# HUMAN FACTORS IN IVE DEVELOPMENT – A CASE STUDY FOR VIRTUAL FEAR OF PUBLIC SPEAKING TRAINING

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## ABSTRACT

Virtual Reality (VR) training applications are a success story for research and development. However, in order to firstly, fully understand human-computer interaction in 3D environments and secondly, designing and implementing effective applications, system as well as user characteristics should be acknowledged. This paper deals with a case study of a virtual fear of public speaking training. First aim of the project was to design and implement realistic audience behavior (high simulation fidelity). Findings from three observational studies are presented that formed the basis for the design of a virtual audience. The second goal was to evaluate the prototype. Results from an experimental laboratory user study are presented, analyzing the effect of simulation fidelity on user experience. Our findings highlight the importance of high simulation fidelity for designing and implementing effective (fear triggering) virtual fear of public speaking applications.

***Index Terms -*** Immersive Virtual Environments, Fear of Public Speaking, Human Factors, User-Centered Design, User Experience

## 1. INTRODUCTION

Virtual Reality (VR) applications are a success story for research and development. Up to now, numerous applications have been developed for various areas like engineering, training and therapy, and gaming [1]. However, literature review shows that human-computer interaction (HCI) in this context has yet to be fully understood, leading to low task performance in Virtual Reality [2] and to low applicability of VR technology outside research laboratories altogether. In order to fully understand human-computer interaction in 3D environments, we propose to acknowledge system as well as user characteristics from the beginning of the design and implementation process and in iterative user evaluations.

In this paper, we present a case study of a virtual fear of public speaking training – highlighting the acknowledgement of human factors in development and implementation. We focus on the one hand on simulation fidelity of a system (realism of replicated objects and environments in IVEs), namely designing realistic virtual audiences. On the other hand, concerning user characteristics, we analyzed the effect of simulation fidelity on presence experienced in an IVE.

## 2. RELATED WORK

Virtual Reality technology offers new possibilities for Cognitive Behavioral Therapy on fear of public speaking: Clients can be exposed to virtual fear-triggering stimuli (exposure) and are able to role-play in virtual and different scenarios, training social skills to overcome their fear

[3]. Those applications are known to be effective by inducing fear in participants [4–6] and can also lead to a reduction of fear of public speaking symptoms [7–11]. However, research on the underlying mechanisms of those effects is still scarce.

State of research shows that immersion or fidelity aspects affect presence and performance in IVEs, especially virtual therapy and training applications [for an overview see 12]. To analyze hard- and software characteristics of IVEs, researchers typically relate on Mel Slater [13] and his definition of "immersion", namely the objective level of sensory fidelity a VR system provides. Presence, in contrast, is defined as user's subjective response to a VR system [13].

Three different aspects of immersion or fidelity can be distinguished [1]: (a) display fidelity, (b) interaction fidelity, and (c) fidelity or realism of the simulation (how faithfully the environment and objects as seen in the real world are replicated in an immersive virtual environment [14], including for example their behavior).

Up to now, mostly prototypical (positive, negative, and neutral or static) audiences were implemented and compared [5]. However, findings show that higher simulation fidelity (in our case realistic audience behavior) does not only lead to higher presence and subsequently to higher user performance, but also to better transfer of gained skills into practice [15]. Therefore, researchers recently have aimed at integrating realistic virtual human behavior into such applications [16–18]. Still, total fidelity does not have to lead to higher feelings of presence and performance. Studies show that sometimes lower-level fidelity applications are indeed a match or even outperform higher-level applications [19]. The interesting question to face is rather what level of fidelity is really needed to create sufficient levels of presence and especially performance. In the end, this refers back to an economic perspective: high-end IVEs need a lot of resources to create high levels of fidelity, as technological infrastructure, personal resources and know-how have to be provided [20].

One aim in our project was therefore to implement realistic audience behavior. The second aim was to examine the effect of simulation fidelity on user experience, namely perceived realism, fear experienced during using a fear of public speaking application, and presence.

## 3. AUDIENCE DESIGN

In order to obtain data on realistic audience behavior, several exploratory cross-sectional non-participant overt observation studies have been conducted. Findings have been used to design and develop a virtual audience for an alpha version of a 3D prototype application. The CryEngine3 (Version PC v3.4.0 3696 freeSDK) was used as a 3D engine for real time rendering.

### 3.1 Frequency and valence of non-verbal audience behavior

As was mentioned in the related works section, previous studies mostly used prototypical virtual audience behavior. In order to design realistic audience behavior, a first exploratory observation study was conducted with the purpose of gaining data on natural non-verbal audience behavior actions.

#### *3.1.1 Method*

A real audience (consisting of $n$ = 18 men and women) in an undergraduate seminar was observed in a structured, non-participant overt observation. We used event samples of three frontal lecture sessions, taping the lectures on video and analyzing the video material.

Behavior frequency of four nonverbal dimensions (eye contact, facial expression, gesture, and posture; $N$ = 5916 behavioral actions in total, coded into 35 categories) was rated by means of a quantitative content analysis, in regard to frequency and positioning across three rows of seats within the lecture room. Further, we analyzed the first, middle and last 15 minutes of the lecture sessions (with a duration of 90 min. each), as we assumed that nonverbal audience behavior may change over time (for example packing away things towards the end of a session).

#### *3.1.2 Results*

In this section, selected findings on facial expressions and behavior patterns will be given (for results on gestures and postures see" [17, 18]).

*Facial expressions*
As Table 1 shows, friendly and neutral face expressions are rather common. Also, they are closely related, as a joyful facial expression changes into a neutral one when coming to an end. Social facial expressions increase with distance to the presenter, maybe to establish a closer contact. Further, neutral and social expressions increase with time.

**Table 1.** Means of frequency of facial expressions for one person per row and per minute

| Facial expression | | First part of session | Middle part of session | Last part of session |
|---|---|---|---|---|
| Pleasure | First row | 0.11 | 0.23 | 0.44 |
| | Middle row | 0.16 | 0.17 | 0.34 |
| | Last row | 0.24 | 0.24 | 0.41 |
| Neutral | First row | 0.12 | 0.17 | 0.24 |
| | Middle row | 0.17 | 0.2 | 0.32 |
| | Last row | 0.24 | 0.17 | 0.32 |
| Anger | First row | 0.03 | 0.02 | 0.04 |
| | Middle row | 0.03 | 0.02 | 0.01 |
| | Last row | 0.01 | 0 | 0.01 |

This can be explained by the fact that at the end of a lecture session, more interactions and discussions take place, as frontal presentations are already finished. The anti-social expression of anger was shown rather seldom, so a natural audience seems to be either social or neutral.

*Behavior patterns*
Several behavior patterns were noted during the qualitative video analysis:

- Turning the upper part of the body sideways is related to start talking with a neighbour. Also, it is accompanied by smiling, either at the presenter or the conversational partner.
- If people take notes (with paper and pencil or laptops), they do so for a very long time, often up to 15 minutes. During this time, they often establish eye contact to presenters.
- People sitting next to each other imitate behavior actions, like adapting viewing direction and imitating body postures.

#### *3.1.3 Discussion*

Results show that audiences seem to be rather positive, frequently showing friendly and neutral face expressions. Additionally, combined and even synchronized behavioral patterns between participants who sit next to each other (like turning to the neighbor and start talking) were registered. These patterns should be acknowledged in virtual audience design, as they may lead to a more realistic perception by users of VR applications.

### 3.2 Attentive and inattentive audience behavior

Another observational study of a lecture (*n*=37) identified students' patterns of both attentive and inattentive behaviors that occur repetitively during a lecture. These include head, torso, and hand movements. Findings are meant to provide a broad choice for behavior simulation in VR.

### *3.2.1 Method*

The study involved videotaping and observing 37 students during a 40-minutes lecture at Ilmenau University of Technology. Based on literature, 79 codes were developed to code occurring nonverbal markers of attention and inattention, such as eye gaze behavior, facial expressions, body posture and movements, occurrence of conversation, role of audience member, and used technical device [21, 22]. Data was analyzed using a data mining script in Matlab.

### *3.2.2 Results*

The codebook helped identify a series of single nonverbal markers for attention and inattention (e.g. eye gaze or a hand movement or a torso movement). In natural settings however, people employ nonverbal behaviors simultaneously, they occur continuously and are fluid. In order to capture these characteristics, the coded data was grouped into two types of patterns: (1) parallel behaviors which co-occur and (2) sequential behaviors which precede one another.

#### *3.2.2.1 Parallel behaviors*

These behaviors occurred simultaneously on a timeline (in minutes and seconds) and all included eye gaze behaviors in combination with any other occurring movement, as presented in the methodological part. Eye gaze behaviors (looking at the speaker and/or taking notes vs. looking to colleagues) was the nonverbal behavior that was used to discriminate between attentive and inattentive behaviors.

The number of unique patterns was identified, as well as the frequency of their occurrence (see Table 2). It could be noted that the number of patters of attention was small in comparison to the frequency with which they occurred, whereas patterns of inattention were much more numerous, but occurred less than the others.

**Table 2.** Type of patterns and their frequency in a 40-minutes lecture

| | **Attention** | **Inattention** | **Total** |
|---|---|---|---|
| Parallel patterns | 14 patterns<br>527 (frequency) | 47 patterns<br>252 (frequency) | 61 patterns<br>779 (frequency) |
| Sequential patterns | 10 patterns<br>1050 (frequency) | 4 patterns<br>196 (frequency) | 14 patterns<br>1246 (frequency) |

An example of attentive pattern was: having a neutral facial expression, looking towards the front (to the lecturer), having the arms and hands on the desk. Inattentive patterns involved looking at fellow students or engaging with laptops and other mobile devices, as well as having an overall fidgety conduct.

#### *3.2.2.2 Sequential behaviors*

The data allowed seeing if certain behaviors occur repeatedly and follow one another. The reason behind this was that virtual humans should also be designed to shift smoothly from one nonverbal behavior to the other. Eye gaze was used as discriminating behavior in identifying the start and end of a sequential pattern. When the eye gaze changed from a position to the other (from looking to the lecturer to looking to a neighbor), a new sequence was coded. A sequential pattern of attention included looking at the lecturer, then shifting the gaze towards the notes on the table, and then back again to the lecturer. Patterns of inattention contained looking alternatively to neighbors and to laptops and other mobile devices.

### *3.2.3 Discussion*

The high variety of unique nonverbal behavior patterns (75) identified in this study proved that even a rather short lecture can serve as valuable material for virtual humans' design. The findings showed that nonverbal cues can be grouped in parallel and sequential manner and these patters can be later used to design virtual audiences.

Another finding was that certain behaviors, such as inattentive ones tend to spread across the lecture hall, from one student to the other. Triggering factors have been identified (e.g. a door opening) and can be also used in the design of the virtual audience.

Further study should measure intensity of displayed behaviors and also connect displayed attentive and inattentive behaviors with actually *felt* attentiveness and inattentiveness.

## 3.3 Interactivity

Simulating realistic audiences means having them react to a speaker's delivery style. Experiments were conducted with students (*n*=36) to see how listeners react to eye gaze direction and voice loudness levels of speakers and the combination thereof. Results help design responsive virtual audiences by implementing voice volume and eye tracking sensors.

### *3.3.1 Method*

The participants to the experiment (19 female, 17 male, *M*=24 years old, *SD*=3.77) were divided into four groups and each group was exposed to a slide speech about popular holiday locations in Germany. The speaker (male) was trained to vary his voice volume and eye gaze behavior. A 2 x 2 between-subjects factorial design was employed with the following conditions: Speech 1 – no gaze to the audience/low voice volume, Speech 2 – no gaze to the audience/normal voice volume, Speech 3 – gazing towards the audience/low voice volume, Speech 4 – gazing towards the audience/normal voice volume.

Subjects were videotaped and had their nonverbal behaviors (eye gaze, body postures, and body movements) analyzed based on a codebook. ANOVA calculations analyzed occurring variance across conditions.

### *3.3.2 Results*

Findings showed that audiences looked more at the speaker only if he would look at them and independently of the voice volume he used, with $F_{(3,32)} = 15.206$, $p < .001$, partial $\eta 2 = .567$ (see Figure 1). Moreover, people took less time looking at the slides when the speaker was looking at them compared to the situation where he would look at his notes or slides. In the latter situation, people would check the slides as well, as if they were following the gaze of the speaker.

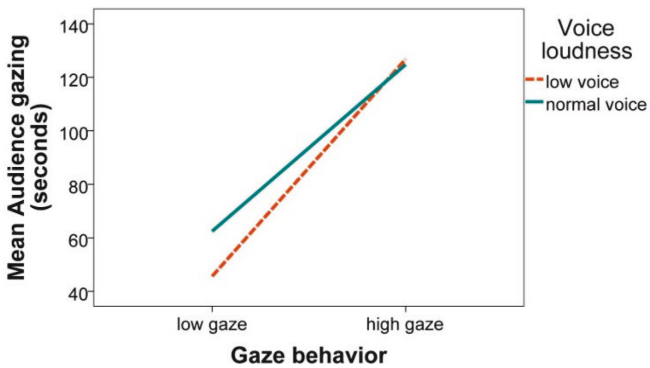


**Figure 1.** Audience gaze towards the speaker

With regard to body postures, people kept longer attentive postures in the speeches where the speaker was gazing towards them, in comparison to those where he averted his gaze. Also, voice proved to foster longer attentive postures, independently on whether the speaker was looking or not looking at the audience. This means that a louder voice managed to capture the attention, even if the speaker was averting his gaze from the audience (see Figure 2).

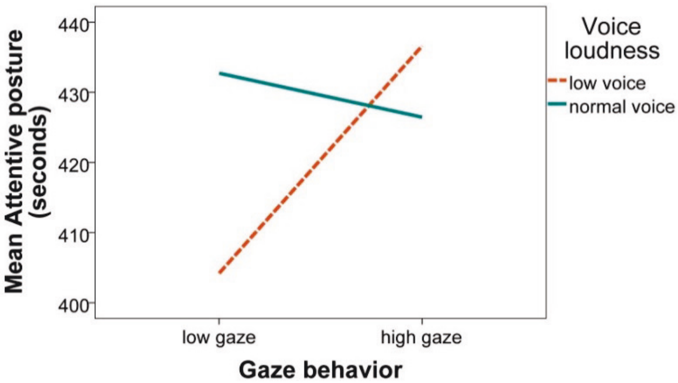


**Figure 2.** Audience gaze towards the speaker

### *3.3.3 Discussion*

People spent more time paying attention to the speakers when they looked directly at them and spoke in high voice compared to low voice deliveries. They also stayed attentive when voice was high, even if speakers' eye gaze drifted. Limitations of the study stem from the fact that the exact nonverbal behaviors of the speaker were not recorded to control for their potential influence on the nonverbal behaviors of the audience.

All in all, the findings prove helpful in planning the design of responsive audiences, by confirming the need for voice volume and eye tracking sensors.

### 3.4 Summary

Several observational studies have been conducted in order to obtain data on realistic audience behavior. The findings were used to design a virtual audience that can display parallel and sequential nonverbal behaviors and which should ultimately be able to react to a speaker's voice volume and gaze direction. The audience was improved by iterative revisions, including more behavior actions and patterns respectively. However, revisions are still on-going.

## 4. USER EXPERIENCE

Subsequently, a user study was conducted in order to evaluate the alpha-version fear of public speaking prototype application. We analyzed the effect of simulation fidelity (static vs. animated audience) on presence as a prerequisite for performance, received realism, and fear experienced during a talk [see also 23]. Due to contradictory findings from state of research, we formulated the following non-directional hypothesis: Being confronted with a static audience (low fidelity) will lead to different levels of experienced presence than being confronted with an animated audience (high fidelity). Further, we explored anxiety induced in the two conditions, as well as perceived realism of the audience.

## 4.1 Method

An experimental, cross-sectional, 2×2 within-subject design was chosen. The first independent variable was level of simulation fidelity, with a static audience display versus an animated audience display of a virtual scene. Order of presentation was the second independent variable to control for sequence effects. Dependent variables were virtual presence, state anxiety, and perceived realism.

## 4.2 Virtual Scene

The virtual 3D scene depicted an audience consisting of 29 male persons sitting in a lecture room. The audience was seen from a first person perspective (see Figure 3). Participants stood in front of the audience (with a distance of approximately four meters from the projection screen). The total duration of the scene was approximately five minutes.

**Figure 3.** Screenshot of the Public Speaking Anxiety Application (alpha-version)

In the static condition, participants saw an audience without behavior animation. In the animated condition, the audience showed random behavior actions like coughing, scratching their heads or leaning forward. Due to the early development stage of the application, only two models were included in the scene. Also, only a small selection of nonverbal behavior actions was implemented at this time.

## 4.3 Procedure

After a short oral briefing, the subject was presented either the static or the animated scene while giving a prepared talk. After the first round, the subject was asked to complete a semi-standardized questionnaire provided on a laptop computer. This process was repeated subsequently with a scene where the display was swapped from static to animated or the opposite. After the second round, the subjects were asked to complete the questionnaire a second time. Finally, the participants were given the opportunity to report their impressions followed by an oral debriefing.

## 4.4 Experimental Environment

The hardware setup for the experiment consisted of a workstation that provided the virtual environment. The VE was created on a DELL Workstation with an Intel(R) Xeon(R) CPU X5650 @ 2.67 GHz, 12 GB of RAM and a NVIDIA GeForce GTX 560 graphics card with 2 GB of RAM. The stereo image was projected on a projection screen with reflective coating (2500 ×1500 mm) by a LG BX327 3D DLP-Projector with a native XGA (1024 ×768) resolution. The incorporated software setup was based on the CryEngine3 (Version PC v3.4.0 3696 freeSDK) as a 3D engine for real time rendering.

## 4.5 Measures

Sense of virtual presence was measured by an adapted version of the Slater-Usoh-Steed (SUS) questionnaire [9]. Fear during the talk was measured by the A-State scale from the short form of the State-Trait Anxiety Inventory [10]. To check on perceived realism of the audience, an item was developed on the basis of the second item of the Reality Judgement and Presence Questionnaire [11].

### 4.6 Sample

A total of 42 undergraduate students and academic staff were acquired through university mailing lists and oral invitations. Two participants were excluded due to technical problems during the experimental session. The final ad-hoc sample ($n = 40$) consisted of 23 men (58 %) and 17 women (42 %) with a mean age of 24 years ($SD = 2.30$). All subjects reported having normal or corrected-to-normal visual acuity with 17 participants wearing glasses or contact lenses during the experiment.

### 4.7 Results

Due to contradictory state of research, we tested a non-directional hypothesis that a static vs. an animated audience leads to different effects in virtual presence experienced. Contrary to this hypothesis, we found a null-effect (see Table 3, $t = .33$, $df = 39$, $p = .73$, $n = 40$). The standardized effect size was minimal ($d = .06$) with an achieved power of $1\text{-}\beta = .06$.

**Table 3**. Means and standard deviations for virtual presence, anxiety, and realism according to simulation fidelity (static vs. animated audience; n = 40)

| | Simulation Fidelity | | | |
|---|---|---|---|---|
| | static | | animated | |
| | *M* | *SD* | *M* | *SD* |
| Virtual Presence | 3.48 | 1.06 | 3.54 | 1.07 |
| Anxiety[a] | 11.10 | 2.96 | 12.98 | 4.06 |
| Realism | 2.78 | 1.64 | 2.73 | 1.38 |

Scales from 1 = not at all to 7 = very much; [a] scale from 1 = not at all to 4 = very much, sum score of means (maximum = 24)

Simulation fidelity led to a significant difference in fear experienced during giving the talk ($t = 3.11$, $df = 39$, $p < .001$, $n = 40$, see Table 3) with a medium effect ($d = .49$). Regarding perceived realism, neither of the audience versions seemed to be very realistic to participants (see Table 3). The means even show a very slight but not significant tendency that static audiences seem to be more realistic ($t = .18$, $df = 39$, $p = .86$, $n = 40$) with a small effect ($d = .17$; $1\text{-}\beta = .19$).

### 5. Summary

Contrary to state of research, no influence of simulation fidelity was shown on virtual presence and perceived realism, but an animated audience led to significantly higher effects in anxiety during giving a talk. The last finding is the most crucial for effective training applications. Although these findings could be explained by an application that might not have been realistic enough (given a simple alpha version of the prototype), they question the role of presence as a mediating factor in virtual exposure applications.

## 6. DISCUSSION

In this project, we aimed at implementing realistic audience behavior in a virtual fear of public speaking prototype, as realistic animations will enhance simulation fidelity. Up to now, data on such audience behavior is still scarce. We managed to close this research gap by conducting observation studies with real audiences. Findings show that real audiences tend to be very social. Further, our results show that a wide pool of realistic behaviors that can be simulated in order to increase simulation fidelity. We also derived realistic triggers for audience non-verbal behaviors that can serve as key elements for implementing seemingly interactive virtual audiences.

Finally, we tested an alpha-version of the prototype in a user study. The results of the study indicate that simulation fidelity does neither have an effect on presence nor on perceived realism, but a medium effect on anxiety experienced during a talk. The latter is a key prerequisite for effective fear of public speaking training. Still, the application might not have been realistic enough, given a simple alpha-version of the prototype, where only two models and only a small selection of behavior actions have been implemented. Although our findings challenge the role of presence and perceived realism as a prerequisite for anxiety, they highlight the importance of high simulation fidelity for designing and implementing effective IVEs.

Prospective development should aim to increase simulation realism (for example implement systems that monitor speakers' eye gaze and voice volume and adjust virtual audiences' behaviors automatically). Also, future studies should explore the interrelation of user factors and system characteristics in more detail, in order to efficiently implement high quality IVEs that are effective.

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