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Effectiveness of VR immersive applications for public speaking enhancement

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Abstract

Augmented and Virtual Reality (VR) technology has recently proved to be useful in many learning and training scenarios. VR applications designed to practice communication skills (also known as Public Speaking Training or PST) are currently among the newest and still-unexplored solutions whose effectiveness is still to be tested. The current paper evaluates the Quality of Experience for a public speaking VR system where speakers can experience a talk session in front of a wide audience that actively reacts to their statements. A double stimulus experiment (with a real and virtual audience) was carried out in order to measure the visual quality, the immersiveness and the effectiveness of the approach. Objective evaluations, users' feedback and public speaking metrics showed that the VR set-up enhanced speakers' gesture and speech control when compared to performing in front of a real audience.

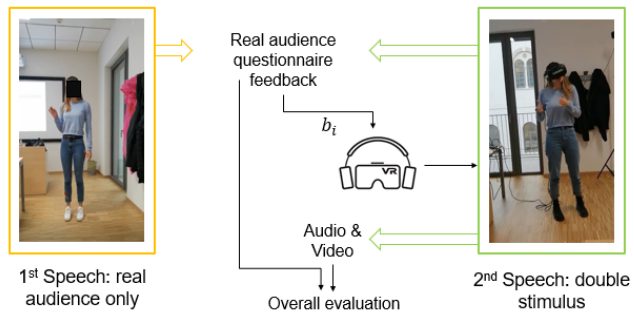


Figure 1. Each speaker performs the experience twice following a double stimulus scenario, at first with a real audience and then with both the virtual and the real audience. Objective and subjective metrics are acquired and analysed to evaluate his performance. Feedbacks from the first speech are collected to estimate the virtual audience behaviour, defined by a stress value b_i.

Introduction

A wide range of studies have shown that communication skills are essential in human interactions, and the costs of poor communication can be extremely high in many working environments [9]. Public Speaking (PS) effectiveness is enhanced by the congruence of gestures, gaze and vocal behaviour, as well as by other non-verbal-features. Gestures have been shown to facilitate speakers' cognitive processes during speech production and help listeners follow the talk [11]. Different kinds of gestures play different functions by reinforcing and integrating speech meanings [12]. Eye contact is a key element for building a relationship with the public. Speakers should maintain eye contact to receive feedback from the audience in order to adapt or change their speech on the basis of the public response [13]. To be effective, speakers should also vary their physical and vocal behavior to keep the audience's attention. Vocal variety (changes in pitch, volume, rate and pauses) is extremely important since it makes listening more pleasant and keeping the audience's attention much easier [14].

Speakers' anxiety or fear may affect their verbal and nonverbal behavior. Among the most frequent and disqualifying effects, we must mention the discrepancies of gestures and gaze with respect to speech and a reduction in speaking fluency.

In order to counter these problems and mitigate speech anxiety, it is possible to expose users to a training process that permits developing their habituation on speech activities. Within a simulated and stressful speaking scenario, trainees learn to deliver a message and pay attention to the correct usage of gestures, gaze and body posture in order to highlight the salient parts of speech and their meanings [10]. In order to practice the speaking abilities in front of an audience, Public Speaking courses prove to be useful, but unfortunately, they can be expensive, time-consuming and could not fit everyone's needs and desires.
More recently, a set of Virtual Reality (VR) tools for Public Speaking practice have been presented in the academic and industrial world. Users have the opportunity of testing their public speaking abilities in front of a VR audience, learning to control anxiety, and improving the quality of speech in terms gesture control and fluency.

The present study aims to verify the effectiveness of VR-based public speaking training applications in enhancing speakers' performance and response to the audience's feedback, by reducing speakers' anxiety while improving the use of gestures and the speech fluency. In order to prove the validity of the hypothesis above, we developed a double stimulus evaluation procedure where a speaker is asked to give the same talk within a virtual auditorium (while being evaluated by a pool of real listeners). and, at a different time, in front of a real audience in a real environment. In both scenarios, the audience reacts to speakers' performances generating different feedbacks that eventually correct the trainer's attitude. The final performance was evaluated with both subjective and objective metrics and the validity of the results was tested verifying the statistical significance of the conclusions.

Related Works

Recent research has highlighted how the latest extended reality technologies, such as VR and AR, can enhance the conventional process of learning in many fields by enriching the user's

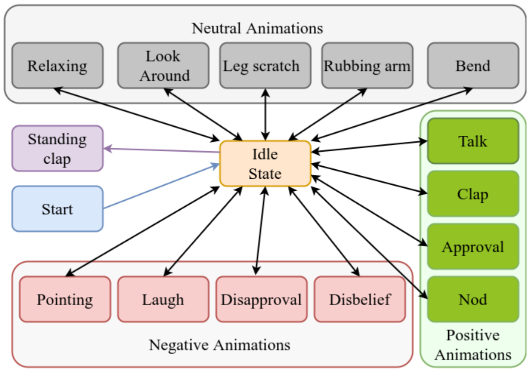


Figure 2. *State machine to control the animation flow of the characters. There are three main groups of animations (neutral, negative, positive) and an idle state where the avatars do not perform any animations.*

cognitive, sensorial and emotional experience [1]. These results suggest the possibility of adopting VR solutions to create new PS training tools. To this purpose, some recent works have focused on extended reality technologies that allow users to practice and improve their communication skills with no risk of public embarrassment [22]. Despite some early studies on this subject, the effectiveness and advantages of using immersive technology for enhancing Public Speaking have not yet been thoroughly investigated.

Palmas et al. [2] describe a virtual meeting room application where users can practice their speech in front of four synthetic persons; during tests, speakers proved adapting their speech according to the reactions of the virtual audience. Yamri et. al. [23] also focused on providing a real time feedback to the user through a virtualized audience; their work was mainly focused on the emotional evaluation of the speech stimulating the speakers in adjusting and changing inflections and involving attitude. Other approaches aim at reducing Public Speaking Anxiety (PSA) or give generic feedback on the user experience [24]. Salkevicius et al. [6] proposed a VR application for safe Cognitive Behavioural Therapy (CBT) treating social phobias like glossophobia (speech anxiety). The VR environment enabled the therapist to regulate and adapt the session intensity for each patient in real-time. Yadav et al. [7] analyzed whether systematic exposure to public speaking tasks in the VR environment can mitigate PSA and to what extent. Lindner et al. [25] confirmed a decrement on anxiety and distress after 3 private VR training sessions, with a perceived increment on the speech performance. Quantifiable physiological estimators of PSA such as electrocardiogram, body temperature and electrodermal activity indicated that participants felt less stress when presenting in front of the real audience after experiencing the VR sessions.

None of these methods consider the peculiar aspects of public speaking evaluation and rely more on generic quality metrics or objective physiological measurements (related to stress or to audience generic appreciation of the speech). At the same time, the interaction with a virtual audience is not clearly defined.

Following these preliminary studies, this paper presents a pilot VR application for public speaking training, where virtual characters are programmed in order to provide speakers with a behavioral feedback (in terms of gesture, body posture and expressions). Thanks to the proposed double stimulus evaluation procedure, our paper highlights the differences of the performances not only with an objective evaluation but also through a thorough study of subjective metrics considered essential for Public Speaking.

Double stimulus performance

The objective of this research is to assess the improvement induced by VR through objective and subjective public speech metrics. To reach this scope, we propose a double stimulus evaluation procedure, where speakers receive feedback on their speech from both a virtual and a real audience.

The VR Environment

To allow the speakers to perform in front of a virtual audience, we developed a VR application in Unity 3D [15] representing a real scale theatre (see Fig. 4) consisting of a stage facing a sitting public of 104 characters. The characters were animated to perform 14 different kinds of body responses, subdivided among three classes of behaviours: positive (clapping, nodding, etc.), negative (yawning, denying, etc.) and neutral (looking around, scratching, etc.). The animations flow is controlled by a finite state machine made of nodes, which represent different avatar actions (see Figure 2). Each state is connected to a central hub, which is the transition node between two animations. At the beginning of the experience, each character's behavior is assigned to one out of three classes. Depending on this assignment, characters' animator state randomly cycles within the pool of possible animations related to the assigned class. It is possible to have an idea of the groups of animation for each class from Fig. 2.

The number of subjects belonging to each class is assigned depending on a numerical stressed value $b_i \in [1,5]$. A lower value corresponds to a better overall audience reaction, i.e., a higher percentage of characters assuming positive or neutral states. A higher score increases the percentage of disagreeing characters (negative state) disputing the users' speech. Considering that, on average, a real public takes one minute to decide their interest in a speaker, the virtual audience has been looped over neutral animations for the first sixty seconds before changing into their class behaviours. At the end of the experiment (which can be decided by the test controller or by an automatic time limit set to 8 min), the virtual characters conclude their animations and stand up clapping. An example of a character animation can be seen in Figure 3.

Hypothesis Testing

In order to measure the efficiency of VR solutions in simulating a public speaking experience with unexpected public behaviour, we run several PS training sessions and evaluated the users' performance. The final aim was to verify the following hypothesis.

- H1: the VR theatre experience works effectively as training instrument for the improvement of speakers' clarity and coordination;
- H2: training through a virtual public could improve users' confidence and self-control w.r.t. unexpected characters' reactions;
- H3: subjects could improve their control on gestures and

Figure 3. *An example of character animations: neutral (left), negative (centre), positive (right).*

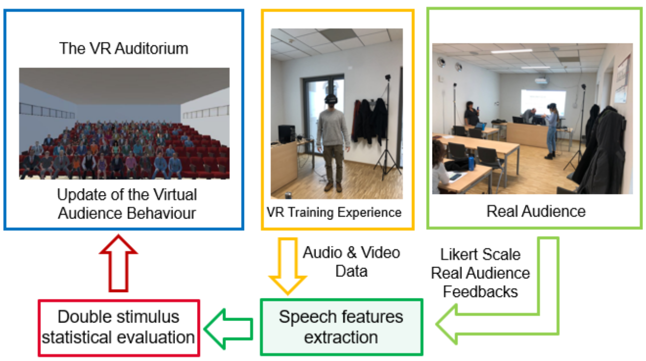


Figure 4. *Double stimulus experience: the speaker receives feedback from both a real and a virtual audience. Following Public Speaking evaluation metrics, objective and subjective features are extracted and analysed from audio and video data recorded during the speakers' speeches.*

speech fluency by training with a VR experience.

Users were asked to act in their most natural way during both experiences, so that it was possible to collect every change in their speeches, usage of gestures and voice modulations. Videos of both talks were acquired to perform a technical analysis on gestures and speech fluency. At the end of both testing sessions, we asked the speakers to provide feedbacks on the VR experience realization and on their feelings.

Experiment Set Up

Tests were executed in a classroom at the Department of Linguistic and Literary Studies of the University of Padova, represented in the green square in Figure 4. The VR set-up was placed in front of the teaching desk, leaving a suitable amount of space for the user to move freely in the virtual stage. The tester was oriented towards the real public that was sitting in front of them. This allowed a complete visibility of the speaker's behaviour for a comprehensive evaluation of the talk. This set-up ensured the reproducibility of the tests and avoided the unintended influence of external factors. The same testing conditions were arranged for the first set of experiences, without the visor usage. An HTC VIVE VR [16] visor was used, without the addition of controllers to allow speakers to openly express with hand gestures. None of the subjects had been informed in advance about the behaviour of the public encountered during the VR experience. Each tester was also asked to avoid comments during and after the experience to prevent influencing the following speakers. The only person aware of that was an operator responsible of helping the testers to wear the VR visor and initiate the virtual experience from a desktop computer connected to the glasses.

Evaluation of the experiment

The experiment involved 13 subjects aged 20 to 25 years old, including 8 females and 5 males. Only one person had previous experience with VR visors and applications. Each subject was required to prepare two different speeches of a maximum length of 8 minutes, the former to present in normal conditions, the latter to test in the virtual environment. The two sessions were executed in two different days in front of the same real public, composed of the other testers which evaluated the speaker's performance on common public speaking metrics (see below). Thus each speaker was evaluated both in the real and the virtual experience by the same audience. During the performances we acquired full-body videos of each subject for the analysis of gestures and speech fluency.

Subjective metrics

At the end of each speech, the listeners were required to fill out a questionnaire, using a Likert scale (from 1 to 5), to provide their feedback on the speakers' performances, covering the following metrics:

- Charisma;
- Comfort;
- Stance;
- Coordination;
- Voice modulation;
- Voice power;
- Pause usage.

The levels of stress applied to the virtual audience during the VR experience were chosen by selecting the average performance score obtained with the listeners' evaluation questionnaires of the first experiment. We then asked the speakers to rank the immersivity of the virtual environment between complete, partial and extraneous levels. Each speaker was required to provide some comments on the VR experience, regarding i.e anxiety and distraction levels. Finally, we collected opinions on how the experience was carried out and on the usage of a VR solution for public speaking training and skills improvement.

Objective metrics

The performance of the k-th speaker was also evaluated by the averages of objective metrics computed from the video and the audio recordings. Audio tracks were converted into text documents using IBM Watson Speech-to-Text [19] which allowed computing the number of words w_k. Speech hesitations h_k were measured and counted using PRAAT [20]. Moreover, speakers' total number of gestures g_k were categorized and counted using the multimodal analysis software ELAN [21]. Assuming that speech length for the k-th user is t_k (in minutes), we computed the following measurements:

- average number of gestures per minute $\overline{g}_k = g_k/t_k$;

- gesture rate: number of gestures for every 100 words or $\overline{g}_k^w = g_k/w_k \cdot 100$;
- hesitation rate: number of hesitations w.r.t. the overall duration of speech $\overline{h}_k = h_k/t_k$;
- speech rate: ratio between the number of words and the overall duration of speech $\overline{w}_k = w_k/t_k$.

We consider a gesture as a movement of the arms or hands from an initial position to their maximum expansion with the return to the same position. For these analyses, we counted beat gestures (identical gestures repeated consecutively) just as a single gesture. A hesitation occurs when speakers either halt or falter during their speeches. The averages of these metrics are all reported in Figure 6.

Results and Discussions

In this section we analyse the public speaking objective and subjective metrics collected during both speech experiences, showing how VR enhances a speaker skills and confidence through a double stimulus evaluation approach.

Subjective Analysis

We carried out a statistical analysis on the results of the questionnaires given to the listeners. Since improvements or decrements in communication skills vary with personal attitude and VR character, we compared speakers' performances in real and VR environments using relative difference metrics, i.e.,

$$\delta S_i = \frac{S_{R,i} - S_{V,i}}{S_{R,i}} \tag{1}$$

where $S_{R,i}$ is the score on the i-th metric of the questionnaire obtained with the real audience and $S_{V,i}$ is the score with the virtual audience. This measure allows evaluating the differences more accurately since the variations in the performance of a fluent speaker are less noteworthy than an improvement obtained by a user with poor communication skills.

After performing outliers removal (2 testers out of 13), we checked the dataset normality hypothesis. Due to the small dataset dimension, the hypothesis was verified through normal probability plots as suggested in [17]. From the visual analysis of the plots, we inferred that the quantiles of the residuals do not fall on or close to the 45° line. Therefore, the normality could not be assumed. As a further verification, we applied the logarithmic and the square root transformations confirming the normality hypothesis rejection. Because of the data distribution condition, we applied the non-parametric Mann-Whitney test as suggested by [18].

Figure 5 summarizes the average subjective evaluation given by the real listeners on both experiences. Comparisons that are not statistically significant are highlighted with red asterisks. The VR training environment didn't enhance considerably the speaker's comfort, since comparisons are not statistically significant (values greater than 5%). This conclusion could also be drawn from the feedback concerning immersivity, reported in Figure 7. Speakers were affected by their theatre and audience artificiality perception w.r.t the real public that was in the room. At the same time, they perceived a constant pressure coming from the evaluation of the real people.

As for the other subjective metrics, all of them have proved to be statistically significant. In particular, p-values for charisma, stance and coordination are 0.0198, 0.0001 and 0.0006. Measurements concerning voice modulation, voice power and pause usage reported p-values equal to 0.0001, 0.0006, 0.0133. These results verify the hypotheses H1 and H2. Generally, speakers' attention was distracted by the virtual characters' unexpected behaviours. Moreover, the speakers lacked direct eye contact with the virtual listeners, and they focused more on their own performance, obtaining better voice modulation, pause usage and power control. All these aspects confirm H2 showing that training with a VR application could improve speakers' confidence and self-control. Positive results on voice modulation, power control and pause usage are also a confirmation of H1, being all of them related to clear speech and concept explanation. Coordination confirms this hypothesis as well: the speakers were able to better understand how to make their words more congruent with their gestures and to express them more clearly.

The final evaluation considers the level of immersivity perceived by the users during the experience. As shown in Figure 7, 76.92 % of users felt partially immersed in the virtual environment, 23.08 % felt extraneous to the environment while none of them was completely immersed. We verified the significance of this result with the Pearson chi-squared test that rejected the null hypothesis with $p = 0.0023$. This acts as a further confirmation of the results encountered on the previous analyses. The lack of advanced tools to create an application that resembles as much as possible the real world is still open research with strong efforts on its realization.

Audio and Video Analysis

Outlier removals and normality verifications were executed before the statistical analysis. No outliers were found for these datasets.

Because the normality hypothesis was rejected by all the tests, we applied the Mann-Whitney test which led to the following results:

- the differences in the average $\overline{h}_k$ and $\overline{g}_k^w$ are not statistically significant being their p-value of 0.0794 and 0.0794;
- the differences in the average $\overline{g}_k$ and $\overline{w}_k$ are statistically significant with p-values as 0.0136 and 0.0136.

The impossibility to see their own arms during the VR experience made users more aware of their gestures, affected the overall gesture control w.r.t. the real experience and caused users to focus more on their overall performance. Thus, they produced less random, meaningless gestures. This resulted in a significantly lower number of gestures per minute, but not in a significantly lower gesture rate, presumably because the speakers used more words in their speech in an attempt to express themselves more clearly.

The speakers' speech rate was also significantly lower during the VR experience, showing that they tried to provide a clearer talk to the audience. Hesitation rate was non significantly higher during the VR experience than the real experience. The speakers' tendency to an increased hesitation rate during the VR experience can be due to the fact that the speakers reported they felt distressed at speaking with the VR while at the same time being evaluated by the real audience. Also, the speakers were surprised at the unexpected avatar animations. The analyses do not confirm H3.

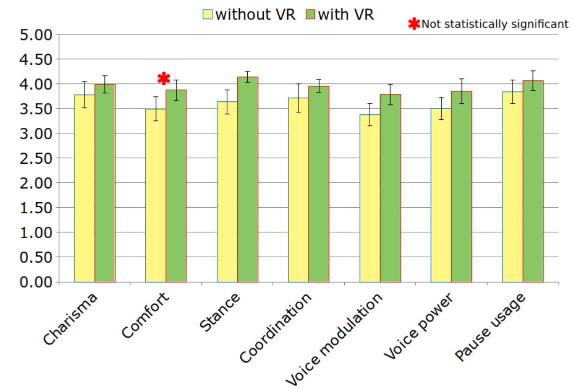
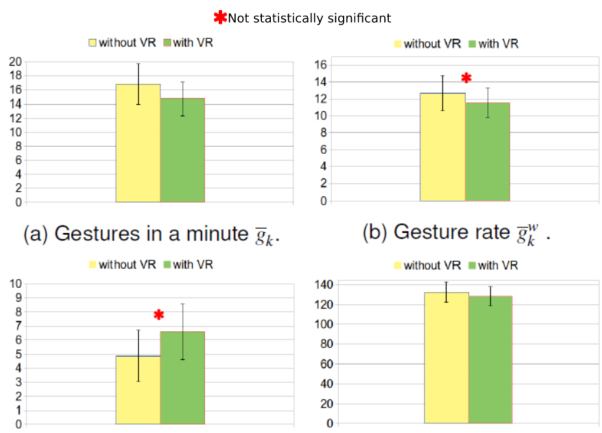


Figure 5. *Average of subjective metrics retrieved from the answers of the listeners' questionnaires.*



(a) Gestures in a minute $\overline{g}_k$.

(b) Gesture rate $\overline{g}^w_k$.

(c) Hesitation rate $\overline{h}_k$

(d) Speech rate $\overline{w}_k$.

Figure 6. *Audio and Video analysis averages of four objective metrics in the two tested scenarios.*

User comments

The users' feedback suggests several improvements which could be applied to the VR experience and its utility for training purposes. They also provide some opinions regarding the proposed test experiences for future realizations. The speakers were more worried about the presence of the real people in the room than the virtual audience. After an initial surprise they became comfortable with the presence of the characters in the virtual theatre by understanding that they were unable to judge them, unlike what occurred with the real public.

Most of the speakers reported that they were affected by the unexpected behaviour of the avatars and that they tried to adjust their tone of voice consequently. Generally, the overall VR experience was considered positive and helpful especially to train in front of an audience whose behaviour is unexpected. They also suggested to integrate the VR application with gloves or controllers to simulate real hands on the virtual room. Another improvement to consider for further releases is the change of the public behaviour depending on the speaker's performance quality.

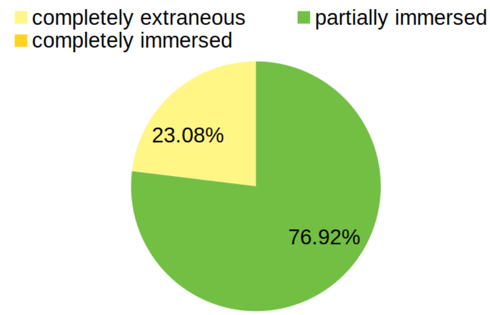


Figure 7. *Level of immersivity perceived by the speakers in the virtual reality environment.*

Conclusions

This paper presented a double stimulus evaluation approach to verify the effectiveness of VR public speaking training applications in enhancing users' performances and controlling speech anxiety. A VR application for Public Speaking Training was created to allow the users to immerse themselves in a virtual auditorium where the audience reacts to their speech with different gestures and body poses. The effects on communication skills were evaluated using both subjective and quality metrics concerning fluency and gesture frequencies. The experimental results and users' feedback have shown that most of the users increased their control over gestures while speaking. The overall communication experience improved according to different metrics as well.

Future works will be devoted to investigating more in depth the coordination between the speaker's speech and the virtual audience reactions, as well as to creating virtual avatars that are able to keep eye contact with the user.

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