., the true negative rate, here, the percentage of participants who are correctly identified as being ND). The area under the curve (AUC) represents the probability that the method used will produce a higher PPG score for the SO selected randomly than for a randomly selected control individual. The AUC values can range from 0 to 1. A value of 0.5 represents differentiation power at the level of chance whereas higher values indicate better performance (Streiner and Cairney 2007). Audio scenarios yielded an AUC of 0.79 (SE = 0.059, 95 % CI 0.70–0.91) while virtual immersion yielded an AUC of 0.90 (SE = 0.052, 95 % CI 0.86–1.0) (see Fig. 4). Confidence intervals were calculated using the bootstrapping approach, which is recommended for small sample sizes (Altman 2000).

Additionally, AUC comparisons between CGC used in virtual immersion and audio stimuli were performed following the method proposed by Delong et al. (1988). This method takes into account the implicit correlations between two curves derived from the same participants. The results indicated significantly different discrimination ability
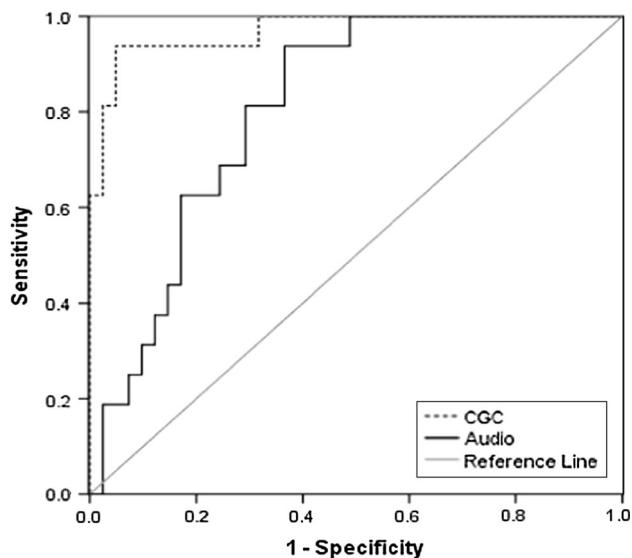
Fig. 4 ROC curves for both presentation modalities

between modalities χ^2 (1, $N = 58$) = 7.91, $p < 0.01$, with virtual immersion performing better than audio stimuli.

7 Discussion

This research has limitations. First, all individuals composing the SO group had previously admitted to having inappropriate sexual behaviors with minors, which is hardly the case in forensic settings where most individuals usually deny any sexual interest for children. Attempts should be made to obtain similar results with individuals denying their involvement in sexual behaviors with minors. Second, since both CGC and immersive VR were used in conjunction, it is difficult to distinguish each of their independent contributions to the results. However, similar results were obtained by using CGC on a standard computer monitor, thereby not using an immersive virtual environment (Goyette et al. 2010). Finally, the order in which the stimuli sets were presented was randomly selected prior to beginning testing and stayed the same throughout the procedure. It was therefore impossible to counterbalance or account for any impact the order of presentation might have had on the results.

In spite of the aforementioned limitations, the results obtained show great potential for these new forensic assessment methods in the field of sexual deviance. The main purpose of this study was to determine how computer-generated stimuli presented in virtual immersion measured to the auditory modality currently used. We first compared both modalities' ability to generate sexual arousal profiles representative of sexual interests. Results suggest that the presentation in virtual immersion evoked

significant sexual responses and generated significantly different genital arousal profiles for SO and ND. This finding is consistent with other studies having recorded arousal profiles specific to sexual interests with CGC (Renaud et al. 2002a, 2005, 2007b, 2010a, 2011a; Trottier et al. 2012). Audio stimuli also yielded significantly different genital reactions between SO and control groups on all scenarios describing sexual activities with prepubescent children, which gave rise to distinct arousal profiles according to group. These results were consistent with previous studies, indicating that our sample was comparable to the samples used in previous research (Barsetti et al. 1998; Lalumière and Quinsey 1994; Laws et al. 2000).

We also compared both modalities' capacity to generate deviance differentials that are characteristic of the presence of problematic sexual interests. Results suggest that virtual immersion using CGC produces deviance differentials which are representative of the presence of problematic sexual interest. Deviance differentials calculated from CGC allowed for the accurate classification of fifty-four of sixty participants. They also yielded a discrimination performance that was significantly superior to chance as attested by an AUC of 0.90. Results therefore suggest that CGC presents a very good discriminant validity. Comparable results were obtained in another study using the same CGC presented on a standard computer monitor (Goyette et al. 2010). In addition, CGC presented in virtual immersion recorded a significantly greater AUC value as well as a significantly higher classification accuracy rate than the auditory modality, suggesting that VR may be more efficient at discriminating men according to their sexual interest than standard sound technology alone. The fact that the performance of CGC used in virtual immersion is statistically superior to the one of audio scenarios shows the potential as well as the relevance of the former as a forensic profiling tool for sexual preferences. It also encouraged our team to develop of an application to intuitively design made-to-measure anatomically correct CGC.

8 Conclusion

Virtual reality and related simulation technologies might indeed change the way we do forensic research, clinical practice, and preventative screening with sex offenders. Assessment of sexual preferences, as presented in this study, but also other dimensions of sexual aggression could be addressed through VR. Among the clinical intervention targets to be considered, because of its direct link to aggression planning and acting out as such, relapse prevention is a good candidate. Relapse prevention with sex

offenders revolves around the topics of sexual arousal and behavior self-regulation. Self-regulation of offending, which is indeed at the core of the problem, is based on a combination of internal (.e.g., neurological dysfunctions, anxiety, and cognitive distortions) and external (environmental) processes that drive the person to manifest (or not) the problematic goal-oriented behavior (i.e., to act-out or not; Ward and Hudson 1998; Ward and Beech 2006). Voluntarily or automatically, this behavioral regulation process, which is conducted over time and in different contexts, manifests itself through the modulation of perceptual-motor processes and attention (Baumeister and Heatherton 1996; Karoly 1993; Renaud et al. 2011a; Ward and Hudson 1998). Interventions with sex offenders would benefit from the use of VR in many ways. For instance, less critical scenarios than those required by our study could be used to track cognitive distortions and planning process of sexual aggression; daily life situations, concrete elements of relapse cycle such as stressing events could be simulated in VR to probe into these aspects of sexual aggression as if they were lived in real time by the immersed individual (see Serino et al. 2013, for a review of stress inoculation and VR). In this way, emotional regulation problems, cognitive distortions, and social difficulties typical of sexual aggression could be addressed in context and be treated using various learning and conditioning techniques (see Gutiérrez-Maldonado et al. 2013, for a VR application in training for facial emotion recognition ability; Hanson and Harris 2000; Marshall 1989; Proulx et al. 1999; Renaud et al. 2011a; Thornton 2002; Ward and Beech 2004, 2006). Virtual reality and related simulation technologies could indeed play an integrative role in giving a concrete and less abstract expression of the treatment modules usually offered to SO.

Alternatively, and in a more direct fashion, self-regulation of sexual offending could be addressed through neurofeedback, i.e., in using a VR-mediated brain-computer interface. The coupling of CGC to real-time brain–computer interface might well give rise to neurofeedback therapeutics for deviant sexual behavior in the emerging field of neurorehabilitation (Birbaumer and Cohen 2007; Renaud et al. 2011b; Sitaram et al. 2009). The goal of the approach would be to modulate through conditioning abnormal activation of specific brain regions associated with pedophilia. With the emergence of neuropsychological and neuroimaging studies characterizing pedophilia, this avenue is now conceivable (Joyal et al. 2013; Polisois-Keating and Joyal 2013). All these innovative intervention techniques will, however, have to be based upon developmentally and anatomically correct made-to-measure CGC in order to optimally address the multiplicity of deviant sexual behaviors.

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