The role of virtual agents and biofeedback in anxiety mitigation

Marta Serafini[1,*]

[1] *HCI Lab, Department of Mathematics, Computer Science and Physics, University of Udine, via delle Scienze, 206, 33100 Udine, Italy*

Abstract

Virtual Reality (VR) has been proposed as a tool to mitigate anxiety, and VR systems for anxiety mitigation can be categorized into two main types: VR exposure therapy systems and VR relaxation training systems. Some of these systems use biofeedback mechanisms to improve relaxation effects by detecting the user's affective state through physiological sensors. Given the potential of virtual agents to influence attitudes and behaviors, their use in anxiety mitigation systems could be beneficial. This paper investigates the role of virtual agents and biofeedback in systems for anxiety mitigation, focusing on three aspects: (i) the role of a single virtual agent and multiple virtual agents as stressors in VR exposure therapy systems, (ii) the role of biofeedback in a VR relaxation training system, (iii) the exploration of different technologies for displaying systems for anxiety mitigation. The paper describes the modalities in which we intend to pursue these goals.

Keywords

Virtual Reality, Anxiety Mitigation, Virtual Agent, Biofeedback, Augment-ed Reality.

1. Introduction and Background

In recent years, Virtual Reality (VR) has been proposed as a technological tool that could be employed in mitigating anxiety, a condition that affects many individuals and has debilitating effects. Indeed, the World Health Organization estimates that anxiety and depression cost the global economy 1$ trillion annually.

In the literature, VR systems for anxiety mitigation can be classified into two main categories: VR exposure therapy systems and VR relaxation training systems. Over the past two decades, VR exposure therapy systems, have increasingly been used as an alternative to in vivo exposure to treat anxiety disorders [1]. In these systems, users are repeatedly confronted with the feared stimulus over time in a virtual environment (VE), resulting in a gradual decrease in elicited anxiety and making the stimulus less fearful. The VE must be able to produce anxiety responses for the de-sensitization process to occur. In contrast, VR relaxation training systems aim to mitigate anxiety through relaxation training techniques in VR, such as slow and deep breathing (e.g., [2, 3]).

The literature has shown that VR is an appealing alternative for treating anxiety as it offers a safe and effective medium that can induce relaxation in both patients (e.g., [4]) and healthy individuals (e.g., [3]). To enhance the relaxation effect, some systems have augmented the relaxing VEs with a biofeedback mechanism by which the VE detects the user's affective state through physiological sensors measuring parameters such as breathing, cardiac, electrodermal, or brain activity. The aim of biofeedback is to help users learn how to change their physiological activity over time to improve health and performance, reduce stress-related symptoms, and enhance well-being. Studies on VR biofeedback systems for relaxation training have shown efficacy in reducing anxiety levels (e.g., [2, 5]).

Persuasive 2023, Adjunct Proceedings of the 18th International Conference on Persuasive Technology, April 19–21, 2023, Eindhoven, The Netherlands

*Corresponding author.

marta.serafini@uniud.it (M. Serafini)

0000-0002-1310-1826 (M. Serafini)

Humanlike virtual agents have been extensively used in education, training, healthcare, and other fields. Increasingly, research is exploring their possible role as persuasive communicators (e.g., [6, 7]) due to their capability to simulate social interaction. To be effective and persuasive, virtual agents should appear credible, trust-worthy, confident, and non-threatening. Since the literature has already shown the ability of virtual agents to induce attitude and behavior change (e.g., [8]), their use in systems for anxiety mitigation could be beneficial.

Our aim is to further investigate the role of virtual agents and biofeedback in systems for anxiety mitigation. Specifically, we will focus on three areas: (i) the use of a single virtual agent and multiple virtual agents as stressors in VR exposure therapy systems, (ii) the use of biofeedback in a VR relaxation training system, (iii) the exploration of different technologies for displaying systems for anxiety mitigation. In the following, we will explain the modalities we intend to use to pursue these goals.

2. Methodologies

2.1. Single and multiple virtual agents as stressors for a specific type of anxiety

To investigate the role of a single virtual agent as a stressor, we are going to design, develop, and evaluate a VR exposure therapy system for test anxiety mitigation. Test anxiety is an emotional state characterized by subjective feelings of discomfort, fear, and worry about the evaluation made by an external authority [9]. Anxiety can have a considerable negative impact on students' academic performance [10, 11], motivating the study of techniques that could help students in reducing it. VR exposure therapy systems for test anxiety should reproduce different exams situations [12], and the simulated exam should be able to elicit anxiety responses in the student to support the desensitization process.

The current literature on VR exposure therapy systems for test anxiety is very limited [12–14] and suffers from three major limitations. First, not all of them assess the capability of the system to elicit anxiety, which is a prerequisite for possible VR exposure use. Second, all of them focus on written exams. Since oral tests elicit higher levels of test anxiety than written tests [15], the availability of VR exposure systems for oral tests would be precious to a large population of students worldwide. Third, existing VR exposure systems for test anxiety require a head-mounted display, posing a barrier to widespread use, especially at home.

Our aim is to address all three limitations by proposing a VR exposure therapy system for test anxiety that will focus on oral tests and will use a virtual examiner to conduct the oral exam. The virtual examiner will perform three different sets of behavior, creating different oral exam scenarios aimed at eliciting three levels of increasing anxiety for purposes of progressive exposure. First, we will assess the feasibility of the system to elicit increasing levels of anxiety through a user study. Then, we will assess the system as a treatment for test anxiety.

To investigate the role of multiple virtual agents as stressors, we are going to de-sign, develop, and evaluate a VR exposure therapy system for public speaking anxiety mitigation. According to the American Psychological Association, public speaking anxiety is the "fear of giving a speech or presentation in public because of the expectation of being negatively evaluated or humiliated by others". The literature has pro-posed several VR exposure therapy systems for public speaking anxiety mitigation that allow the user to give a speech to a virtual audience (e.g., [16–19]). Studies (e.g., [18, 19]) have shown that some of these systems are able to increase the level of anxiety and distress in participants, confirming the feasibility of using VR exposure for public speaking anxiety. Other studies (e.g., [16, 17]) have used the systems for treatment, showing that the VR exposure approach is successful in reducing the level of public speaking anxiety. To the best of our knowledge, there are no studies on systems for public speaking anxiety mitigation that use virtual audiences in AR, and there are no studies that contrast how the same virtual audience is perceived when displayed in VR vs. AR.

We will propose a VR exposure therapy system for public speaking anxiety where a small or a large virtual audience will listen to a user while giving a speech. We aim to examine whether the

level of anxiety experienced by users when speaking to a small or large virtual audience might differ in VR and AR.

2.2. Biofeedback mechanisms for breathing and relaxation training

To investigate the role of biofeedback mechanisms in anxiety mitigation, we are going to design, develop, and evaluate a VR relaxation training system.

In the literature, VR biofeedback systems for relaxation training have substantial limitations. For example, almost all of them employ a single physiological sensor whose value is mapped into one or more VE elements (e.g., [2, 5]). Moreover, they do not explore the ample design space of virtual experiences, as they restrict them-selves to a primitive experience that perpetually mirrors an activity the user has to perform during most of the experience, e.g., maintaining slow and deep breathing. Regarding evaluation, only a few studies of VR biofeedback systems for relaxation training have considered possible placebo effects to ensure that the proposed treatment is actually better by excluding possible user suggestibility [20, 21], which refers to the phenomenon in which an individual's belief in the effectiveness of a treatment produces a beneficial effect, also if the treatment is actually sham.

Our aim is to address these limitations by designing and developing a complex VE representing a natural environment, rich in stimuli, where biofeedback affects several elements of the VE through different mechanisms and using multiple physiological parameters. The system will include compelling components in the VE to encourage and motivate individuals to continue using the system on a regular basis. Additionally, the system will include a narrative into the virtual experience in such a way that, by performing the tasks, the user progresses through the story, to keep user's curiosity, attention, and sense of awe alive.

Our study will also include a placebo biofeedback condition, in which unaware participants will receive a sham biofeedback treatment instead of the real biofeedback treatment. Participants will be assigned to one of two conditions: VR system with real biofeedback and VR system with sham biofeedback, to explore the possible role played by biofeedback. The study will analyze psychophysiological measures and subjective measures to assess state anxiety. Objective measures and state anxiety measures administered before and after the use of the system will be compared to assess the system capacity to mitigate anxiety and the effective contribution of bio-feedback in doing so.

2.3. Exploration of different display modes for the development of systems for anxiety mitigation.

We are going to use different display modes in our proposed systems for anxiety mitigation. Specifically, we will use non-immersive VR in our exposure therapy system for test anxiety to allow users to use the system on their own computers.

We will use both immersive VR and AR in our exposure therapy system for public speaking anxiety to evaluate with a user study whether participants' perception of the virtual audience changes when displayed in VR vs. AR.

We will use immersive VR in our biofeedback system for relaxation training to enhance the user's feel of presence in the VE.

Regarding virtual agents, the literature indicates that the gender of the virtual agent may have an impact on how the user perceives the agent as a communicator (e.g., [8, 22–24]). However, studies on these effects have reported mixed results. Moreover, the role of virtual agents and how they are perceived has mainly been studied in immersive (e.g., [8, 22]), or non-immersive virtual reality (VR) (e.g., [23, 24]), whereas studies in AR are still rare [25–27]. In addition, to the best of our knowledge, there are no studies that contrast how the same virtual agents are perceived when displayed in VR vs. AR. To begin filling this gap, we will carry out a study to investigate whether the user's perception of a virtual agent change when displayed in VR vs. AR and whether the possible change might depend on the gender of the virtual agent.

In our study, users will use the system in VR or AR and will listen to a male or female virtual agent who will give them a speech. The study will analyze subjective measures to assess the amount of attention the participant will allocate to and perceive to receive from the virtual agent, the perceived ability of the participant to understand the agent's emotional and attentional states, and how the participant will perceive the speaker as credible and strong. More details regarding this study can be found in [28].

3. Preliminary and expected results

To date, we have concluded the study on the perception of virtual agents in VR vs. AR. Results have shown that the transition from VR to AR seems to change the perception of some communicator aspects to the advantage of the female agent. Figure 1 shows the female agent and the male agent used in our study described in [28].

Figure 1: The female agent and the male agent used in [28].

In our feasibility study of the VR exposure therapy system for test anxiety, we expect that the virtual agent will be able to elicit different increasing levels of test anxiety. As a result, it will be possible to use the system as a treatment for test anxiety.

In our study of the VR exposure therapy system for public speaking anxiety, we expect that the large virtual audience will elicit higher anxiety than the small virtual audience. Moreover, we expect that the system in AR will be able to elicit in participants a level of anxiety comparable to that elicited by the system in VR.

In our study of the VR biofeedback system for relaxation training, we expect that the system will relax participants and biofeedback will enhance the relaxation effect.

References

[1] Carl, E., Stein, A.T., Levihn-Coon, A., Pogue, J.R., Rothbaum, B., Emmelkamp, P., Asmundson, G.J.G., Carlbring, P., Powers, M.B.: Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials. Journal of Anxiety Disorders. 61, 27–36 (2019). https://doi.org/10.1016/j.janxdis.2018.08.003.

[2] van Rooij, M., Lobel, A., Harris, O., Smit, N., Granic, I.: DEEP: A Biofeedback Virtual Reality Game for Children At-risk for Anxiety. In: Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems. pp. 1989–1997. ACM, San Jose California USA (2016). https://doi.org/10.1145/2851581.2892452.

[3] Rockstroh, C., Blum, J., Göritz, A.S.: A mobile VR-based respiratory biofeedback game to foster diaphragmatic breathing. Virtual Reality. 25, 539–552 (2021). https://doi.org/10.1007/s10055-020-00471-5.

[4] Repetto, C., Gaggioli, A., Pallavicini, F., Cipresso, P., Raspelli, S., Riva, G.: Virtual reality and mobile phones in the treatment of generalized anxiety disorders: a phase-2 clinical trial. Pers Ubiquit Comput. 17, 253–260 (2013). https://doi.org/10.1007/s00779-011-0467-0.

[5] Blum, J., Rockstroh, C., Göritz, A.S.: Heart Rate Variability Biofeedback Based on Slow-Paced Breathing With Immersive Virtual Reality Nature Scenery. Front. Psychol. 10, 2172 (2019). https://doi.org/10.3389/fpsyg.2019.02172.

[6] Verberne, F.M.F., Ham, J., Ponnada, A., Midden, C.J.H.: Trusting Digital Chameleons: The Effect of Mimicry by a Virtual Social Agent on User Trust. In: Berkovsky, S. and Freyne, J. (eds.) Persuasive Technology. pp. 234–245. Springer, Berlin, Heidelberg (2013). https://doi.org/10.1007/978-3-642-37157-8_28.

[7] Roubroeks, M., Ham, J., Midden, C.: When Artificial Social Agents Try to Persuade People: The Role of Social Agency on the Occurrence of Psychological Reactance. Int J of Soc Robotics. 3, 155–165 (2011). https://doi.org/10.1007/s12369-010-0088-1.

[8] Guadagno, R., Blascovich, J., Bailenson, J., McCall, C.: Virtual Humans and Persuasion: The Effects of Agency and Behavioral Realism. Media Psychology. 10, 1–22 (2007). https://doi.org/10.1080/15213260701300865.

[9] Irwin G., S.: Introduction to the study of test anxiety. In: Test-anxiety: Theory, research and application. pp. 57–78. Lawrence Erlbaum Assoc Incorporated, Hillsdale, NJ (1980).

[10] Hembree, R.: Correlates, Causes, Effects, and Treatment of Test Anxiety. Review of Educational Research. 58, 47–77 (1988). https://doi.org/10.3102/00346543058001047.

[11] Sarason, I.G.: Test anxiety and intellectual performance. The Journal of Abnormal and Social Psychology. 66, 73–75 (1963). https://doi.org/10.1037/h0047059.

[12] Alsina-Jurnet, I., Carvallo-Beciu, C., Gutiérrez-Maldonado, J.: Validity of virtual reality as a method of exposure in the treatment of test anxiety. Behavior Research Methods. 39, 844–851 (2007). https://doi.org/10.3758/BF03192977.

[13] Kwon, J.H., Hong, N., Kim, K. (Kenny), Heo, J., Kim, J.-J., Kim, E.: Feasibility of a Virtual Reality Program in Managing Test Anxiety: A Pilot Study. Cyberpsychology, Behavior, and Social Networking. 23, 715–720 (2020). https://doi.org/10.1089/cyber.2019.0651.

[14] Luo, D.: Design and Implementation of Virtual Examination System Based on Unity 3D. 8 (2019).

[15] Sparfeldt, J.R., Rost, D.H., Baumeister, U.M., Christ, O.: Test anxiety in written and oral examinations. Learning and Individual Differences. 24, 198–203 (2013). https://doi.org/10.1016/j.lindif.2012.12.010.

[16] Hinojo-Lucena, F.-J., Aznar-Díaz, I., Cáceres-Reche, M.-P., Trujillo-Torres, J.-M., Romero-Rodríguez, J.-M.: Virtual Reality Treatment for Public Speaking Anxiety in Students. Advancements and Results in Personalized Medicine. Journal of Personalized Medicine. 10, 14 (2020). https://doi.org/10.3390/jpm10010014.

[17] Lindner, P., Dagöö, J., Hamilton, W., Miloff, A., Andersson, G., Schill, A., Carlbring, P.: Virtual Reality exposure therapy for public speaking anxiety in routine care: a single-subject effectiveness trial. Cognitive Behaviour Therapy. 50, 67–87 (2021). https://doi.org/10.1080/16506073.2020.1795240.

[18] Pertaub, D.-P., Slater, M., Barker, C.: An Experiment on Public Speaking Anxiety in Response to Three Different Types of Virtual Audience. Presence: Teleoperators & Virtual Environments. 11, 68–78 (2002). https://doi.org/10.1162/105474602317343668.
[19] Takac, M., Collett, J., Blom, K.J., Conduit, R., Rehm, I., Foe, A.D.: Public speaking anxiety decreases within repeated virtual reality training sessions. PLOS ONE. 14, e0216288 (2019). https://doi.org/10.1371/journal.pone.0216288.
[20] Chittaro, L., Sioni, R.: Affective computing vs. affective placebo: Study of a biofeedback-controlled game for relaxation training. International Journal of Human-Computer Studies. 72, 663–673 (2014). https://doi.org/10.1016/j.ijhcs.2014.01.007.
[21] Tinga, A.M., Nyklíček, I., Jansen, M.P., de Back, T.T., Louwerse, M.M.: Respiratory Biofeedback Does Not Facilitate Lowering Arousal in Meditation Through Virtual Reality. Appl Psychophysiol Biofeedback. 44, 51–59 (2019). https://doi.org/10.1007/s10484-018-9421-5.
[22] Makransky, G., Wismer, P., Mayer, R.E.: A gender matching effect in learning with pedagogical agents in an immersive virtual reality science simulation. Journal of Computer Assisted Learning. 35, 349–358 (2019). https://doi.org/10.1111/jcal.12335.
[23] Nunamaker, J.F., Derrick, D.C., Elkins, A.C., Burgoon, J.K., Patton, M.W.: Embodied Conversational Agent-Based Kiosk for Automated Interviewing. Journal of Management Information Systems. 28, 17–48 (2011).
[24] Rosenberg-Kima, R.B., Plant, E.A., Doerr, C.E., Baylor, A.L.: The Influence of Computer-based Model's Race and Gender on Female Students' Attitudes and Beliefs Towards Engineering. Journal of Engineering Education. 99, 35–44 (2010). https://doi.org/10.1002/j.2168-9830.2010.tb01040.x.
[25] Wang, I., Smith, J., Ruiz, J.: Exploring Virtual Agents for Augmented Reality. In: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. pp. 1–12. ACM, Glasgow Scotland Uk (2019). https://doi.org/10.1145/3290605.3300511.
[26] Huang, A., Knierim, P., Chiossi, F., Chuang, L.L., Welsch, R.: Proxemics for Human-Agent Interaction in Augmented Reality. In: CHI Conference on Human Factors in Computing Systems. pp. 1–13. ACM, New Orleans LA USA (2022). https://doi.org/10.1145/3491102.3517593.
[27] Miller, M.R., Jun, H., Herrera, F., Villa, J.Y., Welch, G., Bailenson, J.N.: Social interaction in augmented reality. PLOS ONE. 14, e0216290 (2019). https://doi.org/10.1371/journal.pone.0216290.
[28] Serafini, M., Chittaro, L.: Perception of Virtual Agents as Communicators in Virtual vs. Augmented Reality by a Male Sample. In: Meschtscherjakov, A., Midden, C., and Ham, J. (eds.) Persuasive Technology. pp. 36–49. Springer Nature Switzerland, Cham (2023). https://doi.org/10.1007/978-3-031-30933-5_3.