Home-Based Virtual Reality Exposure Therapy with Virtual Health Agent Support

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Abstract. To increase the accessibility and efficiency of virtual reality exposure therapy (VRET) this paper proposes a system for home-based use where patients with social phobia are supported by a virtual health agent. We present an overview of our system design, and discuss key techniques such as (1) dialogue techniques to create automated free speech dialogue between virtual characters and patients in virtual reality worlds; (2) a multi-modal automatic anxiety feedback-loop mechanism to control patients' anxiety level; and (3) motivational techniques applied by a virtual health agent. The system was evaluated in a pilot study where five patients with social phobia utilized our home-based VRET system. The results showed that the system was able to evoke the required anxiety in patients and that over time self-reported anxiety and heart rate gradually decreased as expected in exposure therapy.

Keywords: Virtual reality therapy · Virtual coach · Virtual health agent · Behaviour change support system · Social anxiety disorder · Self-therapy

1 Introduction

Social phobia is one of the most often occurring mental disorders, with reports that estimate this to affect around 13.3 % of the US population [1] during their lifetime. Patients with social phobia fear social situations in which they may be scrutinized by others [2], for example when having a conversation with someone, being observed, meeting someone new, or giving a presentation. Exposing patients in virtual reality to these social situations has been suggested [3] as a treatment for this disorder. As for other anxiety disorders, the development of virtual reality exposure therapy (VRET) systems mainly focuses on systems that can be used in a health clinic where a therapist directly controls the system when the patient is exposed [4]. However, with an ever-increasing demand for more efficiency and accessibility, it is desirable to be able to offer this treatment at the patient's home. We therefore

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propose a home-based VRET system where social phobia patients are also supported by a virtual health agent. In the design of this system three specific challenges were addressed that are discussed in this paper. First, how to create a long conversation with a virtual character to let patients experience the required social anxiety? Second, how do you automatically control the patient's anxiety throughout a conversation with virtual characters? Third, how could a virtual health agent motivate a patient to continue with the therapy? We also present the results of a pilot study in which individuals with social phobia utilized our home-based VRET system.

2 Related Work

Providing treatment for social phobia over the Internet is possible. For example, in a randomized controlled trial, Gallego et al. [5] found a significant improvement in patients receiving a remotely delivered treatment using non-interactive exposure video over the internet. The patients' fear of public speaking, work impairment, and avoidance behavior decreased. Instead of using video exposure, others [6] have suggested a system that allowed the therapist to control VRET from a remote location over the internet. Still, this set up required the therapist to be actively involved.

At least part of the exposure does not require the presence of a therapist. In cognitive-behavioral therapy (CBT), homework exposure exercises have been employed as an integral component in the treatment for several anxiety disorders such as obsessive-compulsive disorder, post-traumatic stress disorder and social phobia [7]. Even though effective for some intervention [8], lack of an active involvement of the therapist during treatment has been associated with reduced therapeutic efficacy, such as in relation to depression [9]. In self-therapy settings, patients usually rely on persuasive power of the homework-exercise itself. Whereas when therapists are involved, patients are often also influenced by the therapeutic alliance, even with virtual exposure therapy [10]. This brings forward the questions whether such an effect could also brought about with a virtual health agent?

The presence of a virtual health agent can have a positive effect on treatment outcome [11]. These agents often aim to guide individuals through a specific task thereby stimulating positive behaviour, increasing motivation and adherence [11, 12]. Typically, the health agent applies persuasive techniques to change people's attitude and behaviors [13].

3 System Design

The entire concept of the home-based VRET system was review in a series of discussions with eight clinical psychologists. Based on their input, a number of scenarios were written and again reviewed by eight clinical psychologists, leading eventually to an implemented system called the Memphis system [14]. The system consists of three main entities: (1) the virtual health agent, (2) the virtual reality system and (3) the therapist application.

3.1 The Virtual Health Agent

The main objective of the virtual health agents (Fig. 1) was to guide the patient through the various steps of the therapy and motivate them to continue with the therapy. Guiding the patients through the therapy involved explaining patients how to assemble the system so it could be used. Patients received a set of video's and instructions manuals on how to connect the various hardware elements such as: head mounted display (HMD), head tracker, heart rate device, internet dongle, security dongle, and microphone. Once the Memphis system was started, the virtual health agent helped the patient to calibrate and test the system, for example, training the speech recognizer, calibrating the anxiety measurement, testing sound and internet connection, wearing the heart rate device and finally setting up the HMD and the head position tracker.

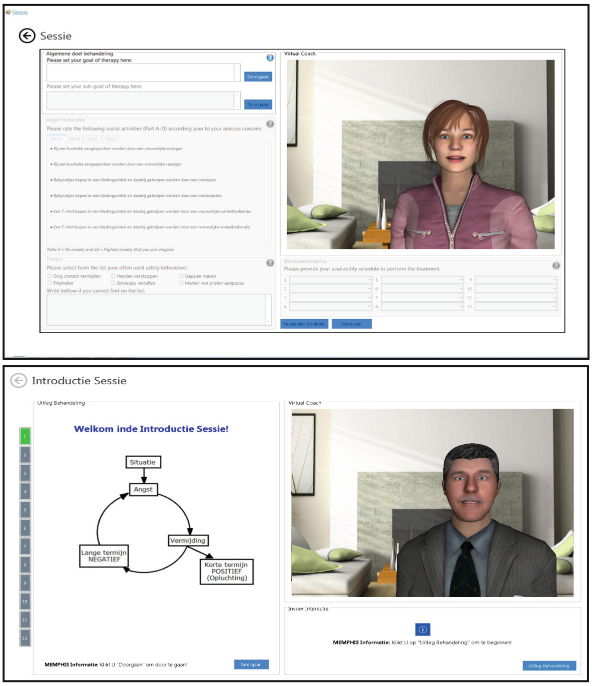

Fig. 1. The female virtual health agent guiding patient to set the therapy goals (top), and the male virtual health agent providing interactive psycho-education (bottom)

Besides guiding patients through the technical aspect of the system, the virtual agent also introduced the patients to the therapy itself. The first motivational strategy the agent applied was to help patients to formulate an achievable treatment goal. After explaining the purpose of setting goals and also giving some example, the agent asked patients to enter their goal. Interpreting this textual formulated goal and providing feedback by the agent was regarded as no achievable. Instead the agent used the strategy of empowering the patients to do this themselves. In other words, after entering the goal, the agent gave patients criteria to evaluate their own goal, for example, achievable, concrete, but also not too easy. Again, it provided this with some examples. Afterwards patients were asked again to reflect on their goal. This procedure was repeated when helping patients to formulate specific sub goals. This information together with information the agent asked about anxiety for specific social situations, and avoidance behaviors were automatically sent through a server to the therapist, who could use the information to create the anxiety hierarchy for social situations and a treatment plan. The second motivation strategy the agent applied was psycho-education. The agents explained what social anxiety disorder is, and the mechanisms underlying it. The agents also explained the therapy and what patients could expect. Besides this general information, the agent also explained in each session all the steps, e.g. filling out questionnaires, conducting virtual reality exposures, and reflecting on the outcome and progress. In the last session, the agents also helped the patients to develop relapse prevention strategies in a similar manner as the agent initially had supported the patient to formulate a treatment goal. The third motivation strategy that the agent applied was helping patients to reflect on their reactions during the virtual reality exposures, and also their overall progress during the treatment. For this the agent used an expert system approach using a therapeutic social anxiety knowledge base. The knowledge base was written and validated by clinical therapists. After patients were exposed in a virtual world, the agent provided patients with an interpretation of the collected heart rate data, self-reported anxiety, and stress level manipulation in virtual world. Internally the agents used eight templates to characterize the data of anxiety progress during the exposure, and three templates to characterize the stress level manipulation. Interpretations were linked to the 24 cells of this a 8×3 matrix. When formulating the reflections, the agent started with explaining what information was shown by the graphics on the screen. This was followed by the data interpretation, possible speculations about the causes of this result and elements of psycho-education. The agent finished with an encouraging remark aiming to improve patient's self-efficacy. The following is an example translated from Dutch of what the agent said: "*After the exercise in the virtual world we can now look together at the results that were collected. At the screen you can see several graphs….The last graph shows how difficult the system has tried to make it for you…if I look at the graphs, there are two things I notice. First, your anxiety level, the combination of your heart rate and self-reported anxiety, started relative high but reduced during the exercise. Secondly, the number of social challenges remained constant during the entire exercise. This exercise nicely demonstrates that after a while your anxiety naturally deceased. This is exactly what we try to achieve with this exercise. Very good! Nice result!*" To avoid repetition of agent reflection over time, each cell include several alternative formulations of what the agent could say.

The last motivation strategy the agent applied was to provide patients with a reflection of their overall treatment progress. For this, the agent looked at the overall anxiety level of the last three sessions and the sessions before this. As with the reflection after the exercises in the virtual world, the agent used a number of templates to characterize the recorded anxiety level across the sessions. Important was also that given the number of exercises scheduled and completed, the agent could recommend patients to contact the therapist if the therapy does not seem to work. Again, an example of a reflection that the agent could offer: "*Let's look at a number of things. First, if I look at the list with exercises, I can see that you have already completed 10 exercises, you are working currently on a new exercise, and that eight other exercises have been planned for you. This is very good! Secondly, if I look at the averages of the self-reported anxiety scores for the last 3 sessions I see scores that are relatively low. In the sessions before that, the anxiety scores were relative low. …Because you have finished more that 60 % of the anxiety hierarchy, is might be a good idea to discuss this with your therapist. It is important to find exercises that evoke anxiety. Also, it is important that you do not use anxiety avoidance strategies during the exercise…*".

Fig. 2. Examples of seven virtual scenarios supported by the Memphis system (left to right). Top: Participating in an English class, having appointment in a restaurant, middle: being ask to participate in a survey, buying t-shirt in a shop, meeting a blind date in a restaurant, and bottom: having presentation in a class, meeting a stranger in a bus stop

3.2 The Virtual Reality System

Virtual Social Scenario. The Memphis system provided 19 different virtual reality social scenarios, such as meeting a blind date in a restaurant, a job interview, visiting a doctor, talking to a stranger at a bus station, buying a t-shirt, and meeting a stranger at a party (Fig. 2). All social scenarios were selected and developed to elicit social anxiety. They are also often used and suggested for exposure exercise in real life [15].

Dialogue Techniques. A key component of the system was to expose patients to free natural dialogues. As this was a home-based system, a dialogue should unfold without the need for direct human control, which is often not the case in current systems. Our system therefore employed key word recognition and speech detection technology. Each dialogue lasted around 18 min. To avoid an ever-broadening dialogue, the virtual characters always took the lead in the conversation, by asking the patients questions, and responding to patient's reaction. In these dialogues there was no room for questions from the patients. Therefore, patients were instructed not to ask questions to the virtual characters.

On average, each dialogue consisted of 78 dialogue units (i.e. [avatar's question] → [patient's answer] → [avatar's response]). Where obvious keywords could be expected in the patient's answer, the system searched for them in the patient answers. When they were detected, the virtual character gave a response directly related to patients' answers, for example: [foreigner character] "*when traveling with a train, how do I know I have to get out of the train?"* If answer of patients included the word "announcement", the virtual character would say: "*Ok than I pay attention to that in the train*". In some cases characters' response was not appropriate, for example, when the wrong keyword was detected. This was however considered acceptable, as the objective was to exposure patients to social situations that would evoke anxiety, and not to expose them to flawless dialogues. By using keyword detection at some places in the dialogue, the hope was to give patients the illusion that character reacted intelligently towards their answers.

The majority of the virtual characters' responses however were not based on keyword detection. Instead, the characters provided responses that patients might think related to their answer, but were in fact independent of their answer. For example, [shop assistance] "*Can you also specify to me the price range that you're aiming for?*" After which an answer of the patient would follow. The virtual character would again respond to this answer "*Well, that's fine*". For the responses it was anticipated that patients would assume that virtual characters would adhere to cooperative principles [16]. In other words, virtual characters and patients pursued mutual conversational goals and the character would try to provide relevant responses and avoid ambiguity. Furthermore, individuals often heavily rely on the process of interfering. In other words, they would assign meaning to the response of the virtual characters in light of the context of the dialogue and social setting. Table 1 provides a list of specific strategies that were used to create character responses.

A potential avoidance strategy patients might apply is to provide short answers to avoid exposure. To address this behavior the system monitored the length of patients' answers. Hence, when a patient gave a short answer, the virtual character engaged the patients into a dialogue that encouraged the patient to provide longer answer, for

Table 1. List of dialogue techniques employed in the Memphis VR dialogue system

Dialogue techniques	Example
Create topic blocks in the story line to avoid repetition in questioning. Blocks start with a monolog where the avatar provides information about him or herself, followed by questions the topic	Block 1: [avatar talking about his family extensively] → [continue with questions about patient family] → Block 2: [avatar talking about his holiday last summer extensively] → [continue with questions about patient summer holiday] → etc.
Create generic avatar's respond that fit to any participant's answer	Avatar: "Hi, it seem that you're looking for someone, may I join you?" → Patient: [answer] → Avatar: "okay"
(Dis)agree on what the patient said	Avatar: "What do you think about the climate change now days?" → Patient: [answer] → Avatar: "Great! I agree with you in this case"
State an attitude or emotion towards the answer	Avatar: "I've been waiting for my food for 20 min now. The service is really slow here, what do you think?" → Patient: [answer] → Avatar: "Ah, I see. I am glad that you mention that!"
Reflect on your original question, e.g. it was not relevant	Avatar: "Do you have OHRA health insurance or do you have another private health insurance?" → Patient: [answer] → Avatar: "OK, I understand that, it does not matter anyway."
State an opinion	Avatar: "What do you think is the most interesting thing to see in the Netherland?" → Patient: [answer] → Avatar: "Yeah, I think visiting a traditional cheese factory, or clogs shop is a nice experiences."
State (mis)understanding of patient answer, and extend response with own information	Avatar: "What do you think about Amsterdam public transport right now?" → Patient: [answer] → Avatar: "Ok, I see your point. I also have pretty similar thoughts since I used it a lot the last couple of years."
State an opinion based on your beliefs, emotion or perceptions	Avatar: "What make you a good team leader?" → Patient: [answer] → Avatar: "Yeah, but honestly I feel that you're not ready yet to become a good team leader by judging your answer and your current experience"
Makes a statement that is always true in relation to the topic	Avatar: "Are you feeling under any pressure or stress lately?" → Patient: [answer] → Avatar: "Okay, please remember that too much stress can affects your health."

example, "*It is not quite clear to me. Can you explain further?*", "*What do you mean by that?*", "*I have plenty of time here, can you explain it to me a bit more?*", or "*Now you make me curious, tell me something more*."

The Phobic Stressors. As a patient's anxiety response towards fear stimuli varies, the system deployed several phobic stressors in each virtual world. First, the dialogue units could either be positive or negative. Controlling the ratio of positive and negative dialogue units has been demonstrated as a key function to induce different level of anxiety [17]. A positive dialogue unit meant a dialogue that consisted of a friendly, affirmative or enthusiastic type of question and avatar response, such as "*I like to know your taste music, what kind of music do you like?*" and was followed by the avatar's response to the patient's answer "*Cool! Nice taste of music!*". On the other hand, the negative dialogue unit meant that the dialogue was formulated in an unfriendly, unenthusiastic and criticizing question and response, for example "*I don't think that you have a good taste of music, but in case I'm wrong, can you tell me what type of music you like?*" followed by the avatar's response "*Mmm… as I have expected, you know nothing about good music!*". A second type of phobic stressors was the avatar gestures, for example the gaze of the avatar. As mentioned in other studies [18], (intense) direct eye gaze can evoke anxiety. Therefore the virtual characters also have the capability to stare at patients, look away, or simulate turn taking gaze behavior in a conversation. Besides gaze behavior, body posture of an audience [19], e.g. an interested audience or an audience that is bored, were used in public speaking scenarios.

The Anxiety Feedback-Loop. The system regulates patients' anxiety level by monitoring their anxiety and in a real-time fashion adjusting phobic stressors in the virtual world to reach the desired anxiety level as set by the therapist prior to a session. To monitor anxiety level, the system used both self-reported anxiety and a physiological measurement in the form of an automatically collected Subjective Unit of Discomfort (SUD) scale using speech recognition technology [20], and heart rate (bpm unit) using Zephyr HxM heart rate monitoring device. Both measurements were collected every four minutes during the exposure. Furthermore, using an individualised linear regression function, these two different modality measures were internally, at run time, combined into a single anxiety measure on which the system acted. As patients vary on how their anxiety is expressed in the two anxiety measures, a calibration procedure was used in the first session of the therapy. Imaginary exposure was used to determine a patient anxiety response in a low anxiety and high anxiety situation. Using relaxing sounds clips, a patient was asked to relax for four minutes while SUD and hear rate data was collected. Next, the patient was asked to imagine giving a presentation and push him or herself to the highest, but still tolerable, level of anxiety using various sound clips of an audience (i.e. from a nice, quiet audience to a loudly boing audience). Again anxiety data was collected for again a period of four minutes.

The automatic feedback loop used the personalised anxiety measure to regulate the patient's anxiety level. Before a session, therapists set the patient's initial target range for the patient's anxiety by defining the lower and upper bounder. At the start of a virtual reality (VR) exposure, the system increased or decreased the patient's anxiety to a level within the target range. The system did this by gradually increasing or decreasing the number or the degree of the phobic stressors in the virtual world. Once the patient's anxiety was within the target range, phobic stressors remained constant, or were reduced if patient's anxiety exceeded the target range. This regulation mechanism allowed patients to experience that their anxiety would naturally decline over time, and ensured that patients would not experienced an undesirable high level of anxiety for a long time.

3.3 The Therapist Application

The therapist application was a standalone application used by the therapist to interact with their patients. Using this application, therapists were able to create a personalized treatment plan for a patient, monitor the patient's progress during the treatment by evaluating the questionnaires, SUD score and heart rate results (Fig. 3), exchange personal messages with the patient using integrated e-mail services, creating and adjusting the treatment schedule, write a patient log book and relapse prevention strategy, and find the Memphis helpdesk contact information in case there is a technical problem. Once a therapist registered a session schedule and a treatment plan in the system, patients could start their treatment at home using the Memphis system.

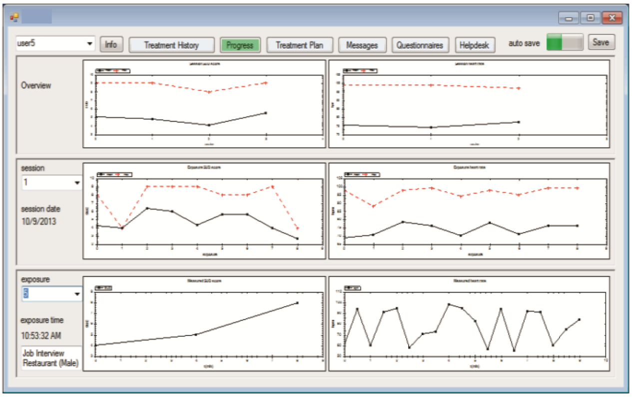

Fig. 3. Monitoring the patient's progress during the treatment by evaluating the SUD score and heart rate results in the therapist application

To support the interaction and communication between the therapist application and the virtual coach application, a secure and centralized database server was established. This database server records all occurring events during the treatment, for example: recording the psychological measurement data, store all questionnaires data, store therapist – patient messaging activities. To ensure security ISO standards on the medical informatics security, such as ISO27001, ISO9001, ISO14001, but also the national guideline (NEN7510) were consulted and work procedures were formulated. Also, prior to treatment both therapist and patients received personalized encryption and decryption keys, which they had to plug into their computer. All data stored on the server and data exchange between server and the therapist and patient application was encrypted using these keys.

4 Evaluation

System operation and testing the usability of the system was done with a group of 5 university students and staff (non-patients) and an experimenter acting as a therapist. This test was conducted on a single set of hardware (Dell Inspiron 7720 laptop running

Windows 7 64 bits). The tests revealed no serious operational or usability problems. The next step, therefore, was to examine the system in a small pilot study with actual patients, a first step towards larger scale clinical trial. The aim of the pilot study was to examine whether the system could evoke social anxiety and resulted over time in anxiety reduction when social phobic patients were exposed in virtual reality. The pilot study was approved by the ethics committee of the University of Amsterdam (Approval number: 2014-CP-3660).

4.1 Subjects

The pilot study was conducted with five social phobia patients who met DSM-IV [2] criteria for generalized Social Anxiety Disorder. The patients first filled in several questionnaires on psychopathology and were then interviewed with Structured Clinical Interview for DSM-IV (SCID-I, SCID-II/avoidant PD). The sample consisted of two males and three females with an age ranging from 38 to 64 years old (M = 49, SD = 10.63).

4.2 Procedure and Apparatus

At the start of the pilot study, patients were invited to the clinic for an introduction meeting with the therapist. In the introduction meeting therapists explained the background of the study and how to utilize the related hardware and software involved. Furthermore they also demonstrated how to setup all devices. Using the therapist application, the therapist registered the patient on the server system. After the introduction, patient received a suitcase with all equipment and a manual that they brought home. Each patient was scheduled to receive 10 treatment sessions. From the 10 sessions planned, 8 sessions (sessions 2 to 9) included exposure in the virtual reality, while session 1 served as an introduction session and session 10 as a relapse prevention session. At the start of each session, the therapist called the patient by phone. During the session the therapist would listen and advice the patient over the phone while the patient was using the system at home.

4.3 Measures

SUD scores and average heart rate were recorded every four minutes during VR exposure. The level of presence in the virtual reality during the first two treatment sessions was measured using Igroup Presence Questionnaire (IPQ) [21].

4.4 Results

Due to technical glitches that arose unexpectedly during treatment sessions, only one patient, who used the same hardware set that was used in the usability test, was able to complete all 10 sessions successfully. For the other four patients, who used another brand of laptop, it was decided to stop the trial and offer them face-to-face treatment.

This meant that for one patient data was collected from only the first six sessions, from two patients from only the first three sessions, and from one patient only the first two sessions.

The overall IPQ results were compared with online IPQ dataset[1] (downloaded on March 2[nd], 2015) for stereo HMD visual stimuli. The overall IPQ rating ($N = 5$, $M = 60.4$, $SD = 4.51$) was significantly higher ($t(40) = -2.79$, $p = .008$) than the overall rating of the online IPQ dataset ($N = 37$, $M = 38.16$, $SD = 17.53$). The system therefore seems to have been successful in establishing significant levels of presence.

A total of 204 SUD scores were collected from the five patients. This data was analyzed with linear mixed-effect models (*lme*) in R taking the SUD scores as response variable and session number (2–9) and order number of the exposure exercise in a session (1–3) as factors nested within random effect variable participant. The objective of the analysis was not to generalize findings to a larger population, but instead to examine how SUD progressed for this sample, which for session 7 to 9 only included data from a single patient. The analysis showed that sessions ($\chi^2(1) = 24.2$, $p. < .001$) and exposure order number ($\chi^2(1) = 11.5$, $p. = .007$) had a significant effect on the SUD scores. No interaction effect between these two factors was found ($\chi^2(1) = 2.9$, $p. = .087$). As Fig. 4 shows, patients self-reported anxiety level decreased over the 22 (8 session × 3 exercises – 2 as first and last session only included 2 exercises) exposures exercises.

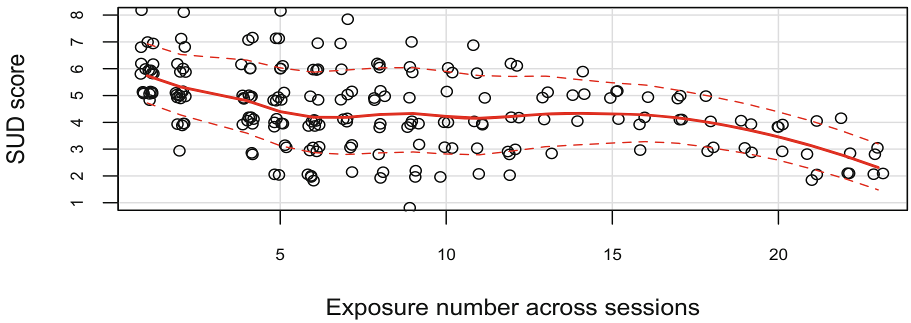

Fig. 4. Self-report anxiety across the treatment sessions including .25 and .75 quantiles spread.

Similar models were fitted on heart rate data ($n = 204$). Both session ($\chi^2(1) = 37.0$, $p. < .001$) and exposure order number ($\chi^2(1) = 71.5$, $p. < .001$) had significant effect on the heart rate data. Again no significant ($\chi^2(1) = 0.3$, $p. = .62$) two-way interaction was found. As Fig. 5 shows also heart rate decreased over 22 exposure exercises.

[1] Data available at http://www.igroup.org/pq/ipq/data.php.

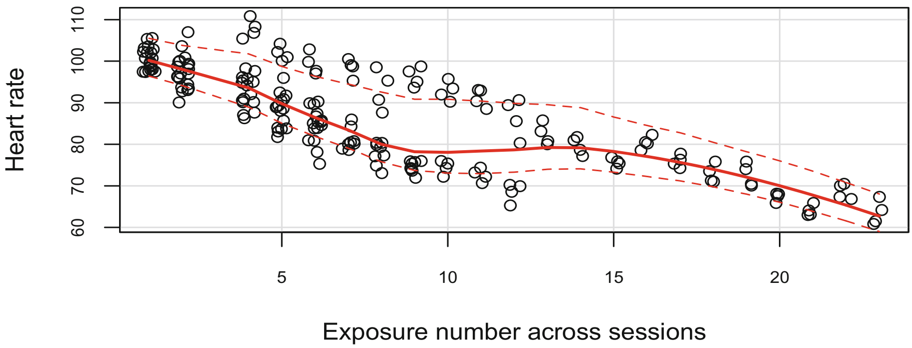

Fig. 5. Heart rate across the treatment sessions including .25 and .75 quantiles spread.

5 Discussion

The pilot study findings show that for this sample (1) the system could evoke anxiety and (2) over time the expected habituation sets in as anxiety levels dropped. Furthermore, the patients reported to have experienced a substantial level of presence, which is encouraging given that the 18 min dialogues were fully automated without intervention of a human to control the virtual characters. The pilot study also revealed a number of serious technical problems. These technical problems need first to be addressed before any further studies with patients can be considered. On the other hand, one patient, who used the non-failing equipment, was capable to complete all 10 of the home sessions, illustrating the system feasibility in treating patients if technical and usability problems are resolved. The technical problems included unexpected software crashes, but also patients forgetting to charge batteries of the mouse, and wireless hear rate device, but also problems getting the HMD to function properly, or simply finding or daring to click on a button. The later is interesting, as it shows that usability issues might be especially important for this user group to address. Apart from the described technological problems, the study has the following limitations. First, although a key step, this represent a pilot study with only a small sample and without a control condition to compare the findings with. Second, because of the technical glitch, patients did not do the exercise completely on their own. Often the therapist also had to provide technical support on the phone. Third, because of ethics considerations it was necessary at this stage to have a therapist listening in over the phone while patients conducted their exercises at home. Besides the insights the pilot study offered into the feasibility of home-based VRET, the scientific contribution of the work presented in this paper lies in the techniques proposed to address three key challenges, namely, (1) techniques a virtual health agent could apply to motivate a patient, (2) dialogue techniques to create 18 min long conversation with virtual characters, and (3) an automatic feedback loop to control the anxiety of a phobic patient. These contributions are not limited to the psychotherapy domain, but might also be beneficial for application domains that require a level of controlled stress in the form of conversation such as serious gaming or as part of stress test, for example Trier Social Stress Test.

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