Use of Virtual Reality and Human-Computer Interface for Diagnostic and Treatment Purposes in Human Sexuality Research

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Abstract. Virtual reality technology allows designing of immersive virtual environment that might be used for diagnostics and treatment of persons with minor sexual preference that is ego-dystonic or is perceived as dangerous to society. We do operate with the theoretical framework that is based on sexual motivational system, which we reintroduce. The eye tracking, electroencephalography and galvanic skin response in combination with phalopletysmography – the change of penile tumescence in male users are data to be collected to distinguish between sexual arousal and stress. The bio-cybernetic loop will consist of combination of positive and negative feedback loop to diverge the scenario. The biofeedback training should allow us to shape the preference by employing biofeedback training of suppression of the arousal to previously created scenario. This procedure might allow better diagnostics and treatment. Although we have in mind individualization of scenario creates problems in comparison during diagnostic phase, and is more important in case of future therapy. The resulting adaptable GNU software will be available to partner and other interested research centers.

Keywords: Virtual reality · Bio-cybernetic loop · Biofeedback · Sexual paraphilia · Diagnostics

1 Introduction

For decades, we may trace the growing interest in design of a direct human-computer connection amongst professionals, enthusiasts, and even public. Until constructing first bio-cybernetic loop (also human-computer interface) [1], the human-computer relationship may be best described as monologic – the initiation has always been on the side of human and all input are highly asymmetric. The standard control of the computer is implementing the keyboards, mouse, joysticks or various types of touchpads, and more recently touchscreens. The volume of information that one person would gather on/from computer is much higher than the computer could gather about the person who is in control. A dialogue, two-way information sharing, would be much more advantageous since there is very specific population that is mostly disqualified from using standard ways of controlling electronic devices i.e. users with disabilities.

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There are several approaches to enable their engagement in computer control. The first and currently easily accessible interface is a voice-control that allows a user to execute the additional activity while using their hands for primary activity simultaneously. So, in this case we can talk about the monologue even literally. Electroencephalograph (EEG) has also been implemented to allow paraplegic users to control their electronic devices.

EEG was originally, in HCI context, applied to diagnose specific brain activity and distinguish between several mindsets such as engagement in the task or extreme workload. That is why NASA has adopted this technique to diagnose pilots' ability to cope with specific situations that can occur during aerospace operations for example [2]. The examples listed in this contribution do relate to the unidirectional information flow from human to computer. These examples can also state control measures during psychological testing to obtain data about the subject´s attention where adaptation is not undergoing analysis based on the EEG data [3]. These approaches are characterized by the fact that does not need real time feedback and might be analyzed retrospectively but are generally applicable to non-patient population.

With a priority to focus more on the dialogic options, we might set an extension of the above mentioned examples to change the environment based on the information obtained through psychophysiological measures [4]. Users of such loop are often healthy users and one of the intended implementation is in area of entertainment. We are informed about ongoing research on other applications of bio-cybernetic loop in psychology related research.

While there are unquestionable benefits raising from adoption of such approach, we may trace related risks. The gameplay relation must be executed in a real-time or close-to-real-time mode of analyses and adjustment. The user and gaming-like application need to set up a sort of co-evolution while using such a platform, especially in the initial phases. In other words, the butterfly effect of player-game interaction will occur [5]. That avoids comparative measuring of players' gameplay performance due to differences in gaming environment design as each players' gameplay establishes an individualized environment for each player. The same problem we can spot when using bio-cybernetic loop for scientific use, namely diagnostics. In our research, we attempt to challenge this premise.

Currently, we do proceed with a research on (above-listed options) at the Laboratory of Evolutionary Sexology and Psychopathology associated with National Institute of Mental Health in the Czech Republic.

2 Current Research

Our recent research activity has been including as one of the team priorities a focus on utilization of immersive virtual reality technology and animated avatars design. We may list a number of benefits when implementing virtual reality technology in sexuality research such as: (a) bespoke animated stimuli can be created and customized, that is especially important when researching paraphilia (unusual sexual preference) and sexual preferences; (b) stimulus production is less expensive and easier to produce when compared to real world stimuli; (c) virtual reality allows our researchers to record

data such as physiological reasons to stimuli, data that would be normally not available to capture before (without resorting to self-report measures that are especially problematic in this research domain); (d) ethical, legal, and health and safety issues are less complex since neither physical nor psychological harm is being caused to animated characters, which allows for the safe presentation of stimuli involving vulnerable targets [6].

This research intends to combine the various approaches and design a diagnostic tool and training environment for users with various difficulties such as social, developmental and, since it is our primary interest, sexual preference disorders that will allow us to more accurately diagnose, and possibly treat these users.

The final product interface/software with adaptive environment control should be available to wide public since all patents we would produce would be of GNU General Public License and can be adapted for various implementations. Namely, we would like to employ the bio-cybernetic loop for diagnostic purposes of people with unusual (in scientific literature also called minor) sexual preferences such as pedophilia or sexual aggression. For each case, the loop will be applied in a specific way as described further.

2.1 Theoretical Framework of Paraphilia

First, we should explain theoretical approach to paraphilia that is being employed for better understanding of the loop design and paradigm of changes. Currently, the research in its entirety to be primarily focused on men since their sexual reactivity is object and activity specific as opposed to women, who seem to exhibit much less stable sexual preference and reactivity. Also male paraphilics are much more common, therefore scientific literature on female paraphilia is rather scarce, and male offenders are more dangerous to society than female ones. Moreover, there is relatively high concordance between self-report measures of male sexual arousal and measures obtained by using psychophysiological measures. As for preference of object (usually a person, but not necessarily) and activity we feel need to give decryption of terms used further in text. Preference for sexual partner of adult age is called teleiophilia and in the article it will be used as opposite to pedophilia which can be described as predominant preference for sexual partners that are underage, in research usually defined as being between 4 and 12 years of age (even though we are aware that the complete opposite is gerontophilia – predominant preference for partners of elderly age).

Also we will use description of two types of sexual behavior towards partner differing based on consent. The usual preference during which the partner is cooperative and willing will be called consenting. People with this preference do have conventional sexual preference and usually are healthy controls[1]. The second type, coercive, where aggression and pressure is present and the sexual intercourse is initiated even when the sexual partner is non-consenting. This distinguishes such preference from consensual sado-masochistic preference where is also present certain degree

[1] Non-patient population used to show contrast between specific participants and "normal" population.

of violence but both partners are consenting, and the interaction can be interrupted at any moment. To be able to diagnose and treat patients with unusual preference we need to understand etiology of such preference.

One of the influential theories having its origin in research conducted in the Czech Republic attempts to explain various unusual sexual preference as an expression of a common "underlying disorder" is the theory of disruption of Sexual Motivation System derived from the model of "courtship disorders" by Freund [7] and the "theory of vandalized lovemaps" by Money [8]. SMS posits premise that sexuality can be seen as hierarchically ordered and an interconnected system of particular sexual motivation levels that refer to a sequence of courting behaviors found in female mammals including humans and corresponding male reactions. According to the SMS approach, pre-intercourse cognitions of a female sexual object and its sexual interest precede the start of male sexual reaction and successful sexual act. Particular parts of male SMS system are:

- Attractivity (attention to a sexual stimulus with specific physical traits, e.g., adult female)
- Proceptivity (appetence for signals of female attraction to a male and attempts to seduce),
- Receptivity (appetence for signs of female readiness to copulate and of cooperating copulative behavior) [9].

Importantly, SMS theory suggests that the hierarchy of behaviors and their specific cognitive patterns occur sequentially. That is, the fulfilment of lower motivation levels must be achieved for the next step in motivation to be employed (e.g., attractivity must be complete before proceptivity is employed). If the motivational levels occur out of sequence, or some are omitted, the system inhibits sexual arousal (e.g. proceptivity of a female without previous attraction to her). The first two phases are key phases to understand unusual sexual preferences. In the first one, attractivity, the object (most likely person of preferred age and sex) plays major role. Male heterosexual teleiophilic would be attracted to adult female, male homosexual teleophilic would be attracted to adult men. Male heterosexual pedophile would be attracted to underage girl and male homosexual pedophile would be attracted to underage boy. In the second, proceptive, phase it would decide whether the courtship would be consenting or coercive (based on positive or negative signals coming from the sexual object chosen in phase of attractivity).

2.2 Environment

The research that includes the bio-cybernetic loop design has an objective to design environment that will enable for testing of sexual preferences, or rather distinguishing between various (above described) pre-defined preferences. This type of testing method is especially helpful when combined with immersive virtual reality environment and implementations of near-photorealistic designed avatars. The implementation of virtual reality environment will offer to design (technically speaking) infinite amount of realistic appearing avatars with a goal to increase the fit of preference of each person tested. This is especially advantageous in case of studying preference of sexual

aggressors and pedophiles since in both cases they seem to "have a type". In other words, the person does prefer certain characteristics such as specific age, sex, color of hair and eyes, etc. The first part of the procedure is aimed to determine the preferred type of interacting avatar.

The environment itself will be created in one of the commercially available game engines. We are still in testing phase of the study and based on the outcome, Unity[2] or Unreal[3] game engine will be used to meet criteria such as immersion, photorealism, and loop design functioning. Preferably, there will be no animated objects or other avatars in any of the scenarios. We expect that the environment does not need to be complex since the attention should be focused solely on the interacting avatar itself. In case of out of the door scenario, the city environment will be used with unified color and light conditions will be controlled since eye-tracking and pupilometry used during this phase are light-condition sensitive procedures. Indoor scenario will always take place in same looking room, with low complexity for the above mentioned reasons. All scenarios will be presented from first person perspective.

The avatars will be interacting in the same manner, the same (on scientific literature [10] based, consenting and coercive) behavior – the movement will be the same (except for underage avatars, as described lower in the text). For this purpose, prototypic types of appearance respecting avatars will be pre-made. The expected amount is 10 avatars of each sex and age group to capture the variability of population. In the first set, only Caucasian race will be present since racial diversity of Czech population is very low. There will be four age groups present in the stimuli sets: (a) 4–6, (b) 10–12, (c) 14–16, and (d) 20–25 years of age. The age groups are based on previous scientific literature and Tanners development stages. In total, there will be 10 (appearance) × 2 (sex) × 4 (age) = 80 different types of avatars. Each avatar will also be presented in consenting and coercive proceptive behavior (80 × 2 different types of stimuli). Also sexual activities represented for each avatar type will be presented but in this case, only genital interaction (of neutral age) respecting the sex of the preferred avatar will be presented (2, penile-vaginal or penile-anal intercourse) for ethical reasons. The total amount of stimuli prepared for this study will be then 162.

Four time-loops with same amount of behavioral displays of each type (consenting and coercive) will be created to create illusion of ongoing interaction for case of prolonged exposure in training with a possibility of terminating the loop and starting a new one, with fluent change. In case of biofeedback, we expect that there can be two possible ways of visualization. One is to present the person with bars representing degree of arousal and stress. The other, perhaps more useful in later stages of training, is processing of saddle color changes in the environment, such as color filter engagement, respecting certain amount of stress and arousal. Or only specific object color change can be applied (e.g., vase on a table will change color on a scale from blue to red, clock will change time based on arousal (minute hand) and stress (hour hand) to allow biofeedback training with smaller amount of disruption of the situation, which we find novelty. The whole project is under development and actual outcome may differ.

[2] https://www.unrealengine.com/what-is-unreal-engine-4.

[3] https://unity3d.com/.

2.3 Procedure

The participant will be comfortably seated in room with all the equipment ready, researcher will attach all the sensors. Participant will be asked to attach the head-mounted-monitor (if compatible, eye-tracking is available, if not, monitor and eye-tracker will be used). Neutral movie with controlled light environment will be presented to obtain basal levels of psychophysiological measures.

First, the participant will be virtually walking on a street (speed will be adjusted) and on each side of the street there will be an avatar of certain type. Since visual attention and sexual preference are in concordance in men, as was shown in past research, the type of avatar that will be given attention will be automatically further developed in scenario. During this part, EEG data will also be collected to distinguish the preference. We expect that avatars will be presented wearing clothes, but possibly they will be presented naked in case of adult ones and in swimming suit for case of children. The decision logic will be tested but by now we expect that the hierarchy of choice will follow these lines: sex (male vs. female), age (10–12 years old vs. adult avatars) – in case of preference of underage avatar, all three underage categories will be tested against each other. Number of trials will be chosen based on pilot study and specific physiological reaction, expectedly EEG data will be used, accompanying the eye-tracking procedure. Once age and sex are selected, other properties will be tested as well.

As an alternative to this procedure there is one suggested by Patrice Renaud and his colleagues, using magnetic resonance [11]. In this scenario, the age of pre-chosen sex is dynamically changing and based on psychophysiological reactions during certain period of presentation, highlighting the age of avatar can be used as decision-making procedure. Such design is especially helpful in treatment in future phases.

Nevertheless, once the looks are decided, the scenario will shift to interior spaces where the avatar will be presented in the non-interactive manner to fulfill the phase of attractivity. Length of presentation will be also adjusted based on pilot study and individual reactivity. As next, both, coercive and consenting proceptivity will be presented in randomized order directly followed by receptivity (sexual act). During all phases, psychophysiological measures will be collected to distinguish between the above mentioned sexual preferences. As control condition, non-preferred avatar will be presented in the same scenarios and data from both conditions will be compared. The same will follow, but this time the appearance will be kept, but proceptivity will differ. In case of clear negative reaction (change of EEG pattern, change of galvanic skin response are expected variables) towards the stimuli, the scenario will be changed. During the calibration phase, self-report data will be also collected. This will allow us to create profile of preferences that the person has for future testing.

Such scenarios will be, in case of patients, saved for case of bio-feedback training during which the person will learn how to cope with their sexual preference.

Since one of the intended implementation of the loop is treatment and behavior adjustment, the biofeedback training will be employed. Based on previous diagnostic session, the scenarios will be created respecting the appearance and activity that the tested person exhibited. In case of participants with sexual preference that, for legal or personal reasons, needs modification, alternative scenario, respecting target preference, will be constituted. In the next part we will use original scenario – the one based on

participant's preference, and target scenario – the one that is respecting legal, or personal (in some cases) boundaries.

In phase of biofeedback training, during scenario presentation, the tested participant will be exposed to visual representation of his mental state, especially sexual arousal and stress (generally negative reaction). The aim of the procedure is to enhance participant's ability to suppress their sexual arousal in inappropriate scenario, but also to maintain control over their negative and stressful reaction during periods of suppression. In ideal world, we would hope to enhance ability to consciously increase arousal in the appropriate scenario.

Since the theory of SMS is based on hierarchical model where each phase is followed by hierarchically higher motivation (attractivity => proceptivity => receptivity), we can let the participant stay in specific phase for all the time needed to achieve the goal and change the scenario based on outcome of the previous phase.

2.4 Sample of Participants

Since we want to use the diagnostic tool to distinguish between males with usual (homosexual teleiophilia is considered usual sexual preference) and unusual sexual preferences based on the age they prefer (child or adult), sex they prefer (male or female) and type of proceptivity (positive and negative). For this reason we decided to ask patients with the matching sexual preferences (pedophilic preference, sexual aggressors, approx. 15 of each preference, 30 in total) and healthy controls (male heterosexuals and homosexuals of matching age, with no history of sexuality related problems, approx. 40) to participate in the study. All participants will go through procedure of sexual diagnostics before participation and rules for ethics of psychological research will be strictly obeyed. Advantage of use of these target groups is also that each target group reacts by positive reaction and sexual arousal to presentation of stimuli that match their preference but has rather negative reaction towards all other categories of stimuli.

2.5 Measurements

In the past research, many potential problems of measurement have been identified. The primary problem is that representation of mental state by changes in psychophysiological measures does not have to be linear. For more, the psychophysiological change can relate to more than one state. And vice versa, one state can be demonstrated in more than one psychophysiological measure change.

In the existing scientific literature, it has been recommended to use more than one measurement to represent the mental state of a person. As suitable for such loop construction several psychophysiological measures were suggested. Among these, eye tracking[4] and pupilometry[5], galvanic skin response[6], electrocardiography[7], data about

[4] Area of visual attention related data are collected to estimate area of interest.

[5] Measuring the size of pupil to estimate mental states.

[6] Measured to estimate level and type of excitation.

[7] Data about heart rate change will be collected to distinguish between emotional states.

respiratory rate[8]. Newly, we would like to add penile-pletysmography[9] on the list of measures used to construct bio-cybernetic loop, since it is one of measurements with relatively high accuracy and is well studied in scientific literature [12]. Also electroencephalography is possibility that will be considered since scientific literature shows that specific emotional states can be represented by changes in electrical activity of the brain and specific response is demonstrated when their preference matching type of stimuli is presented. The advantage is that since different part of human body are used to collect data, more measurements can be collected simultaneously resulting in possibility of using variety of combinations to define mental state more accurately. All of the above mentioned measures have also been used in research of human sexuality individually or in combination, and we believe we will create functional loop based on these measurements. Process of testing is described lower in text.

2.6 Equipment

For this study we dispone with dedicated experimental room at National Institute of Mental Health of Czech Republic. The bio-cybernetic loop will consist of: personal computer (HP Envy gaming series 2015 desktop seems to meet the our requirements so far) – head mounted display (e.g., Oculus Rift, FOVE or 4 k phone display) – human – device for psychophysiological data collection – computer. We will employ BioPac MP[10] as the device for psychophysiological data acquisition allowing the collection of more physiological measures simultaneously, when special modules, present in the lab to be added to the device. All of the above mentioned psychophysiological measures can be measured using one single device. The device also can be used for signal amplification and redirection of the data to computer to close the loop.

Specialized software is to be used to collect data about the user, as an interface, and set thresholds on individual variables allowing storing individual profiles of tested participants in memory. The software will also be used for visual representation of mental state, or single variable(s), on the screen for the bio-feedback training in later phases that are not described in this article. Also, we will use a device for self-report data acquisition preferably of a lever construction with possibility of visual representation of choice on the screen to allow employ the head-mounted monitor on. Virtual reality environment is currently developed and tested in Unity 5 game engine, while Unreal 4 having as a possible alternative. All devices and software are being tested with the goal to identify and optimize the virtual environment production pipeline (capacity, compatibility, efficiency, and ease of use).

2.7 Testing Process and Development of the Loop

Testing of the loop will follow 6 phases suggested by Fairclough [13]:

[8] Collected since it is related to emotional states and for more is under voluntary control.

[9] Data about penile blood flow are collected to estimate sexual excitement.

[10] Device for psychophysiological measurement data acquisition.

1. Conceptual Model (s) – Model of psychological states during specific situations was put together based on scientific literature to conceptualize specific user behaviors. In our case we made bipolar labels of possible reaction on stimulus. As mentioned above, we expect rather sexual positive reaction on preference matching stimuli and rather sexual negative reaction on all other categories of stimuli.
2. Psychophysiological Interference – At this stage we have elected and chose psychophysiological measures to represent each mental state. Namely, we focused on eye tracking data, EEG, and PPG measures for which scientific literature is very clear and we will test all other variables in combination to find best possible solution. All participants will go through all possible testing scenarios collecting data from psychophysiological measures as well as self-reports. Also there will be phase during which they will have possibility of voluntary decision in times where the future loop would make scenario shift.
3. A Quantified Model of User State – We will develop the way in which the user state or behavior is represented within the bio-cybernetic loop. The minimum requirement of the quantified model will be that the user is represented with sufficient fidelity to enable the process of adaptation within the loop. In other words, the target states that drive the adaptive logic of the loop will be clearly defined during this part.
4. A Real-Time Model of User State – Based on previous generic formulation defining "data space" the model to trigger adaptation in real time. The model will be populated with criteria and classes that define regions of user state representation. Also individual user customization of thresholds possibility will be brought out in this stage.
5. Design of Adaptive Interface – The way that the loop makes adaptations will be tested during this testing phase. Main concern would be whether the change is efficient and noticed or not by the participant, and the change is in concordance with researcher's expectations and matches preference of each tested target group. Testing will also focus on concordance with self-perceived adequacy of the change and states before and after change will be compared to see whether the change does not create confusion or immediate notable change in participant's state showing that the change can be rather disturbing.
6. Evaluation – During this stage all benefits of creation of bio-cybernetic loop will be considered and analyzed, and the result will be compared with possibility of direct testing or use of other method to reach the goal of research.

The loop will be designed as a combination of positive and negative control loop, so called "toggling loop". Negative control loop has been proven to be more stable and seem to be advantageous in cases in which psychological comfort and wellbeing during testing is preferred. In all instances of testing and biofeedback phases there will be "safe" (neutral) scenario for case of procedure induced stress where participant would be redirected if needed. The positive control loop is applied in case of scenario diverting (for each sexual preference based on change of psychophysiological changes during presentation of the stimuli) but will have control in negative control loop to ensure the stability and control for time variable.

2.8 Ethical Aspects of the Proposed Study

There are a number of ethical issues associated with the design and use of physiological computing systems. This technology is designed to tap private psychophysiological events and use these data as the operational fulcrum for a dynamic HCI. The topic is even more tormenting since the primary use of this loop is sexual diagnostics which is very sensitive topic in general, for more it is related to sexual acts that are in conflict with law (pedophilia and sexual aggression).

All personnel directly participating on this research are skilled researchers of human sexuality with years of training, trained psychologist and a medical doctor will be present for case of need of intervention. After the whole session, there will be time for debriefing that will take approx. 20 min and will consist of watching neutral video about traveling (to induce calm emotional state), and short consultation with a skilled psychologist. The debriefing will be prolonged in case of complication. Permission of institutional review board will be obtained before the whole study will be conducted and all participants will be informed about sexual nature of the experiment and will be clearly informed that they can terminate their participation at any time. We also guarantee strict anonymization of the data as well as blindness of researchers to individual sexual preferences during testing phase. Underage avatars will not be present in the erotic pose; the main focus is on child typical nonverbal displays in avatars. Consultations of stimuli content with forensic experts and judge advocates in field of sexology is clear.

3 Conclusion

We would like to emphasize the option to design an environment that is based on user's preference and allows for more accurate diagnostics than currently available methodology due to possibility of authoring the stimuli to fit user's preference in appearance and behavior. This should allow us to distinguish between sexual aggressors, pedophiles and healthy controls. We do consider two mental states, sexual arousal and stress (negative reaction), that will allow us to distinguish between preference for such stimuli or aversion towards it in male users. As a theoretical framework for minor sexual preferences, we have decided to apply a theory of sexual motivational system that can be seen as hierarchically ordered and an interconnected system of particular sexual motivation levels that refer to a sequence of courting behaviors. In phase of attractivity, the looks and appearance will be selected, in second stage, proceptivity, the consent related behavior will be decided. The advantage is that persons with chosen minor preferences are known to be highly reactive towards preferred stimuli and do not react (by arousal) to other types of stimuli, the opposite is valid for healthy controls who are rather repulsed and vice versa. To distinguish between the two mental states, we will collect data about eye gaze, brain activation, and galvanic resistance of skin in combination with the change of penile tumescence. There will be total of 162 stimuli needed to be created to fulfill the criteria of testing. We hope that once the user is

correctly diagnosed with sexuality related disorder and the therapy is needed, the biofeedback training will allow them to suppress their arousal in inappropriate situations and hopefully to shape it toward more socially and personally acceptable preferences. We are aware of numerous ethical issues related to such procedure but only skilled and experienced professionals will participate on the whole procedure.

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