Investigating the Physiological Responses to Virtual Audience Behavioral Changes A Stress-Aware Audience for Public Speaking Training

Mathieu Chollet, Talie Massachi, Stefan Scherer

Investigating the Physiological Responses to Virtual Audience Behavioral Changes

A Stress-Aware Audience for Public Speaking Training

Mathieu Chollet, Talie Massachi, and Stefan Scherer

Institute for Creative Technologies, University of Southern California
12015 Waterfront Drive, Playa Vista, CA, USA
{mchollet,tmassachi,scherer}@usc.ict.edu

Abstract. Virtual audiences have been used in psychotherapy for the treatment of public speaking anxiety, and recent studies show promising results with patients undergoing cognitive-behavior therapy with virtual reality exposure maintaining a reduction in their anxiety disorder for a year after treatment [17, 21]. It has been shown virtual exhibiting positive or negative behavior trigger different stress responses [16], however research on the topic of the effect of virtual audience behaviors has been scarce. In particular, it is unclear how variations in audience behavior can make the user's stress levels vary while they are presenting. In this paper, we present a study where we intend to investigate the relationship between virtual audience behaviors and physiological measurements of stress. We use the Cicero virtual audience framework which allows for precise manipulation of its perceived level of arousal and valence by incremental changes in individual audience members behaviors. Additionally, we introduce a concept of a stress-aware virtual audience for public speaking training, which uses physiological assessments and virtual audience stimuli to maintain the user in a challenging, non-threatening state.

Keywords: Virtual Audience, Physiological Signals, Challenge and Threat

1 Introduction

Public speaking can be a very stressful task, to the point where some individuals report it as their number one fear [4, 9]. However it is also a very common task that we are often required to perform in our lives, and good public speaking skills can help an individual in their professional career as well as in their personal lives. As such, tools that allow users to improve their public speaking skills, or to reduce the amount of stress they experience while performing public speaking, are very desirable. Virtual audiences were first studied for treating public speaking anxiety in the early 2000's [10, 13, 16]. Since then, a number of experiments have been realized that have shown that exposure to virtual audiences can reduce public speaking anxiety [2, 21, 26, 27].

However, the scenarios used in psychotherapy often do not use the full potential of virtual humans, as the virtual audiences used are often scripted or controlled by an experimenter. In particular, multimodal interaction technologies now allow for the real-time perception of user behaviors and physiological states, and recent advances in the field of virtual humans enable a high realism level and precise behavioral control. Pertaub *et al.* studied the influence of virtual audience valence (*i.e.* negative, neutral or positive) on the stress level of participants, and shown that the type of valence influenced the stress response of participants. However, the valence of the audience did not change through the experiment and it is unclear how changes in audience behavior affect user's physiological states.

In previous work, we proposed to use virtual audiences for training public speaking skills. We introduced the Cicero public speaking training system [6], which uses a virtual audience to produce feedback in the form of non-verbal behaviors from the audience. Recently, we investigated the perception of virtual audience behaviors and how virtual audience comprising members of disparate states (*e.g.* two positive, four negative) are perceived, and found that the overall perception of the audience could be precisely manipulated by varying the behaviors of individual audience members [5]. In this paper, we propose to use the Cicero virtual audience framework to investigate more systematically how different types of virtual audiences behaviors can affect users' physiological states, and how varying these behaviors in real-time can be used to influence their states during a training or exposure session. In the next section, we begin by presenting related works on public speaking training using multimodal technologies, and studies on the effect of virtual audiences for reducing public speaking anxiety. We then present the Cicero virtual audience framework, which can be used for finely controlling the stimuli perceived by a user when they are practicing their public speaking. In section 4, we propose an experimental framework for studying the effect of varying virtual audience behavioral stimuli on users. Finally, we present in section 5 a concept for a stress-aware interpersonal skills training system which uses virtual humans stimuli and physiological assessment to maintain users in a challenging, nonthreatening state.

2 Related work

Multimodal interaction systems for training public speaking skills are becoming a popular research topic numerous systems have been introduced in the recent years which offer various approaches to it. The Rhema [23] and Logue [8] systems use Google Glass to provide feedback to public speakers while they speak. Schneider *et al.* introduced the Presentation Trainer system [22] which uses visual and haptic feedback (using a vibrating wristband) to provide feedback to trainees on mistakes (*e.g.* crossing arms, inappropriate volume) they make while presenting. Barmaki and Hugues presented a system for training teachers to adopt better body postures, using a virtual classroom populated with manually controlled virtual students augmented with a feedback screen displaying red or green stimuli depending on the user's body posture [1]. Tanveer *et al.* [24] introduced Automanner, a training system which focuses on detecting and providing feedback on presenters' mannerisms, *i.e.* body movements frequently exhibited by a speaker, often unbeknownst to them.

A particular paradigm for interfaces for public speaking training is the virtual audience. Such a system aims at reproducing a public speaking situation with high fidelity, using an environment that is typical of public speaking situations and populating it with virtual characters acting as listening to the user. Virtual audiences have first been investigated to treat public speaking anxiety. North *et al.* found in a series of studies that virtual audiences were effective in reducing public speaking anxiety [10, 13]. Researchers also investigated the effect of three different types of virtual audiences, namely a neutral, a positive, and a negative audience, consisting of eight virtual characters [16]. They showed that the three settings had an influence on participants, generating anxiety even in participants who were not particularly afraid of public speaking situations, underlining the immersive characteristic of such virtual audiences. A virtual reality version of the Trier Social Stress Test (TSST) was investigated in [26], with three virtual characters being used instead of three human actors, and the authors found that participants' heart rate patterns were similar to those of participants enrolled in real instances of the TSST. A randomized clinical trial was realized by Safir *et al.* [21]. 88 participants were randomly assigned between 3 conditions: a waiting list, cogntive-behavior therapy (CBT) with imagination (participants had to imagine a public speaking situation), and CBT with virtual reality exposure including virtual audiences. The experiment included 12 standardized sessions of one hour. Using self-rating anxiety questionnaires, the authors found a statistically significant reduction of anxiety in both CBT groups. A follow-up one year after the treatment found that the reduction in anxiety was maintained for both groups, which is very promising. While there was no difference in anxiety reduction between the two CBT groups, the group that underwent CBT with virtual reality suffered much lower attrition rates (15 dropouts in the imagination group, 6 in the VR group). Another group realized a large scale clinical trial comparing a group undergoing CBT with virtual reality exposure with virtual audiences and a group undergoing group exposure therapy [17] and found similar results: both groups benefited from a significant reduction in public speaking anxiety, maintained a year after the treatment. No difference was found between the virtual audience condition and the traditional group therapy condition. In a related domain, Bissonnette *et al.* studied the use of virtual audiences for reducing musicians' performance anxiety (MPA), successfully reducing it after 6 sessions of using the system over 3 weeks [2]. A review of the studies on the use of virtual audiences and virtual reality for treating social anxiety disorders can be found in [27].

While all these studies show strong evidence that virtual audiences are a valuable tool for mitigating public speaking anxiety, all the audiences used suffered from limitations. They were either static in the type of feedback they produced, or manually controlled by an experimenter. The effect of the behaviors of a virtual audience on the physiological state of users were not systematically studied. In this paper we propose to investigate this aspect of virtual audience effects. In the next section, we introduce the virtual audience framework we intend to use for this study.

3 The Cicero Virtual Audience Framework

In previous work, we introduced the Cicero virtual audience framework [6]. The architecture of the system is presented in Figure 2. Our primary goal for this system was to study public speaking training. In a preliminary experiment to validate the potential of virtual audiences, we designed a behavioral reinforcement training scenario where the user would train one specific behavior at a time, and the virtual audience would produce feedback on this particular behavior. For example, one training scenario would be designed to help participants avoid pause fillers (*i.e.* hesitation words such as *hmm* or *err*): when the participants produced a pause filler, some audience members would start to shake their head in disagreement. Conversely, if the participants did not utter any pause filler during a certain duration, the audience members would nod. The main idea behind this training paradigm would be that positive feedback would reinforce the users' tendencies to produce appropriate behaviors, whereas negative behaviors would inhibit them from producing them unwanted behaviors. The experiment produced positive results as we found the virtual audience system not only improved the participants' performance as evaluated by public speaking experts, but also fostered high engagement by participants, which presumably improves the likelihood of participants to sustain training with the system for prolonged periods of time.

Fig. 1: Screenshot of the Cicero virtual audience.

More recently, we studied the behaviors of the virtual audience more systematically, in order to find out which are the most relevant stimuli for public speaking training [5]. We realized a first experiment using a crowdsourcing methodology [14]: participants had to choose behaviors (*i.e.* postures, gaze patterns, head movements, facial expressions) for an individual audience member in order for it to express a particular level of arousal and valence, out of 5 possible levels (*i.e.* very low, low, medium, high, very high). We chose arousal and valence as previous studies showed that those are the primary dimensions that participants could identify in virtual audiences [12]. Using the data we collected by crowdsourcing, we built a model for choosing audience members' behaviors based on their individual state. We then realized a second study in order to validate the overall perception of virtual audiences using our model. We found that we could incrementally change how participants perceived an audience by modifying the state of individual audience members: this means we can precisely control the stimuli received by a user while they are training their public speaking with our system. In this paper, we propose to use this result to investigate the effect of audience behavior change on physiological states.

4 Proposed experiment

The main idea behind the experiment is to expose participants to various successive changes in virtual audience behaviors while they are presenting. The system used in the experiment is illustrated in Figure 2.

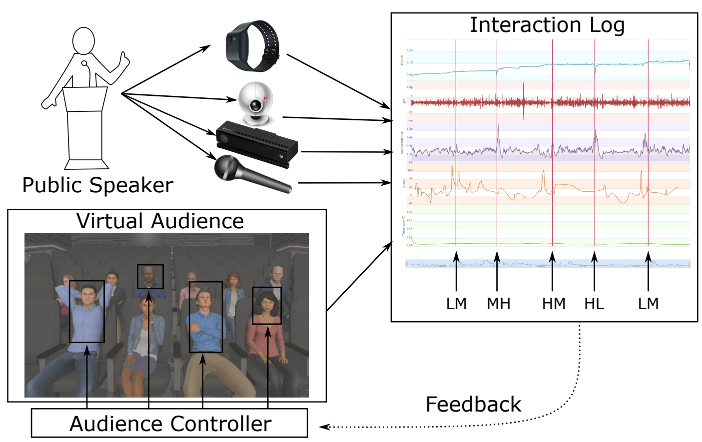

Fig. 2: The architecture of the system that will be used in the experiment. The dotted feedback line represents an envisaged addition to the our public speaking training framework where physiological data would be looped back to alter the virtual audience states. We discuss this concept in Section 5.

Participants are recorded through a variety of sensors: a webcam (centered on their face for monitoring facial expressions), a Microsoft Kinect and a microphone. Additionally, an Empatica E4 wristband[1] is used in order to capture physiological measurements. One advantage of using a wristband is that it does not hinder participants' movements at all, leaving them to behave as they would do in a pubclis speaking situation. During the participants' presentations, the virtual audience's behaviors are manipulated. While the participants are told that the system chooses to adjust the virtual audience behaviors depending on their performance, the virtual audience behaviors are in fact fixed in order to follow trajectories defined by the condition they are in. For instance, in the first moments of a presentation, the virtual audience will change from neutral to positive, then back to neutral, and will finish negative. The research questions, protocol, virtual audience behaviors and measurements are described in more detail in the following subsections.

4.1 Research questions

In this experiment, we want to assess whether participants' experiences are affected by virtual audience behaviors. We will look at this question using three perspectives: a physiological perspective, a self-efficacy perspective, and a behavioral perspective. Specifically, we will look at the following questions:

R1 Are participants' stress levels affected by a change in virtual audience stimuli?
R2 Are participants' perception of self modified by a change in virtual audience stimuli?
R3 Do participants exhibit different behaviors after a change in virtual audience stimuli?

For **R1**, we will utilize physiological measures to assess participants' stress levels after different trajectories of virtual audience behaviors. For **R2**, we will a self-reported measures from participants. Finally, for **R3**, we will the recorded use audio-visual data.

4.2 Virtual audience behaviors

In order to study the effect of virtual audience behavioral changes on users' physiological states, we designed a software component, the *Audience Controller*, that transitions the state of the overall audience from a starting state S_i to a target state S_t over a period of time of duration d. We validated in [5] that we can adjust the perceived overall state by incrementally modifying the state of its individual members; therefore the Audience Controller adjusts individual audience member states over time in order to reach the target audience state. We designed this component so that a transition instance from S_i to S_t over time d can be saved and replayed: this allows us to expose different participants to the exact same stimuli.

[1] https://www.empatica.com/e4-wristband

Using this component, we recorded different audience behavior sequences, that we call *trajectories*. For reducing the amount of variables in the experiment, we fixed the arousal level at a medium value, and only investigated valence changes. We also fixed the duration of transitions at 45 seconds. We defined 6 trajectories: LN (low to neutral), LH (low to high), NL (neutral to low), NH (neutral to high), HL (high to low) and HN (high to neutral).

4.3 Measurements

Our primary mode of investigation will by the physiological data recorded by the Empatica E4 wristband, which consists of measurements for temperature, electrodermal activity, heart rate, and acceleration. Additionally, we will be recording every interaction using a webcam for facial expressions, a Microsoft Kinect for full body behavior, and a microphone for vocal behavior. These 3 channels of recording will be synchronized together and with the E4. We intend to use these additional modes of recording to perform multimodal analyses.

Questionnaires will also be used. At the beginning of a session, every participant will fill in a demographics questionnaire, the Personal Report of Confidence as a Speaker [15], which allows use to get a self-rated measure of public speaking anxiety, and the 10-item Big Five Inventory [20] for assessing participants' personalities. After each presentation, they will fill in the Positive and Negative Affect Schedule [7]. At the end of the session, participants will also fill in the immersive experience questionnaire [11].

Finally, during the public speaking presentations, participants will be asked regularly to rate how they feel they are doing. For this to be minimally invasive, we will ask the participants to simply do a *thumbs-up* or *thumbs-down* gesture with one or both hands (no hands means neither positive nor negative).

4.4 Protocol

The experimental protocol is the following. When arriving for the experiment, they participants are fitted with the E4 Empatica wristband and are asked to sit and rest for five minutes as the experimenter prepares the software. This allows us to get baseline measurements for the participant. The participants then fills in a number of questionnaires. After this, the participants realizes four impromptu presentations: given a list of topics, the participants has to give his opinion in a speech after being given 5 minutes for preparation. During each of those presentations, the virtual audience is configured to behave following a fixed set of four trajectories. The set of trajectories constitutes the experimental condition, and is randomly chosen. Each of the trajectories last for 45 seconds. Between each trajectory, a popup appears on the screen, asking the participant to give their impression of their performance in a quick *thumbs up/down* gesture. After the first 3 minutes, the audience then picks trajectories randomly, and continues behaving until the participant is finished. Once the four presentations are finished, the participant fills in the last questionnaires, and is then debriefed.

4.5 Expected Outcomes

This experiment will allow us to study the three research questions outlined in subsection 4.1. We here describe a number of hypotheses that we will study in the data analysis that will follow the experiment.

Heart Rate Variability (HRV) refers to the variability between each successive inter-beat intervals, and prior research indicates that HRV may reflect emotion regulation [18]. Therefore, we hypothesize that participants with higher resting HRV will be less affected by negative audience trajectories compared to participants with lower resting HRV, as they will be better able to compensate for the negative stimuli:

H1a *High resting HRV will be less correlated with higher heart rate after negative audience trajectories due to individuals' increased emotion regulation abilities.*

Electrodermal activity, on the other hand, reflects current levels of stress [25]. Therefore, we write our second hypothesis: EDA will rise when the audience changes to a more negative state, and lower after a trajectory where it is getting more positive.

H1b *EDA will be lower after a increase in audience valence, and higher after a decrease in audience valence.*

In terms of self-efficacy, the only measure that we will obtain is the gesture performed by participants between audience trajectories. We simply assume that the virtual audience affects the participants' perception of self, regardless of how they are actually performing:

H2 *Participants will display more* thumbs-up *gestures after a positive trajectory, and more* thumbs-down *after negative trajectories.*

One other hypothesis we will study is that the type of audience stimuli will affect the participants' behaviors: if the audience is very positive, the public speaking performance of the speaker will improve. For instance, they make make less hesitations and display more positive facial expressions. As a first step, we will have annotators watch the videos and rate how they thought the participants did.

H3a *Ratings of participants' performance will be higher for segments after a positive trajectory compared to segments following a negative trajectory.*

Finally, recent advances in multimodal have allowed for the automatic assessment of public speaking. Using existing approaches such as [19], we will compute a performance score automatically for all segments of participants' presentations, and will study the following hypothesis:

H3b *Predicted scores of participants' performance will be higher for segments after a positive trajectory compared to segments following a negative trajectory.*

In the next section, we present a concept for a new type of public speaking training framework, which will utilize the results of the study presented above.

5 A Stress-Aware Virtual Audience for Public Speaking Training

In this section, we present a concept for a stress-aware public speaking skills training system. Using physiological measurements, the idea is to assess the stress level of the participant in real-time, and to adjust the stimuli produced by the virtual audience to maintain an appropriately challenging but not threatening training experience.

The theoretical framework behind this concept is Blascovich's challenge and threat framework [3]. The main idea behind this framework is that performance situations will be seen by an individual as challenging or threatening depending on cognitive and affective appraisals on the demands required by the situation and the resources that the individual has at their disposal to meet these demands. By performance situations, we mean situations where an individual is evaluated, either by others or oneself, and where this evaluation determines the outcome of a relevant goal for the individual, for instance career goals. Public speaking is often a good example of such a performance situation. The appraisals of a situation's demands refer to the perception of the situation's risks (*e.g.* losing one's job over a poor presentation), required effort or uncertainty, while the appraisal of resources refers to assessing what skills are deemed available in this situation (*e.g.* the participants' perception of their knowledge about the presentation topic). Challenge occurs when individuals believe they hold sufficient resources to meet the demands, and conversely threat occurs when those resources are seen as insufficient. Challenge and threat states affect patterns of cardiovascular activity, and as such can be assessed through physiological measures.

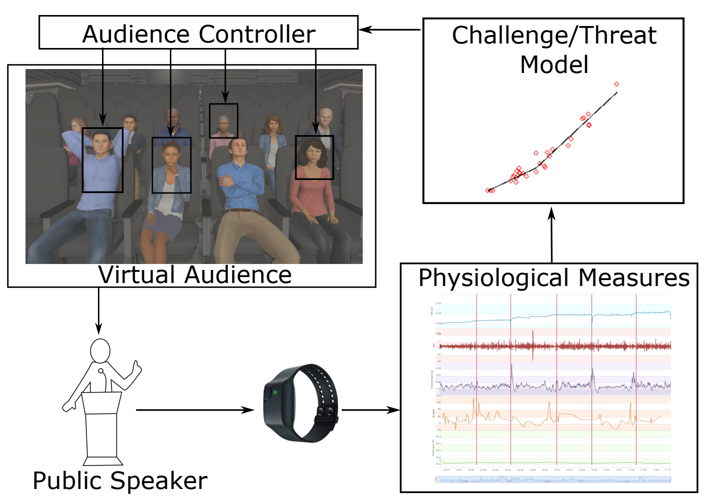

Fig. 3: Our concept of a stress-aware virtual audience.

Assuming that the hypotheses we formulated in section 4.5 are at least partly verified (*i.e.* virtual audience behavior changes affect the participants' states), we can frame the effect of the virtual audience stimuli as part of the challenge and threat framework. Our view is that changes in virtual audience stimuli affect the demands appraisals of the speaker; if the audience produces more positive feedback, then the user will see the situation as less emotionally demanding, and vice-versa. Using physiological measurements of the participants' heart rate, we can assess in real-time their psychological state, and adjust the virtual audience stimuli in order to keep them in a nonthreatening, challenging state. The concept of such a system is illustrated in figure 3. Such a concept should be applicable in any social situation that fits the requirements of the challenge and threat theory, that is, any evaluative performance situation which goals are important to the user. Therefore, a similar architecture should be usable for other applications such as job interview skills training or negotiations training.

6 Conclusion

Virtual audiences have been shown to constitute an effective tool for helping treating public speaking anxiety and social anxiety disorders in general. However, the virtual audiences used in earlier experiments did not use the full capabilities of virtual humans, in particular they did not systematically investigate the role of audiences behaviors. In this paper we presented an experiment that is designed at evaluating the influence of virtual audiences behavioral changes on physiological states. We hope this research will help improve the understanding of how virtual audiences can be used for mitigating public speaking anxiety and training public speaking, and ultimately lead to better alternatives for patients and users. Additionally, we presented a concept for a public speaking training system that relies on the virtual audience's behaviors to manipulate the user's stress level, in order to keep them in a challenging, nonthreatening state.

We are currently running the study, and expect we may be able to show preliminary results at the workshop. In future work, we will process and analyze the data collect within the experiments, in order to study the hypotheses presented in section 4.5. Additionally, were those hypotheses to be verified, we will implement our concept for a stress-aware virtual audience and evaluate its potential for public speaking training. We believe this concept should be applicable to other interpersonal skills training scenarios, such as job interview training, and will also look at expanding our domain to those other settings.

Acknowledgments This material is based upon work supported by the National Science Foundation under Grants No. IIS-1421330 and U.S. Army Research Laboratory (ARL) under contract number W911NF-14-D-0005. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation or the Government, and no official endorsement should be inferred.

References

1. R. Barmaki and C. E. Hughes. Providing real-time feedback for student teachers in a virtual rehearsal environment. In *Proceedings of the 2015 ACM on International Conference on Multimodal Interaction*, ICMI '15, pages 531–537, New York, NY, USA, 2015. ACM.
2. J. Bissonnette, F. Dubé, M. D. Provencher, and M. T. Moreno Sala. Evolution of music performance anxiety and quality of performance during virtual reality exposure training. *Virtual Reality*, 20(1):71–81, 2016.
3. J. Blascovich and W. Mendes. Challenge and threat appraisals: The role of affective cues. inj. forgas (ed.), feeling and thinking: The role ofaffect in social cognition (pp. 59–82), 2000.
4. G. D. Bodie. A racing heart, rattling knees, and ruminative thoughts: Defining, explaining, and treating public speaking anxiety. *Communication Education*, 59(1):70–105, 2010.
5. M. Chollet, N. Chandrashekhar, A. Shapiro, L.-P. Morency, and S. Scherer. Manipulating the perception of virtual audiences using crowdsourced behaviors. In *to appear in Proceedings of Intelligent Virtual Agents*. 2016.
6. M. Chollet, T. Wortwein, L.-P. Morency, A. Shapiro, and S. Scherer. Exploring Feedback Strategies to Improve Public Speaking: An Interactive Virtual Audience Framework. In *Proceedings of UbiComp 2015*, Osaka, Japan, 2015. ACM.
7. J. R. Crawford and J. D. Henry. The positive and negative affect schedule (panas): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, 43(3):245–265, 2004.
8. I. Damian, C. S. S. Tan, T. Baur, J. Schöning, K. Luyten, and E. André. Augmenting social interactions: Realtime behavioural feedback using social signal processing techniques. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 565–574, New York, NY, USA, 2015. ACM.
9. T. Furmark, M. Tillfors, H. Stattin, L. Ekselius, and M. Fredrikson. Social phobia subtypes in the general population revealed by cluster analysis. *Psychological Medicine*, 30(6):1335–1344, 2000.
10. S. R. Harris, R. L. Kemmerling, and M. M. North. Brief virtual reality therapy for public speaking anxiety. *Cyberpsychology and Behavior*, 5:543–550, 2002.
11. C. Jennett, A. L. Cox, P. Cairns, S. Dhoparee, A. Epps, T. Tijs, and A. Walton. Measuring and defining the experience of immersion in games. *International journal of human-computer studies*, 66(9):641–661, 2008.
12. N. Kang, W.-P. Brinkman, M. B. van Riemsdijk, and M. Neerincx. The design of virtual audiences: Noticeable and recognizable behavioral styles. *Computers in Human Behavior*, 55:680–694, 2016.
13. M. M. North, S. M. North, and J. R. Coble. Virtual reality therapy: An effective treatment for the fear of public speaking. *International Journal of Virtual Reality*, 3:2–6, 1998.
14. M. Ochs, B. Ravenet, and C. Pelachaud. A crowdsourcing toolbox for a user-perception based design of social virtual actors. In *Computers are Social Actors Workshop (CASA)*, 2013.
15. G. Paul. *Insight vs. Desensitization in Psychotherapy: An Experiment in Anxiety Reduction*. Stanford University Press, 1966.
16. D.-P. Pertaub, M. Slater, and C. Barker. An experiment on public speaking anxiety in response to three different types of virtual audience. *Presence: Teleoperators and virtual environments*, 11(1):68–78, Feb. 2002.

17. M. Price and P. L. Anderson. Outcome expectancy as a predictor of treatment response in cognitive behavioral therapy for public speaking fears within social anxiety disorder. *Psychotherapy*, 49(2):173, 2012.
18. K. S. Quigley and L. F. Barrett. Emotional learning and mechanisms of intentional psychological change. 1999.
19. V. Ramanarayanan, C. W. Leong, L. Chen, G. Feng, and D. Suendermann-Oeft. Evaluating speech, face, emotion and body movement time-series features for automated multimodal presentation scoring. In *Proceedings of the ACM International Conference on Multimodal Interaction*, ICMI '15, pages 23–30. ACM, New York, NY, USA, 2015.
20. B. Rammstedt and O. P. John. Measuring personality in one minute or less: A 10-item short version of the big five inventory in english and german. *Journal of research in Personality*, 41(1):203–212, 2007.
21. M. P. Safir, H. S. Wallach, and M. Bar-Zvi. Virtual reality cognitive-behavior therapy for public speaking anxiety: one-year follow-up. *Behavior modification*, page 0145445511429999, 2011.
22. J. Schneider, D. Börner, P. van Rosmalen, and M. Specht. Presentation trainer, your public speaking multimodal coach. In *Proceedings of the 2015 ACM on International Conference on Multimodal Interaction*, ICMI '15, pages 539–546, New York, NY, USA, 2015. ACM.
23. M. Tanveer, E. Lin, and M. E. Hoque. Rhema: A real-time in-situ intelligent interface to help people with public speaking,. In *Proceedings of the 20th ACM Conference on Intelligent User Interfaces*, pages 286–295, 2015.
24. M. I. Tanveer, R. Zhao, K. Chen, Z. Tiet, and M. E. Hoque. Automanner: An automated interface for making public speakers aware of their mannerisms. 2016.
25. Z. Visnovcova, A. Calkovska, and I. Tonhajzerova. Heart rate variability and electrodermal activity as noninvasive indices of sympathovagal balance in response to stress. *Acta Medica Martiniana*, 13(1):5–13, 2013.
26. M. Wallergård, P. Jönsson, K. Österberg, G. Johansson, and B. Karlson. A virtual reality version of the trier social stress test: a pilot study. 20(4):325–336, 2011.
27. B. K. Wiederhold and S. Bouchard. Social anxiety disorder: Efficacy and virtual humans. In *Advances in Virtual Reality and Anxiety Disorders*, pages 187–209. Springer, 2014.