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Emotional Contagion in Collaborative Virtual Reality Learning Experiences: An eSports Approach

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Abstract
Emotional contagion is an intriguing subject in many academic fields, and it is also relevant in collaborative learning where learners share a physical or virtual space. We aimed at exploring the possibilities of motivating, fascinating, and experiential elements of virtual reality (VR) in a collaborative learning context, with a focus on emotional contagion. We adopted the eSports mode as a competency development strategy in collaborative learning, using VR to evaluate emotional contagion that is invoked between the presenters and spectators. For this purpose, we created a VR application (HHVR) that allows freshmen students to learn about the premises and academic life at a university. We then divided 43 adult participants into presenters ($N=9$) and spectators ($N=34$); the presenters experienced the HHVR application first-hand, whereas the spectators watched the experience through a monitor. We used a questionnaire and semi-structured interviews to measure what feelings of being — existential feelings that affect the way we react to the world — the participants experienced. The collected data were analyzed by Principal Component Analysis and qualitative data coding and the results revealed emotional contagion; the spectators who followed the presenters on a monitor showed similar emotional engagement with the presenters who used the application. In conclusion, the proposed eSports mode can be a useful pedagogical technique in the context of collaborative learning with VR, as it engages emotionally both the presenters and spectators. These findings can be helpful for designing emotionally engaging collaborative learning experiences with VR and for conducting group-based UX evaluations of VR applications.

Keywords User experience design · eSports · Virtual reality · Emotional engagement · Feelings of being · Emotional contagion · Collaborative learning

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1 Introduction

Students today use a variety of digital solutions and media types in their educational activities. Education can, therefore, be provided and students can be engaged through a variety of media, including games, social media, and other forms of entertainment, such as virtual reality (VR) simulations. Moreover, it is not uncommon for students to move to study at a university from other regions where they have different cultures, learning approaches, and learning environments. The adjustment process to a new environment can take time for freshmen. To address the gap, the study investigates the use of VR in making an adaptation of freshmen to a new environment more engaging and effective. In addition, we aim to assess the motivational factors that drive student engagement in the educational medium individually and collectively.

In this paper, we examine the use of VR technology in a collaborative and group-learning setting, mimicking an eSports event. We chose eSports as the theme because many students, being part of the "digital natives" generation, are familiar with it. An important characteristic of the eSports culture is the existence of large tournaments, which take place in sizable stadiums (Jenny et al., 2018), thereby offering a fascinating "rally experience" (Schütz, 2016) for the participants. Following and watching such events either in a co-located manner at a stadium or via digital streaming is a common practice among digital natives (Salo, 2017). Therefore, including similar experiential, motivational, and fascinating events (Rothwell & Shaffer, 2019) as a part of introductory studies for new students is a concept worth exploring.

VR technology offers the means to create a learning environment that enables learners to immerse themselves in rich augmented surroundings. Virtual models tend to replicate the real world using three-dimensional (3D) objects or videos (Huang et al., 2010). Moreover, VR enables versatile ways of using all five senses. It has been shown in a previous study that immersive VR increases students' engagement cognitively, behaviorally, and emotionally (Liu et al., 2020). These findings indicate that students have a high tendency to accept VR technology in classroom settings.

A Virtual Reality Learning Environment (VRLE) (Al-Amri et al., 2020) approach focuses on educational objectives and offers ubiquitous learning opportunities in multiple contexts that are unique to the learner and the learning content. A previous study demonstrated that VRLE creates easy cognition for participants, leading to a more efficient and effective learning experience (Dirin, 2020). These findings have mainly been obtained from individual VR application usage and not from group setups. This is possible because a VR experience typically involves highly individualized interaction between the user and the virtual environment in which the user is embedded. However, much of learning takes place in social surroundings and group settings. Furthermore, learning outcomes may also benefit from group settings (Enghag & Niedderer, 2008). As learners explore new concepts together, their understanding of the studied themes improves through this shared exploration. With this perspective, we explore the uses of VR technology in social learning surroundings—in the traditional classroom.

In this study, we investigate the application of VR technology to a classroom environment that is organized in a format of an eSports event. eSports events invoke emotions both among presenters and spectators (Abbasi et al., 2021). Understanding that emotions support and boost learning (Tan et al., 2021) we want to study how emotions experienced by the presenters can be shared among the whole classroom including the spectators following the presentation. An example of this setup is seen in Fig. 1, where a VR-supported classroom session in an eSports mode takes place at the beginning of studies for new students. One of the students uses the VR interaction devices and the others observe. The content of the session is an introduction to the campus premises and introductory practices for the beginning of new studies. Such an eSports approach supports constructive learning as in each session the participants are actively engaged in constructing knowledge in a group. In this study, we hypothesize that a VR-based instruction implemented using an eSports mode can help students develop competencies akin to traditional classroom teaching. Our specific focus is on the shared experiences and feelings among the presenters and spectator in a classroom setting. In other words, we aim at examining whether emotional contagion exists between the presenters and spectators. Specifically, we explore whether feelings of being (FoB) — existential feelings that affect the way we react to the world — can be transferred between presenters and spectators when experiencing an immersive VR contents in a shared situation.

Emotional contagion is a phenomenon often witnessed in the context of music, and it has been investigated from various perspectives. For instance, Garrido and Macritchie (2020) demonstrated that emotions can be contagious between the musician and spectator in a concert. Outside the domain of music, emotional contagion is induced via social media and by social bonding. An example by Xiong et al. (2018) shows that emotion propagation in social media depends upon community structures: in a small community, a leading figure can influence the mood of others to a relative degree. In social media settings, emotional contagion is carried often

Fig. 1 A collaborative learning session in eSports mode using VR

through different time zones and locations, between presenters and spectators, thus time and place do not constrain emotional contagion. Additionally, emotional contagion has also been demonstrated in the context of VR between the user and virtual characters (Volonte et al., 2021); however, to the best of our knowledge, our study is the first attempt to explore emotional contagion between presenters and spectator in a classroom setting based on the eSports mode.

2 Related research

2.1 Immersive VR and user's behavior

VR is a form of communication between the content creator, technology, and the user (Jerald & Marks, 2016). Robust VR applications relay the digital world to the user through stimuli or by tricking the brain into experiencing that the virtual world events and objects are real. Hence, a successful VR experience allows users to be immersed in an environment that does not exist. The immersive process happens by changing the way that the brain processes information, e.g., the user can fly across the space (Seedhouse, 2022) or be immersed in the world of cartoons. Research has additionally demonstrated that VR changes behavior; e.g., Slater (2009) demonstrates this fact with two groups of test users in a first-place illusion and the second group in a plausibility illusion. The results indicate that the participants responded realistically to virtual reality. Aligned with this study, Jones et al. (2016) demonstrated that VR impacts the relieving of chronic pain. VR has also resulted in positive attitudes from users. For example, Tussyadiah et al. (2018) showed that VR increases the feeling of enjoyment. Dobrowolski et al. (2014) explored the notion that VR can impact consumer attitudes towards brand preferences. Jerald and Marks (2016) recommended quantifying immersive VR applications based on matching the sensory input of VR matches with the correspondent in the real world. Furthermore, studies from Zakaria et al. (2020) and Lee et al. (2022) demonstrated that VR can be an efficient tool in an educational context, and the former showed that VR applications are convenient tools that engage students in their learning processes. Han (2020) also demonstrated that VR is an efficient tool in an educational context that is both engaging and gives the feeling of presence in addition to saving money and time. She has, however, put forward the suggestion that a lack of physical interaction is the main drawback of VR applications.

2.2 Measuring emotional arousal

Study on emotional arousal measurements falls into the field of affective computing (Cambria, 2016). VR can provide an immersive stimulus that impacts emotional arousal. Marín-Morales et al. (2018) demonstrated that the elicitation of various emotional states (e.g., high and low arousal) using neural and cardiac measurements through VR environments. Similarly, Felnhofer et al. (2015) showed that VR environments can elicit emotions, such as joy, sadness, boredom, anger, and anxiety. They randomly selected 120 students for one of the five VR scenarios, each presenting a certain emotion (joy, sadness, boredom, anger, and anxiety). This is one of the reasons why psychotherapists are interested in the use of VR applications in their treatment for, for example, anxiety disorders (Diemer et al., 2015). Similarly, Marín-Morales et al. (2019) compared the emotional invocation in real and VR environments. Their findings indicate that the brain reacts to emotional arousal in a similar fashion in both VR and real environments. This is why VR applications have been utilized in helping autistic children, as indicated by Lorenzo et al. (2016).

Different approaches have been proposed for measuring emotional arousal. Scherer (2005) categorized emotion measurement methods into three categories: (i) subjective measurements, which researchers utilize in forms such as questionnaires and self-reporting scales, and experiment samples; (ii) behavioral measurements in which the behavior of users is measured, e.g., with facial coding systems (Ekman & Friesen, 1971) or expert observations. Facial gestures and poses are used as measurements; for example, happiness can be associated with smiling; and (iii) physiological measurements, in which researchers use various sensors to measure emotions.

Kukkakorpi and Pantti (2021) identified VR elements that result in emotional engagement such as space to invoke character's emotions, places, and dialogues. Each of these elements impact on human sensory perceptions which results in emotional engagement. Similarly, Dubovi (2022) investigated how emotional engagement varies among learners in VR, and how emotions impact learning. For example, she suggested that anger results in decreased learning achievements. Related to this, Dirin et al. (2022) proposed a feelings of being (FoB) model for systematic UX design and measurement that addresses the user's emotional engagement with mobile applications over time. The model comprises 13 FoB (ownership, engagement, contribution, security, trust, adjustability, enjoyment, empowerment, effectiveness, frustration, excitement, gratification, and needs fulfilment) that are defined by Ratcliffe (2005) as existential feeling that affect the way we react to the world as well as our attitudes and dispositions to act.

2.3 Digital emotional contagion

People, and specifically students, spend extensive time with digital media, and are subjected to various emotions expressed by others or by avatars. The emotions expressed in digital media contents may impact users who consume the media, thereby triggering similar emotions in them; this process is called digital emotional contagion (Goldenberg & Gross, 2020). Emotional contagion in general refers to an automatic and unconscious transfer of emotions between people. The emotional exchange occurs through verbal or non-verbal leads; for example, by mimicking body expressions such as facial expressions (Zajonc, 1985). Cheshin et al. (2011) demonstrated that emotional contagion also occurs in virtual environments even if the communication is merely text-based. Their findings indicate that transferred emotions also change the behavior of persons who interact in the virtual environment, and even observers who witness the communication. Goldenberg and Gross (2020) also investigated which emotions have high exposure in online environments. Their findings indicate that some emotions, such as anger, spread faster than other emotions in social media. Furthermore, Kramer et al. (2014) showed through experimental evidence that emotions expressed on Facebook invoke similar emotions in others related Facebook users. Similarly, Rosenbusch et al. (2019) discovered that YouTube users also develop emotions as the spectator of video clips. In the context of education, the presenter's facial expressions in video lectures impact learners, as demonstrated by Wang et al. (2019). Their findings indicate that students' learning satisfaction is higher when there is a heightened level of positive instructor expressions than there would be in conventional or audio-only lectures. However, instructors' facial expressions do not impact the participant's short-term recall.

2.4 eSports events

Electronic sports, eSports, or competitive gaming (Wagner, 2006), has been a rising phenomenon around the world in recent years (Hollist, 2015), taking place largely in the digitized world. In recent decades, the popularity of eSports events has increased rapidly (Taylor, 2018). Nowadays tens of thousands of people gather up live at stadiums to watch different teams play video games in tournaments and to experience the intriguing atmosphere (Taylor, 2015).

The social aspect of eSports events appears to be important. Henricks (2006) investigates the social aspects of play from a sociological perspective, and remarks how playing is a social action. As one of the social extensions of gaming, spectatorship is a crucial part of eSports events. People follow the performance of eSports athletes either live at the scene or through streams over the internet (Taylor, 2015).

Sjöblom and Hamari (2017) investigated motivations for watching eSports. They found that escaping everyday life, acquiring knowledge about eSports, novelty, and the enjoyment of aggression were the main reasons for watching eSports. In this study, fresh and novel means for a brief break or escape from everyday school life that could act as a motivation. On a similar note, Cummings (2018) investigated the motivations for spectating eSports by physically attending eSports events. As this study features a live event, it is a comparable point of interest. They found that meta-narratives, excitement, and passion were the biggest motivators for spectating eSports events live. Specifically, excitement is relevant to this study, but there are perhaps elements of passion included. For example, in a school environment, a VR introduction could be not only a novel experience, but also an exciting one. To include a more exciting feature to the VR introduction, perhaps an element of competition (for example, a race to finish the course as fast as possible, or a challenge to find interesting collectibles or collect achievements that can be counted at the end of the tour) could be introduced to the VR experience.

2.5 Immersive and emotional VR experiences

Jerald (2016) recognized VR as a communication technology in which communication happens between the creator, the user, and the device. Furthermore, Jerald suggested that immersiveness in VR applications must have the following factors:

1. Extensiveness/engagement: the extent to which the VR application engages users through various senses such as hearing, seeing, or any other physical means as the user engages with the application in the real world.
2. Surroundings/involvement: the unique environments and the surroundings in which users interact with the application; for example, field of view, and imagery.
3. Intractability/empowerment: in which the VR application enables the user to interact with the world similar to how the user interacts with the real world.
4. Sensations/enjoyment: the match between what is seen or done in VR in comparison to the corresponding real-world experience.

Jerald (2016), however, did not explore which feelings result in user engagement to continue their use of the application. In this study, we pursue the extension of Jerald's findings by identifying the feelings that can be associated with VR applications' usage between presenters/users and the spectator. In the educational context, the applicability of VR has been abundantly investigated as indicated by Radianti et al.'s (2020) systematic literature review. Their findings indicate that most of the research on VR applications in educational contexts has been focused on the usability of the applications, and that VR learning outcomes have not been researched thoroughly so far. Furthermore, the list of articles that they have identified in their systematic literature review shows that none of the VR articles are shared as a group presentation – for example within the classroom – whereas we have experimented with this and discussed results within this article. Immersion, presence, and interactivity have been proven to be the main features of a VR application, e.g., by Servotte et al. (2020) but the factors that result in immersion have not been explored from an emotional engagement perspective.

2.6 VR in collaborative learning environments

Already in 2008, Monahan et al. (2008) recommended a model which utilized VR in a collaborative e-learning environment. In their solution, they developed a virtual learning environment system in which each student selected an avatar and interacted with others in a VR classroom. Students interacted with the system and each other either through mobile phones or through a web-based application. Aligned with this study, Thompson et al. (2018), proposed a theoretical framework as to how VR can be utilized in a team-working and collaborative learning process in which different participants learn data in both an immersive and non-immersive format. In another example, Lindblom et al. (2021) developed a multi-user VR system for mining education, which provided various interaction and content creation tools to educators and students. The system was designed to be used in a classroom setting whereby the teacher orchestrates a virtual, interactive tour to a mine during a regular class. A similar approach was proposed by Kalkofen et al. (2020) in the context of VR based on 360-degree videos for enriching mining education. Their system demonstrated innovative methods to make static 360-videos interactive while providing a synchronized presentation to multiple students sharing the same virtual space with their teacher.

VR in an educational context has been applied to achieve various objectives, such as improving the self-efficacy and user engagement (Chen & Hsu, 2020), improving the sense of the presence, and utilizing multisensory capabilities (such as visual, auditory, and tactile) in the learning process (Servotte et al., 2020). VR has been used to bring new forms of simulation experiences both for individual students and groups (Aebersold et al., 2020). Nonetheless, VR as an enabler technology in an educational context has proven to be efficient and effective for students in the learning process (Liu et al., 2020). Furthermore, Liu et al. (2020) and Rubio-Tamayo et al. (2017) have demonstrated that the immersive VR has a high level of usage and acceptance in the classroom, and most students enjoy using the VR application as an enhanced educational tool, as was investigated by Bogusevschi et al. (2020) and Freina and Ott (2015).

3 Research objective, questions and methods

The objective of this study is to investigate emotional contagion brought about by the usage of a VR application named HHVR in a classroom setting that mimics an eSports event. HHVR, which is described in detail in the next section, is a seven-stage application that allows users to explore the Pasila's campus at the Haaga-Helia University of Applied Sciences (HHUAS) in Helsinki, Finland. The evaluations of the application were carried out by the presenters and the spectators in a manner similar to eSports events. To reach the objective, we pursue answering the following research questions:

1. How are experiences shared in VR-supported co-located orientation studies in higher education? How is HHVR experience shared among the presenters and spectators?
2. What is the shared emotional experience, i.e., emotional contagion, between the presenters and spectators?

We conducted the experiment by a mixed-method post-test approach comprising qualitative and quantitative methods, which are explained in the following sections. The questionnaire and interview data were collected after the participants experienced the VR stimulus either as a presenter or spectator.

3.1 HHVR application

We developed the HHVR application with the help of the mLUX framework (Dirin & Nieminen, 2015) and based it on the data which we had gathered from a previously developed augmented reality (AR) application (Nguyen et al., 2018). The target users of the HHVR application were HHUAS freshmen and HHUAS visitors. The HHVR application enables the user to learn about the Pasila campus by browsing 360 views guided by a virtual character guide named Riitta. Additionally, Riitta, who was modelled based on a student advisor at HHUAS, tells relevant information about studying and student life at the HHUAS, and answers to frequently asked questions. Riitta and other virtual characters were designed to be personal and act naturally, as we aimed at avoiding the uncanny valley (Stein & Ohler, 2017) for the target users.

The virtual tour also contains a gamification element in form of a "finder" game. During the virtual tour, the user is asked to find cats that are scattered across the campus. This helps to engage users with the tour and to pay more attention to the details of the application. Fig. 2 presents a sample of the HHVR application screenshots including Riitta, the cat, and the graphical user interface (GUI).

In designing the application's graphical content, we used the Sung and Mayer's (2012) study on the effect of graphics in online learning. The graphics match the intended goals of learning as defined for instructive graphics. The 360-degree images of the actual environment, such as the instructive presentation of each of the campus' services and functions, are based on the actual experience that the user would have in the real environment. For example, descriptions of the services are done by a representative virtual character. Furthermore, we use the emotionally seductive content to invoke users' emotions during the application's usage, using events such as the appearance of the cat, or by mimicking closely the behavior of the educational advisor of the real environment. For the decorative graphics we only used the aspects of the real environment. For example, the virtual board used is identical to the university board used in the real environment.

The HHVR application collects contextual data such as nationality and age from users through Unity Analytics, based on which the university may generate a report on user behavior with the application. However, users may reject any contextual data that the application collects. Each choice that is made by the user is recorded and

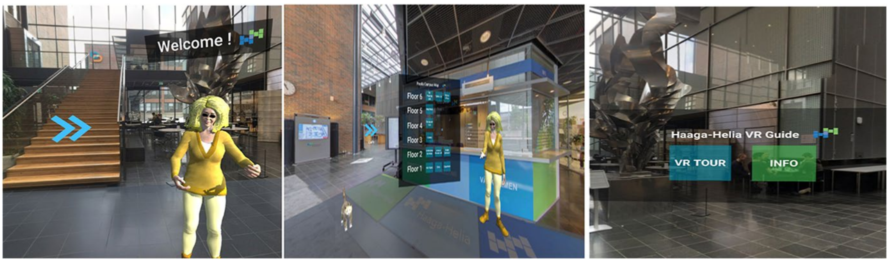


Fig. 2 Sample of HHVR screenshots

can be interpreted for further personalization of educational offerings. Furthermore, the analysis can be used for marketing, educational exports, and other service development purposes.

The HHVR application's visual system is shown through the display of the Oculus Quest VR head-mounted display in a first-person view. Each scene in the application is based on 360-degree images, wherein the user can naturally turn around by moving their head. The user can interact with the application's GUI with the help of Oculus VR controllers. The primary index finger button is used for most of the interactions with the GUI. Furthermore, we use the.mp3 audio format for all narrated descriptions and presentations given by the Riitta virtual character and other characters in the application. The C# programming language was used for scripting the Unity Analytics for gathering data. The gathered data are presented in the Unity dashboard section on the Unity website.

3.2 Participants

Although the HHVR application is primarily aimed at freshmen students and visitors to explore the university premises, we evaluated it among university students and staff members to collect data from adults of different ages and occupations (students, teachers, administration, marketing). The HHVR application evaluation was conducted during February and March 2020 at HHUAS. The evaluations were set up in two different courses: 1. User Experience Design (N = 23), and 2. Digital Service Design (N = 10). The students in the User Experience Design class were in their second semester and the students in the Digital Service Design class were in their third semester. We picked these groups since they were still relatively new at the university and had gained enough experience to share further needs and requirements with us. Besides these experiments, we also set up additional test sessions with HHUAS staff (N = 10) on various occasions during the mentioned periods. We considered students and staff members as adult participants rather than two distinct groups formed by their roles at the university. Therefore, we did not investigate the differences between the students and staff members in this study. Table 1 summarizes the demographics of the participants and the applied data collection methods.

Two of the student participants did not fill in the questionnaire despite participating in the classroom. Because the questionnaire was collected anonymously, it was not possible to identify who did not want to submit it.

Table 1 Summary of the data collection methods and participants of the VRHH application evaluation

Data Collection Methods	Gender			Age			
	Male	Female	Prefer Not to Say	Mean	Std. dev	Min	Max
Interview	4	5	0	36.4	15.44	20	50+
Questionnaire	25	15	3	32.5	7.15	19	50+

3.3 Data collection

We conducted the first experiment in the User Experience Design class. Five students voluntarily agreed to carry out the test (i.e., the presenters). The rest of the students (i.e., the spectators) observed the experimentation through a large monitor in the classroom. We conducted thereafter semi-structured interviews with the presenters (one-to-one interviews) and the spectators (group discussion). We asked them about their feelings on the test they had carried out or witnessed. We recorded all the interview sessions with mobile phones for further analysis. Prior to conducting the test, we collected informed consents from all participants for collecting data, taking pictures, recording the test session, and recording the interview.

A questionnaire (Appendix A) was administered immediately after the experiment using Google Forms. The first part of the questionnaire consisted of the user's basic information, such as first name, age, gender, and the user's previous experience with VR applications. The second part of the questionnaire focused on the emotional aspects of the experience. In particular, we applied the subjective measurement technique for measuring emotional engagement using the FoB model that were identified in previous research (Dirin et al., 2022), including values, trust, excitement, empowerment, effectiveness, security, freedom, and ownership. The data were collected using an initial questionnaire and conducting a semi-structured interviews. The second part of the questionnaire had 12 questions on a five-point Likert scale.

After the test, we asked voluntary presenters and spectators to share their opinions in a semi-structured interview. We prepared a set of predefined interview questions (Appendix B) that were used during the interview sessions with both presenters and spectators. The interview questions were prepared to provide more in-depth answers to complement the questionnaire data. All interviews were recorded with the participants' signed consents. A question was asked by the interviewer, which was promptly answered by the interviewee. In order to gain deeper understanding on the given answer, the interviewer often followed up with related questions. Each interview session lasted 15–20 min depending on the interviewee's responses.

The data collection process was carried out in a similar manner in the Digital Service Design course and with the HHUAS staff. Figure 3 presents photographs of the experiment in a User Experience Design classroom. For collecting rich data and

Fig. 3 Experiment in progress

diverse sampling, we utilized the purposive sampling (Robinson, 2014) approach. Additionally, we conducted interviews with both novice and advanced presenters and the spectators after each test session. All interviews were organized in English and recorded only after receiving consent from the participants.

3.4 Data analysis

To analyze the questionnaire data, we transferred the data from Google Forms to Microsoft Excel, and for an in-depth investigation, we applied basic descriptive statistics such as the mean, standard deviation, and Fisher's Exact, to the gathered data. In order to explore the data for further remarks, we also applied the principal component analysis (PCA) which is an appropriate technique for reducing the dimensions of the datasets whilst increasing the interpretability of the data (Jolliffe & Cadima, 2016). Abdi and Williams (2010) pointed out that the goal of PCA is to minimize the dimensions of the dataset to obtain and yield the highest curve variability. We utilized SIMCA (2022) to analyze the data and calculate the PCA. The details of the analysis are presented in Appendix C.

The recorded interview data were first transcribed. Then, all quotes of interest were systematically transformed into feelings. Furthermore, to assess the frequencies of the responses, we employed the QDA Miner Lite software (Lewis & Maas, 2007). The identification of feelings from the interview transcripts was based on the exact words or synonyms used by the participants to describe their feelings. Furthermore, we identified the undertones of the terms such as love, fun, hate, and engagement that the participants described during the interviews. The identified feelings were used as keywords to define the frequencies of each keyword.

4 Results

4.1 Questionnaire results

Tables 2 and 3 present the mean ages of the spectators and presenters, and their prior experience with VR, respectively, whereas Appendix A presents the questionnaire that the participants were asked to respond to.

Table 4 presents the results of our analysis of the data gathered from the presenters and spectators through the questionnaire. For each question, the table presents the mean, standard deviation, and the Fisher's Exact values. In the following, we

Table 2 Mean ages of the spectators and presenters, and their prior VR experience

	Spectators		Presenters	
Mean Age	34.7		26.5	
	Female	Male	Female	Male
Proportion	32.4%	67.6%	62.5%	37.5%

Table 3 Prior VR experience of the spectators and presenters

	Spectators				Presenters			
	None	Once	Twice	More	None	Once	Twice	More
Proportion	32.4%	17.6%	38.2%	11.8%	50%	12.5%	25%	12.5%

Table 4 Statistical analysis of the questionnaire data

Questions	Presenters		Spectators		Fisher's Exact
	Mean	Std	Mean	Std	
Q1. Trust	3.62	0.95	3.63	0.92	0.036
Q2. Excitement	3.47	0.96	4.25	1.035	0.002
Q3. Frustration	2.38	1.10	2.125	1.13	0.044
Q4. Empowerment	2.97	0.97	3.875	0.64	0.004
Q5. Enjoyment	3.38	0.92	4.5	0.76	0.001
Q6. Effectiveness	3.65	0.92	3.75	1.04	0.053
Q7. Gratification	3.18	0.97	3.625	0.74	0.016
Q8. Engagement	3.56	1.21	4	0.76	0.002
Q9. Adjustability	2.97	1.14	3.375	1.41	0.009
Q10. Ownership	2.62	1.02	3.5	0.76	0.003
Q11. Contribution	3.24	0.92	3.625	0.52	0.055
Q12. Security	3.65	0.81	3.625	0.92	0.049

present a summary of the questionnaire analysis and the details of the analysis are available in Appendix C.

The Fisher's Exact statistic results presented in Table 4 are not sufficient to conclude the differences between the spectators and presenters. Therefore, we chose PCA as a complementary method to apply to our dataset since PCA supports datasets with multi variances. Although PCA has been generally suggested to be used for larger sample sizes (Streiner, 1994), Shaukat et al. (2016) showed that it may be used with similar sample sizes than ours. Using PCA, we reduced the dimensions of the data since our dataset includes multiple variance directions and the data is much dispersed. Our secondary goal was to explore how PCA can applied in this type of study. However, the analysis of the data and the discussion are not based on the PCA analysis only; the Fisher's Exact values along with the interview data have a central role. In Fig. 4, the eigenvalues indicate how much variance we have in the data. The principal component is the eigenvector which has the greatest eigenvalue.

Figure 5 presents the results of a PCA between spectators and presenters, which are based on the eigenvectors shown in Fig. 4. The correlations among the spectators' data indicate that sample 19 has the least correlations with the other samples. Furthermore, samples 36 and 40 among the presenters have the least correlations with other samples of the presenters. The correlations of all participants to feelings are presented in the loading (variables) plots in Figs. 5 and 6. The results indicate that frustration has a stronger negative correlation in comparison with other feelings

	Trust	Excitement	Frustration	Empowerment	Enjoyment	Q6.Effect	Gratification	Engaement	Adjustability	OwnerShip	Contribution	Security	(Audiance)	(Presenter)
Q1. Trust	1	0.358473	0.00792014	0.274367	0.329978	0.327551	0.310745	0.46223	0.301818	0.345108	0.328412	0.643906	-0.0031228	0.0031228
Q2.Excitement		1	0.0513186	0.574952	0.59811	0.329184	0.467567	0.596595	0.421481	0.460677	0.609307	0.243448	-0.306404	0.306404
Q3.Frustration			1	-0.0455128	-0.097404	-0.175646	-0.0868627	-0.097195	-0.143443	0.108469	-0.0341079	0.270794	0.0932435	-0.0932435
Q4.Empowerment				1	0.591213	0.376452	0.756068	0.461404	0.561126	0.542757	0.521033	0.247548	-0.367875	0.367875
Q5.Enjoyment					1	0.486938	0.45847	0.364913	0.369505	0.41755	0.574766	0.328168	-0.449044	0.449044
Q6.Effect						1	0.410555	0.321573	0.213711	0.0256338	0.312345	0.319975	-0.0440714	0.0440714
Q7. Gratification							1	0.520898	0.622668	0.389357	0.376551	0.187625	-0.189925	0.189925
Q8.Engaement								1	0.479325	0.349212	0.506407	0.380258	-0.153291	0.153291
Q9.Adjustability									1	0.449107	0.552066	0.417772	-0.135247	0.135247
Q10.OwnerShip										1	0.65119	0.341562	-0.342143	0.342143
Q11.Contribution											1	0.534578	-0.17819	0.17819
Q12.Security												1	0.010677	-0.010677
$M7.DA(Audiance)													1	-1
$M7.DA(Presenter)														1

Fig. 4 Eigenvectors of the feelings, the spectators, and the presenters. The eigenvectors present the relation between different feelings with a nonzero vector

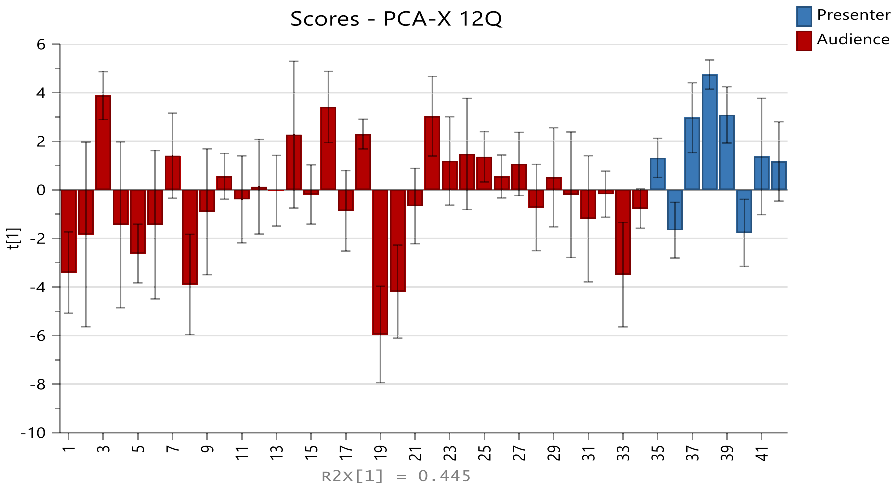


Fig. 5 PCA results of the spectators' and presenters' questionnaire responses

for both groups. In contrast, empowerment and excitement have the highest correlation among both groups.

Figure 5 depicts the distributions of the participants among the spectators and presenters based on Fig. 4. The individual distributions and the associated feelings are arranged into a quadrics function graph. This is also aligned with Q3 in Figs. 6 and 7.

As shown in Fig. 7, we are investigating two-dimensional data comprising the presenters and the spectators. Axes indicate the direction where the most variations occur. Fig. 4 and Fig. 7 depict the variances of our datasets, respectively. Furthermore, we measured how the spectators and presenters have shared feelings. For example, Fig. 7 shows how positive feelings (variance), such as ownership, empowerment, and excitement, are grouped, and thereby form the first principal component.

Fig. 8 presents the results of linear discriminant analysis (LDA) of the spectators and presenters. As indicated and aligned with Fig. 7, enjoyment, empowerment,

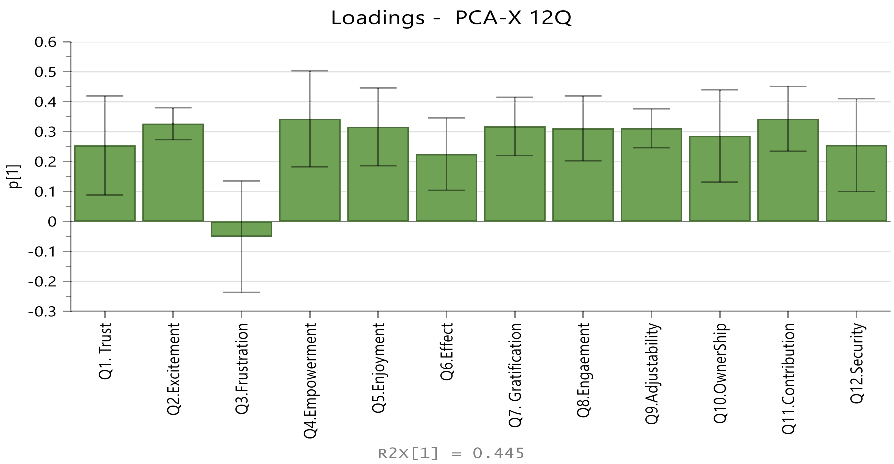


Fig. 6 Distributions of the feelings based on the PCA analysis

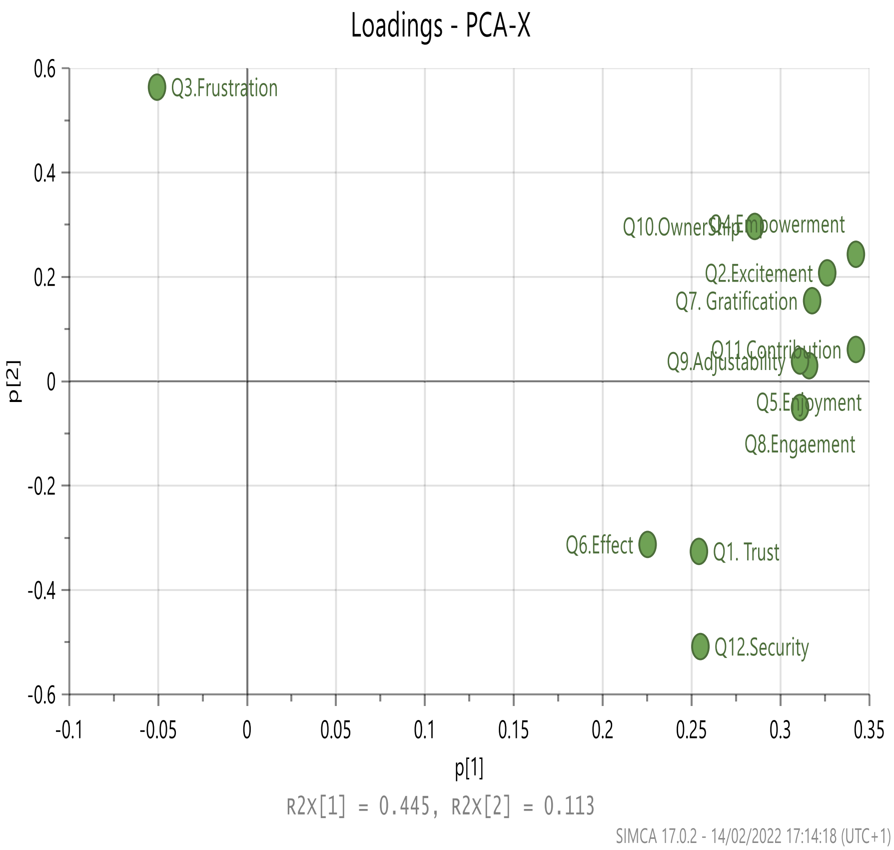


Fig. 7 Directions of the feelings (variance)

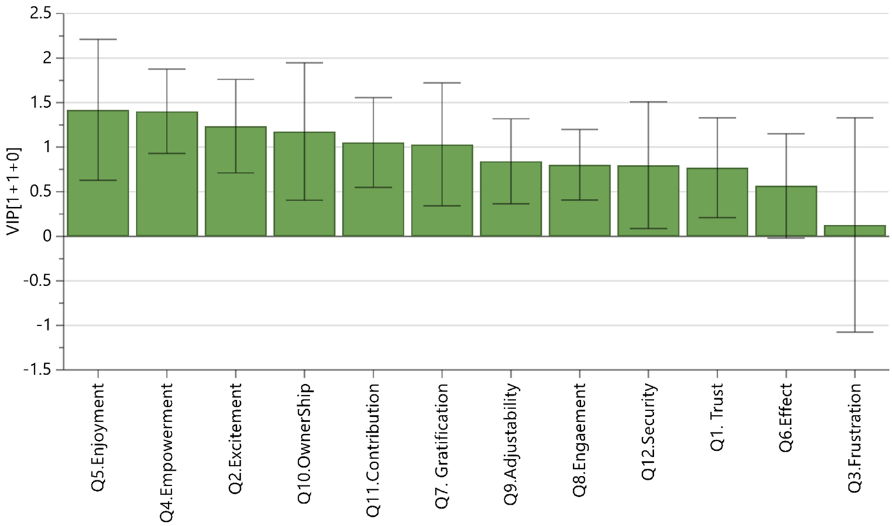


Fig. 8 Linear discriminant analysis of the feelings between the spectators and presenters

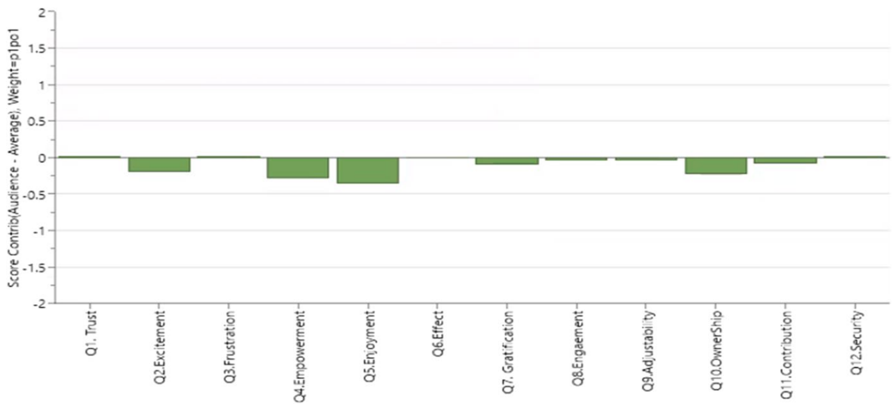


Fig. 9 The feelings (FoB) that the spectators experienced during the experiment

and excitement have the highest correlations between the spectators and presenters, whereas the feeling of frustration has the least correlation between these two groups.

The covariance values in Fig. 8 are aligned with Fig. 4, thus indicating that all feelings except frustration correlated between the presenters and spectators. Figure 8 shows that the jackknife error variance is high; this is due to the fact that the sample size (N = 43) was not significant. The feelings experienced by the spectators and presenters are depicted Fig. 9 and Fig. 10, respectively. In contrast to the spectators' feelings in Figure 9, the presenters reported higher levels of feelings, particularly with regard to excitement, empowerment, enjoyment, and ownership.

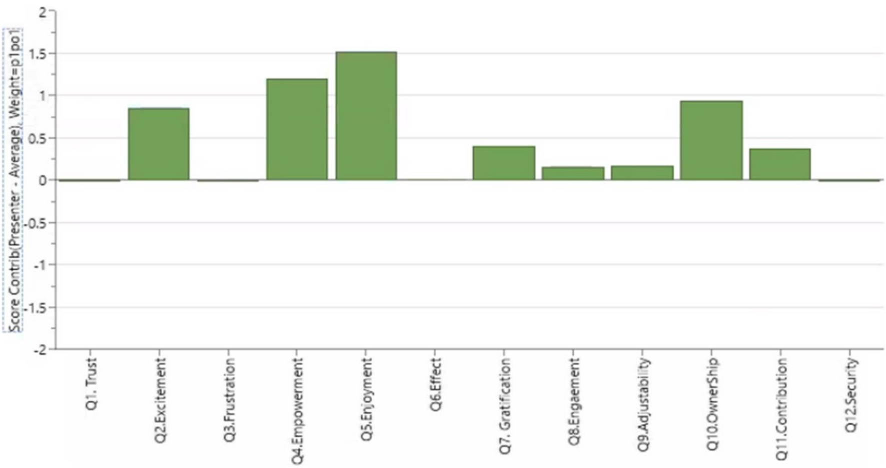


Fig. 10 The feelings (FoB) that the presenters experienced during the experiment

4.2 Interview results

In Table 5, we summarize the feelings that the presenters and the spectators reported during the interviews along with sample answers from the interviewees. We applied the QDA Miner Lite application to do the qualitative data analysis and to pick the sample feelings that have the highest frequencies. The texts in the interview transcript were interpreted according to the exact words or synonyms used by the participants to describe their feelings. Further, we identified the undertones of terms such as love, fun, hate, and engagement that the participants described during the interviews. The coding (qualitative categorizing) of the transcribed interviews revealed that the spectators and presenters alike expressed feelings of trust, engagement, fun, security, and excitement. This result is aligned with the questionnaire results given in the previous section. However, this study did not measure the intensity of the feelings experienced by the presenters and spectators.

Based on the interview results with both groups, we can conclude that the presenters felt more immersed than the spectators due to the use of the HMD. However, there still remains work to be done in increasing the immersion of the VR experience based on the recorded 360-degree materials, as the following comment from a presenter suggests: "…you could improve the immersion. For example, when you are standing in the lobby, the background could be more dynamic, now it is static. The sound effect could be improved as well, like when you turn your head the voice should change accordingly." (male, 30). Nevertheless, both groups found the VR content engaging and memorable. For example, a spectator's comment "*I still remember the app which I have seen only once*" (male, 32) is aligned with the following statements from two presenters: "*It was really good and engaging. When you talked to me, I did not even notice what you said, I was engaging with the game.*" (male, 22) and "*the app gives a real image, serves an actual purpose,*

Table 5 Results of the analysis of the interview transcripts

No	Feelings	Spectators	Presenters	% of interviewees
1	Excitement	"All the phrases that represent excitement, e.g., I still remember what I saw on the screen. It was exciting to follow." (Male, 26)	"I think it was exciting to see the places as they really are." (Female, 45)	33.3%
2	Fun and joy	"It was interesting, something new, and fun to find the hidden item." (Female, 24)	"It was simple, no need to have fear and full of fun." (Female, 48)	55.6%
3	Trust	"There were known people's avatars which made me to trust them." (Female, 40)	"Yes, I trust the content, I know who has made the content." (Male, 33)	66.7%
4	Engagement	"It gives a deep information, more accurate information and visual." (Female, 24)	"It was really good and engaging, when you talked with me I have not even noticed what you said, I was engaging with the game. It was good." (Male 30)	100%
6	Security and safety	"HHVR is already publicly available there so no need to be afraid." (Female, 40)	"No, since you were beside me and know the table where I test." (Female, 45)	33.3%
7	Frustration	-	"The heights of the building and the rooms were big so I felt that everything was bigger than the reality." (Female, 27)	11.1%

and gives you a good memory" (female, 29). The PCA of the two variances and the direction of the variations is shown in Fig. 8. Based on the PCA results, frustration had the least correlation between the spectators and presenters. The feeling of frustration was raised by one presenter when we asked her during the interview what was frustrating in the experience: "*the heights of the building and the rooms were big so I felt that everything was bigger than the reality*" (female, 27). In contrast, excitement, gratification, contribution, and ownership demonstrated the most correlation between the two groups whereas trust, security, and effectiveness had less correlations between the two groups. This is consistent with the interviews; for example, some of the interviewed participants were not concerned about the trust and security of the applications, since they did not save any personal information or records, for example: "*I trust the application as I do not share any personal information*" (spectator, male, 51) and "*I haven't had any security concerns since you were beside me and I know the table where I tested it*" (presenter, female, 52). In addition, during the interviews, some participants expressed the opinion that this application was less effective since they knew everything about the premises that this application presented.

5 Discussion

5.1 Contributions and impacts

What users perceive in a VR application is not real, but their perception system in the brain constructs the scene as though it were genuine. Therefore, VR experiences aim to trick the user's senses to forget the real environment and to immerse oneself in the virtual world. In this process, also emotional arousal and behavioral changes can occur which are the results of the HHVR experience. In this study, we investigated whether the feelings (FoB) that are experienced by the presenters are contagious to the spectators who witness the experiment. In other words, we investigated whether the presenters and spectators experience similar perceptual illusions that led to emotional engagement.

Our study demonstrates that feelings (FoB) can be contagious in a context where a presenter shares a VR application with spectators comprising classmates and colleagues. Our results suggest that enjoyment, empowerment, excitement, ownership, contribution, gratification, adjustability, trust, and engagement were shared and correlated between the presenters and spectators. Consequently, these feelings (FoB) were positively influenced by these groups. Conversely, the feeling of frustration appeared reversed between the presenters and spectators.

Perhaps the positive feelings (FoB) such as enjoyment, excitement, empowerment, and ownership are more contagious than negative ones such as frustration. This information can be useful for designing future collaborative learning environments and activities; they can be designed to elicit positive feelings (FoB) among learners, which, through emotional contagion, can spread. In broader settings, the outcomes of this study can benefit educators, user experience designers, and practitioners. In particular, those educators who plan to utilize VR technologies in their course offerings and have challenges with providing HMD devices for all students can benefit from our experiences and results.

This study involved 43 adult participants who were students and staff members of a university in Finland and who either experienced the HHVR immersive VR application first-hand (presenters) or through large screens (spectators). We hypothesize that the results can be applicable to adults in general who use an immersive VR application based on content recorded with 360-degree camera and including virtual characters that interact with the user. However, different FoB may emerge as emotional engagement is a subjective phenomenon. Similarly, we expect that emotion contagion can happen in immersive VR experiences that are delivered via eSports mode involving presents and spectators, much like in competitive eSports and sports where fans celebrate or mourn with their team. Additionally, the proposed eSports mode can be beneficial in assessing UX of applications collectively in a group of users.

5.2 VR in collaborative learning

VR technology is a unique intervention that can be used to construct immersive learning experiences for learners and help gain positive outcomes. For example, Shi et al. (2022) revealed that immersive game-based VR environments can increase student achievement and motivation for learning math among adolescents compared to a conventional learning method. But to what extent can VR support different learning experiences? Dale (1969) categorized the cone of experience into three main groups: (i) direct, wherein learning occurs as a result of doing; (ii) iconic experiences, in which learning happens through observation; and (iii) learning through abstractions meaning the symbolic experiences. VR as an enabler technology provides all these three experiences for learners. However, Dale did not define the interrelations of these categories, nor the emotional involvement in each learning approach; our study explored the emotional contagion, thus showing the importance of considering feelings in the design of collaborative learning scenarios utilizing VR equipment.

Collaborative learning environments in general have been shown to possess pedagogical and motivational affordances, such as engagement, communication, resource sharing, monitoring, regulation, and community building, that make them attractive to teachers at all levels of education (Jeong & Hmelo-Silver, 2016). In a recent study, Nakata et al. (2022) confirmed that socially-sharing regulations are a key factor in a positive classroom environment as students influence and motivate each other. Further, Fernandez-Perez and Martin-Rojas (2022) revealed that in collaborative learning, empathy, self-awareness, self-regulation, and social skills affect positively student performance. Although collaborative learning in VR environments has been studied relatively little, Zheng et al. (2018) discovered that VR-based collaborative learning also possesses similar affordances in the areas of social interaction, resource sharing, and knowledge construction. Moreover, VR has recently gained popularity as a collaboration medium. For example, Burova et al. (2022) described a case of utilizing VR for development and documentation in the area of industrial collaboration. Moreover, Kalkofen et al. (2020) and Lindblom et al. (2021) proposed collaborative VR learning environments with rich interaction capabilities based on 360-videos and 3D environments, respectively, related to mining education. However, to the best of our knowledge, previous systems and experiments on VR-based collaborative learning have not considered the aspects of emotional engagement or emotional contagion, thus indicating a need for our study.

We evaluated the use of VR applications in an eSports mode as a collaborative learning setup. During our experiment, we were primarily concerned with emotional contagion. As the results demonstrated, the spectators and presenters experienced, to some extent, similar feelings during the experiment, thus showing possible emotion contagion between the groups. These results also indicate that the proposed eSports mode based on immersive VR can be useful for achieving emotional engagement among presenter and spectator students in a classroom-based learning environment. Overall, VR applications are getting their momentum among students of higher education; a previous study showed that the number of higher education students at a university in Finland who have experienced VR headsets usage has increased from (10%) to almost (50%) since 2017 (Dirin et al., 2019). This is an indication that student populations are becoming more familiar with VR, thus making VR a potential medium to offer education at higher education institutes, especially for immersive learning purposes (Horst & Dörner, 2019). This is an attractive trend, as a prior study by Makransky et al. (2020) has shown that immersive VR is an efficient and effective way to increase students' interests and aspirations toward science education.

5.3 Evaluating UX through eSports mode

Evaluations of VR applications are associated with some challenges, such as cybersickness (Chong et al., 2018), head rotational speed (Upenik & Ebrahimi, 2017), accuracy of user input (Yang et al., 2019), and emotional engagement. According to our literature review, VR UX evaluations typically occur individually, not as a group with a single head-mounted device. Herscher et al. (2019) and Wienrich et al. (2018) conducted collective spectator evaluations but each participant had their own devices during the experiments. In contrast, our study contributes to the body of research on collective VR UX measurement using a single head-mounted device with group of spectators. In our eSports mode setup, the presenter explored the VR content, and the spectators followed the test on a large monitor. The results of the evaluation suggest that the spectators experienced almost similar feelings (FoB) to the presenters as indicated in Figs. 7 and 8. An implication of this is that the eSports mode of experimentation demonstrated in our study can be adopted as yet another UX measuring approach for VR applications in which the UX evaluation occurs in a group setting. This is particularly true for user studies that require a large number of participants but have limited resources (devices, time, and financial affordability). We believe this study is an initiative to design and develop a conceptual method and approach to measure collective VR applications with a single head mounted device.

In our experiment, we have been able to measure the positive and negative feelings (FoB) of the presenters and spectators. However, we did not propose or apply any psychometric measurement for presenters' and spectators' feelings (FoB) since we considered it as out of the scope of the study.

5.4 On emotional contagion

In the following, we present a detailed discussion on selected feelings (included in the feelings of being model, the FoB) that were evaluated in our study. The feelings included in this section are chosen for the impact they have on both presenters and spectators.

5.4.1 Trust

Trust has been considered to be a fundamental factor in digital technology usage. Kim and Peterson (2017) demonstrate that trust in technology impacts the user's interaction with the technology, which is an important decision factor for users. Salanitri (2018) explores the factors that impact trust in VR, such as technology acceptance, usability, and felt presence. Their findings indicate that usability has an indirect on trust. In the context of education, trust has a significant impact on students and the way they interact with technology (Bahmanziari, 2003). Mayer (2017) recommends using relevant animations and visuals to reinforce the audio, which results in constructing credibility and trust in multimedia-based learning. We applied this recommendation, especially when using a familiar virtual character and animations whenever an interaction is required by the application. As a matter of fact, we sought to engage spectators in a similar way as presenters during the learning process via relevant animations, graphics, and voice-over. The animations and graphics are based on real imagery and the audio voices are all of the real people with variations made on the accent, just as in the real-life of the university. In our experiment, as shown in Fig. 6, both the presenters and spectators showed a feeling of trust. The interview analysis indicated that 66.7% of the participants did not have any issues with trust. The other 33.3% did not show any concerns about trust since they did not share any private information through the application, as the following quotes demonstrate: "*There were known people's avatars which made me trust them.*" (spectator, female, 40) or "*Yes, I trust the content, I know who has made the content*" (presenter, male, 33). This issue is also reflected in the questionnaire as indicated in Fig. 7. Constructing trust in VR has been investigated from various perspectives, such as the impact of the sense of presence on trust (Salanitri et al., 2016), and the effects of cybersickness on trust (Seiler et al., 2022).

5.4.2 Excitement

Reeve et al. (1986) demonstrated that excitement has a significant impact on the user's intrinsic motivation. Figures 6, 7 and 8 indicate that both spectators and presenters became excited with the HHVR application. The interview results confirmed this: "*I still remember what I saw on the screen, it was exciting to follow*" (spectator, male, 49) and "*I think it was exciting to see the places as they really are*" (spectator, male, 26). Our findings on excitement are aligned with the findings of Ito et al. (2018), who revealed that immersive experiences in VR can result in the feeling of excitement; however, our study also showed excitement among the spectators. Furthermore, Radianti et al. (2020) and Parong and Mayer (2018) also identified that VR technology within lecture sessions makes lectures more exciting than traditional lecture sessions. The interviews and questionnaire analysis of our study indicated that the spectators became excited almost at the same levels as the presenters. This is the result of the emotional contagion of the impact itself or the live performance presented on the monitors.

5.4.3 Enjoyment

The questionnaire analysis illustrated that the spectators and the presenters equally enjoyed the HHVR application, as shown in Figs. 6, 7, and 8; this demonstrates that the spectators and presenters enjoyed the experiments. The level of enjoyment varied between these two samples but it is clear that the presenters' enjoyment and spectators' enjoyment do correlate, as shown also in the interview excerpts in Table 5. The frequencies of the repeated words from the QDA Miner Lite analysis indicated that fun and enjoyment were expressed by more than 55.6% of the presenters and spectators. It is vital to identify the factors that result in enjoyment. This is specifically important for application designers and educators for developing a supportive and engaging collaborative learning solution keeping in mind that enjoyment in VR is can be driven by various factors. For example, Li and Chen (2019) identified that ease of use and usefulness have a positive impact on the enjoyment of VR applications. Aligned with this, Shafer et al. (2019) revealed that sensory conflict reflects enjoyment in VR applications.

We believe that the gamification aspect of the HHVR application impacted the feeling of enjoyment among the presenters and spectators. This was evident in interview quotes such as: "*I like the cat and it was very good, it was really fun*" (presenter, female, 22) and "[it was] *nice to see real people's avatar and the cat*" (spectator, female, 45). Similarly, Cohen et al. (2016) demonstrated that enjoyment is contagious for TV co-viewing. Their finding showed that social context is the reason for contagious emotional transfers during entertainment experiences. Further, Parong and Mayer (2018) found that having VR in the classroom makes learners happier and creates excitement. Their findings show that VR provides in general more positive feelings than, for example, simple slideshows. Nevertheless, research on the shared enjoyment in VR classrooms is vague, and we have not yet come across any significant research on this issue.

5.4.4 Engagement

The invoked engagement among the spectators, as shown in Figs. 6, 7, and 8, can be interpreted as they were influenced by the presenters' engagement. This is aligned with Torrente et al.'s (2013) findings, which suggested that positive emotional impacts are shared among teams. Akman and Cakir (2020) demonstrated that VR engages students with learning experiences and thereby can impact students' academic achievements more effectively. Aligned with this study, Irshad and Perkis (2020) showed that narrative-based VR applications more effectively and efficiently engaged users, and invoke emotional responses in users. The feeling of engagement can be expressed in different forms by spectators. For example, Romney and Johnson (2020) showed that in social media engagement is expressed as a "like" or as "comments". In our experiment, the engagement was also indicated through the interviews with the spectators and presenters. Examples of this include when the presenters played with the cat: "*It was really good and engaging, when you talked with me, I did not even notice what you said, I was engaging with the game. It was good."* (presenter, male, 30), and the behavior of the Riitta virtual character that matches the behavior of her real-world model's appearance and voice: "*Riitta was looking more like herself in reality and less like a matrix movie character!*" (spectator, female, 24). Human-like virtual characters thus impacted the participants' interaction, trust, and closeness. This was also highlighted by George et al. (2018) who suggested that human-like virtual characters have a significant impact on users since users feel a sense of togetherness. This was supported by the participants: *"[They] give a real image and serve an actual purpose. Gives you a good memory"* (presenter, male, 30), and: *"Riitta makes the application more humanistic"* (spectator, female, 42). This is yet another proof of what Mayer (2009) proposed: "People learn better when narration is spoken in a human voice rather than in machine voice., p.242".

Our findings are linked to previous research (Mousas et al., 2018) that found that virtual agents need to be trustworthy so that users feel comfortable buying products. They proposed a model in which a trustworthy agent needs to have two factors – emotions and knowledge – which results in a high-level of trust in the users. Furthermore, Volante et al. (2016) demonstrated that the virtual human appearance can affect emotional reactions, as well as interpersonal training, and the perception of personality and social characteristics. In another study (Van Pinxteren et al., 2020) showed that using human-like agents along with certain communication behaviors have a significant positive impact on the intention to use.

5.4.5 Security

Figure 6 indicates that the spectators and presenters valued security. However, as indicated by Fig. 7, the HHVR application did not invoke the feeling of security among the spectators and presenters. This is possibly because they did not express concerns about security since they were not required to share any data or any private information. This is also aligned with the interview answers shown in Table 5. Cherdantseva and Hilton (2013) defined security as the protecting of elements, e.g., confidentiality, integrity, and availability of a system from intruders. Spiegel (2018) argued that three main concerns are associated with VR application usage. First, the psychological impact, which results in depersonalizing as well as derealization interferences. Second, the physiological impact, in which the user may ignore the presence of being in one's own body. Third, the security concerns which are the results of misused and unauthorized processing of personal data. The latter may lead to manipulations and threaten the emotion, belief, and behavior of the users. In our experiments, the participants' main concerns were on the data integrity of the application. Therefore, as they were not sharing any data, they had little concerns to express.

5.4.6 Empowerment

The feeling of empowerment enables the user to use their full capacity to achieve the tasks and allows the user to push their boundaries. As indicated in Figs. 6, 7 and 8, both the spectators and presenters felt empowered by the HHVR application as much as they enjoy using or observing the application. This issue was also reflected in the interviews: "*I think this is the best ways to learn things that it is not possible otherwise, like I never been in emotion lab in real life*" (spectator, female, 48). Riva et al. (2009) explored the claim that VR is a recommended technology for personally empowering learners, where learners can act and perform without having a feeling of threat. In the health sector, VR has been applied for various empowering purposes, such as motor-cognitive neuro-rehabilitation (Perez-Marcos et al., 2018) and to help patients with stress management (Pallavicini et al., 2016).

5.5 Effects and recommendations for collaborative learning

The use of eSports mode and VR in a collaborative classroom-based learning setting bears some novelty as we have yet come to find another similar study. Based on our experiences in running the experiment in this setup, we identified several effects, as shown in Table 6, that the combination of eSports mode and VR has on collaborative learning. Additionally, Table 7 presents our experience-based practical recommendations for using the eSports mode and VR in collaborative learning scenarios in higher education. These recommendations can be of use to researchers and practitioners working in the area of collaborative learning.

5.6 Limitations

The main challenges in this study related to the small sample size and discrete data that made continuous analysis infeasible. We acknowledge that PCA analysis may

Table 6 Effects of using the eSports mode and VR for collaborative learning

Category	Effects
Learning and teaching	The eSports mode is applicable for large classroom sizes, especially in contexts where visual presentation results in better learning
Engagement evaluation	The eSports mode is a potential approach to measure the students' engagement in education, and how they feel about the topic, teaching and learning
Learning Experience Design	The eSports mode is a new approach of teaching and learning that digital generations can adopt as an alternative to traditional classroom-based education
Team work	Our experiences with the eSports mode demonstrated that it can facilitate team work through in-depth discussions after the VR experience. For example, the role of virtual characters and the gamification resulted in extensive discussion between the presenters and spectators
Constructing mental models	Using a VR application in eSports mode for collaborative learning demonstrated to be efficient both for the presenters and spectators. This is an initial approach to construct a mental model for applying new technologies in educational settings
Overcome Device Constraints	Many students cannot afford to purchase VR headsets because they are not cheap. Consequently, this study showed that device limitations are not an obstacle to the use of this technology in a group setting

not be the most suited based on the nature of the data; however, we pursued to gain insights onto different aspects of our data through the conducted PCA analysis. Although Streiner (1994) suggested that the minimum number of participants for PCA is 100 or 5 times the number of variables, Shaukat et al. (2016) showed that a sample size of 40 is sufficient to achieve stable eigenvalues and eigenvectors in PCA. In future studies with relatively small sample sizes, the use of partial least squares (PLS) might be an option to address this issue and explore findings in more detail. Another limitation is that the numbers of presenters (9) and spectators (34) were not identical; hence the analysis is not based on samples of equal sizes. There were also differences in the average ages between the presenters and spectators. To achieve common ground in our analysis, we used a negative logarithm. These differences do not appear to have a direct impact on the results. Furthermore, we do not have enough evidence to conclude that learners' emotional engagement also contributes to their learning processes. The recorded emotional engagement may also be the result of the experiment setup which did not follow the learners' existing mental model of a conventional classroom. Another limitation is that the study was conducted with a group of adults using a single VR application. Therefore, the results cannot be applied to other VR applications and other age groups (e.g. children, older adults) without further study. Finally, the data was collected using a self-reporting questionnaire and interviews. Although these subjective methods accepted and used in the field (Scherer, 2005), they also contain potential bias. To get more reliable and objective results, we recommend conduct similar experiments with physiological

Table 7 Practical recommendations for using the eSports mode in educational context based on our experiment

Category	Recommendation	Justification
Presenters	Presenters should be volunteers who have previous experiences with VR headsets, or join an onboarding session before the actual class commences. Being a presenter is not recommended if the student is prone to cybersickness	To reduce the likelihood of cybersickness during the experiment and to become familiar with using the VR devices
Spectators	The eSports mode is mainly applicable for group learning to engagement more efficiently. Therefore, the spectators are open to all participants	The maximum group that we experimented with was 40 and had no challenges. Our results suggested that although all group sizes demonstrated some level of emotional contagion, smaller groups seemed to have a stronger degree of emotional contagion
Presenter-Spectator Ratio	One presenter for 10–15 spectators	We recommend an optimal size for the spectators to be 10–15, as demonstrated with our experiment with the staff. With a small size, the spectators can become more easily engaged in reflections and discussions
Session Length	It is recommended that VR applications be used in 15–20-min timeframes (chapters). This is an ideal time for spectators and presenters. The engagement between spectators and presenters becomes more efficient when there is a short break between chapters	The recommended length of a VR session depends on the context where we need to apply VR. Our experiment took ten minutes for each chapter
Dedicated project	The eSports mode is especially well-suited for small-scale projects where the group size is up to five people	Our experiment with small group (staff) demonstrated that the eSports mode results in higher user engagement
Competition	We recommend including a competitive aspect in the eSports mode because it can engage both spectators and presenter more effectively, as shown in eSports tournaments	To gain a higher score may increase the sense of competition among the participants and lead to more intense emotional engagement
Context of Use of the Application	The eSports mode is especially is well-suited for pedagogical situations where practical real-world experimentations are not feasible, e.g., space visiting or mining	For example, space travel, or experimenting in nature is not often feasible by students so the proposed eSports mode with VR is an appropriate approach

sensors (e.g. electroencephalogram, galvanic skin response, and heart rate variability) that are widely used in emotion recognition research (Dzedzickis et al., 2020) combined with expert observations.

6 Conclusion

In this study, we demonstrated that feelings (FoB) are contagious between presenters of a VR application and the spectators who witness the use of the VR application. However, the experienced FoB varied between the presenters and spectators. Furthermore, the gamification feature of the application engaged the presenters with the application, and the human-like virtual character invoked togetherness and a familiar environment both for the presenters and spectators.

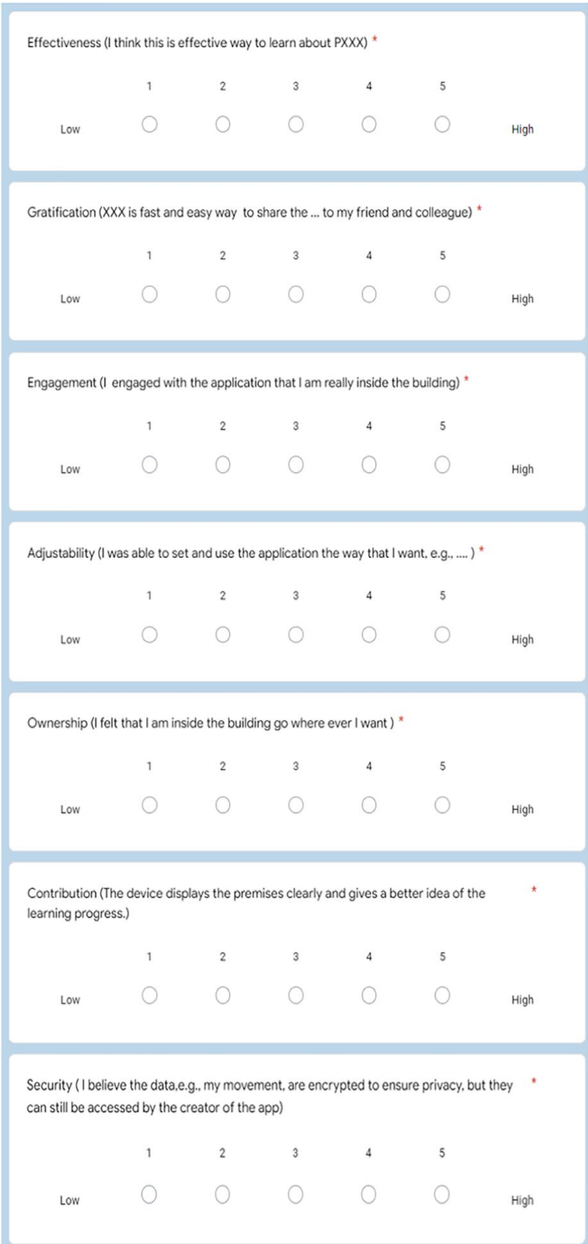
The usage of VR applications has increased in recent years. This development is rooted in technological advancement, which makes VR application development accessible and affordable. Furthermore, affordable prices of VR devices such as head-mounted displays have made VR popular among students. The main objective of this study was to explore the factors that help engage the presenter and the spectator emotionally with the application. To the best of our knowledge, this study is the first to empirically investigate the role of immersive VR in emotional contagion. The experiment shows that both the presenters and spectators developed similar emotional engagement regarding excitement, enjoyment, security, and trust. Therefore, the results show that FoBcan be contagious in the context of immersive VR delivered through eSports mode. Further, our outcomes are aligned with Parong and Mayer's (2018) findings that individual learning through immersive VR provides more positive feelings.

The emotional contagion occurred between the presenters and spectators in almost all FoB that we assessed. It is possible that many of the participants experienced the eSports mode for the first time. Unlike the coherence principle (Mayer & Mayer, 2012), which indicates that people learn when extraneous is excluded, this study demonstrates that VR in a group setting can engage both the presenters and spectators, and therefore emotional contagion may occur in the classroom. However, as this study was scoped to involve only adult participants and a single HHVR application, the results cannot be generalized to other applications and age groups.

For future work, we aim to enable the user to personalize the virtual characters and evaluate the impact of personalization on emotional contagion. Furthermore, we want to assess to what extent a pet-like virtual character can be involved with users without impacting the user's learning process. We also seek to validate these results by conducting further experiments with different age groups and VR applications. Finally, we plan to study whether emotional contagion on FoB can also happen in the context of multi-user VR applications that remove the barrier of shared physical location.

Appendix A: Questionnaire

https://docs.google.com/forms/d/e/1FAIpQLSdWGn_NiGmkUOUyckBa7Iryewot8J26iUqZ-N6oCxIFJgtCIQ/viewform



Effectiveness (I think this is effective way to learn about PXXX) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Gratification (XXX is fast and easy way to share the ... to my friend and colleague) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Engagement (I engaged with the application that I am really inside the building) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Adjustability (I was able to set and use the application the way that I want, e.g., ...) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Ownership (I felt that I am inside the building go where ever I want) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Contribution (The device displays the premises clearly and gives a better idea of the learning progress.) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Security (I believe the data,e.g., my movement, are encrypted to ensure privacy, but they can still be accessed by the creator of the app) *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Appendix B: Semi-structured interview questions

1. What was the most important experience for you?
2. What is your first experience on VR devices?
3. What were the exciting things for you in this experiment?
4. Do you think this would excite and will be interesting for freshmen?
5. Would you like customize the application according to your own preferences?
6. Does this application cause you any concerns about trust?
7. Are you interested in a human-like or animal-like avatars in the HHVR application? Why?
8. Was it fun and did it make you to continue using?
9. Do you think it is a secure app? do you have any concerns from the security or safety perspective?
10. Please give three positive things about the application:
11. Please give three negative things about the application:

Appendix C: Detailed questionnaire data analysis

Descriptive statistics

	Mean Pres	Std. dev	Mean Aud	Std. dev	Mean All	Std. dev
Q1. Trust	3.625	0.916125	3.61765	0.95393	3.61905	0.935802
Q2. Excitement	4.25	1.0351	3.47059	0.960912	3.61905	1.01097
Q3. Frustration	2.125	1.12599	2.38235	1.10137	2.33333	1.09693
Q4. Empowerment	3.875	0.64087	2.97059	0.968763	3.14286	0.977089
Q5. Enjoyment	4.5	0.755929	3.38235	0.921616	3.59524	0.989198
Q6. Effect	3.75	1.0351	3.64706	0.917254	3.66667	0.928326
Q7. Gratification	3.625	0.744024	3.17647	0.968303	3.2619	0.938591
Q8. Engagement	4	0.755929	3.55882	1.21084	3.64286	1.14384
Q9. Adjustability	3.375	1.40789	2.97059	1.14111	3.04762	1.18841
Q10. OwnerShip	3.5	0.755929	2.61765	1.01548	2.78571	1.02495
Q11. Contribution	3.625	0.517549	3.23529	0.923065	3.30952	0.869205
Q12. Security	3.64286	0.821107	3.625	0.916125	3.64286	0.821107

Correlation matrices

Presenters

	1	2	3	4	5	6	7	8	9	10	11	12	13
1		Trust	Excitement	Frustration	.Empowerment	Enjoyment	)6.Effect	Gratification	Engaement	Adjustability	OwnerShip	ntribution	Security
2	Q1. Trust	1	0.414284	-0.363531	0.882034	0.515711	0.941554	0.602557	0.618853	0.789159	0.515711	0.564933	0.829787
3	Q2.Excitement		1	-0.643494	0.699897	0.912871	0.333333	0.510113	0.547723	0.416622	0.547723	0.733333	0.564933
4	Q3.Frustration			1	-0.569161	-0.419591	-0.337068	-0.277098	-0.335673	-0.30414	-0.587427	-0.888635	0.778995
5	Q4.Empowerment				1	0.73721	0.807573	0.486854	0.589768	0.692696	0.73721	0.699897	0.882034
6	Q5.Enjoyment					1	0.365148	0.635001	0.5	0.60404	0.5	0.547723	0.515711
7	Q6.Effect						1	0.417365	0.547723	0.563664	0.365148	0.6	0.790906
8	Q7. Gratification							1	0.762001	0.698943	0.127	0.324617	0.392972
9	Q8.Engaement								1	0.402694	0.25	0.365148	0.412569
10	Q9.Adjustability									1	0.60404	0.416622	0.6784
11	Q10.OwnerShip										1	0.547723	0.721995
12	Q11.Contribution											1	0.86623
13	Q12.Security												1

Spectators

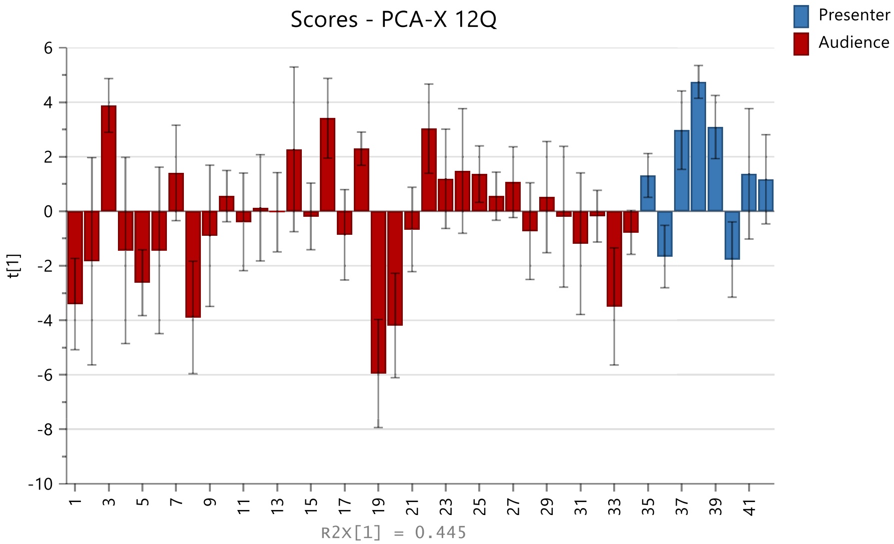
	1	2	3	4	5	6	7	8	9	10	11	12	13
1		Trust	Excitement	.Frustration	Empowerment	.Enjoyment	.Effect	Gratification	.Engaement	Adjustability	.OwnerShip	ribution	Security
2	Q1. Trust	1	0.367535	0.08568	0.216998	0.343669	187421	0.2721	0.452942	0.184223	0.345026	0.311752	0.602841
3	Q2.Excitement		1	0.25433	0.503607	0.475024	331671	0.429131	0.600556	0.399908	0.376314	0.588828	0.180452
4	Q3.Frustration			1	0.0676615	).000878042	132335	-0.0367719	-0.051461	-0.087227	0.270149	.0876682	0.149467
5	Q4.Empowerment				1	0.488144	328983	0.780998	0.427771	0.547432	0.450273	0.482394	0.178989
6	Q5.Enjoyment					1	558783	0.397492	0.318672	0.29916	0.29046	0.567837	0.347713
7	Q6.Effect						1	0.413431	0.2921	0.105587	-0.0516703	0.280006	0.193826
8	Q7. Gratification							1	0.481946	0.608189	0.37888	0.358976	0.158673
9	Q8.Engaement								1	0.494752	0.326909	0.502376	0.391548
10	Q9.Adjustability									1	0.408416	0.582149	0.348151
11	Q10.OwnerShip										1	0.648468	0.309089
12	Q11.Contribution											1	0.518372
13	Q12.Security												1

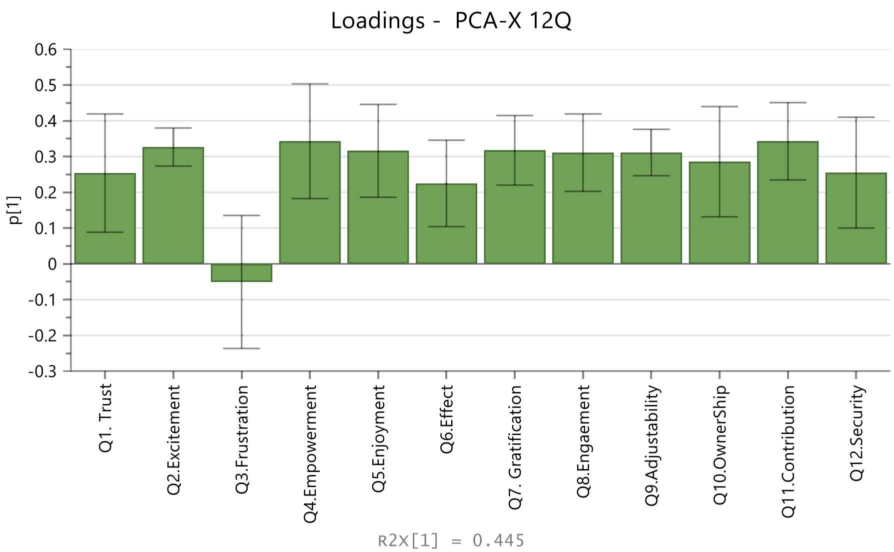
All

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		Trust	Excitement	Frustration	Empowerment	Enjoyment	Q6.Effect	Gratification	Engaement	Adjustability	.OwnerShip	Contribution	Security	(Audiance)	(Presenter)
2	Q1. Trust	1	0.358473	0.00792014	0.274367	0.329978	0.327551	0.310745	0.46223	0.301818	0.345108	0.328412	0.643906	-0.0031228	0.0031228
3	Q2.Excitement		1	0.0513186	0.574952	0.59811	0.329184	0.467567	0.596595	0.421481	0.460677	0.609307	0.243448	-0.306404	0.306404
4	Q3.Frustration			1	-0.0455128	-0.097404	-0.175646	-0.0868627	-0.097195	-0.143443	0.108469	-0.0341079	0.270794	0.0932435	-0.0932435
5	Q4.Empowerment				1	0.591213	0.376452	0.756068	0.461404	0.561126	0.542757	0.521033	0.247548	-0.367875	0.367875
6	Q5.Enjoyment					1	0.486938	0.45847	0.364913	0.369505	0.41755	0.574766	0.328168	-0.449044	0.449044
7	Q6.Effect						1	0.410555	0.321573	0.213711	0.0256338	0.312345	0.319975	-0.0440714	0.0440714
8	Q7. Gratification							1	0.520898	0.622668	0.389357	0.376551	0.187625	-0.189925	0.189925
9	Q8.Engaement								1	0.479325	0.349212	0.506407	0.380258	-0.153291	0.153291
10	Q9.Adjustability									1	0.449107	0.552066	0.417772	-0.135247	0.135247
11	Q10.OwnerShip										1	0.65119	0.341562	-0.342143	0.342143
12	Q11.Contribution											1	0.534578	-0.17819	0.17819
13	Q12.Security												1	0.010677	-0.010677
14	$M7.DA(Audiance)													1	-1
15	$M7.DA(Presenter)														1

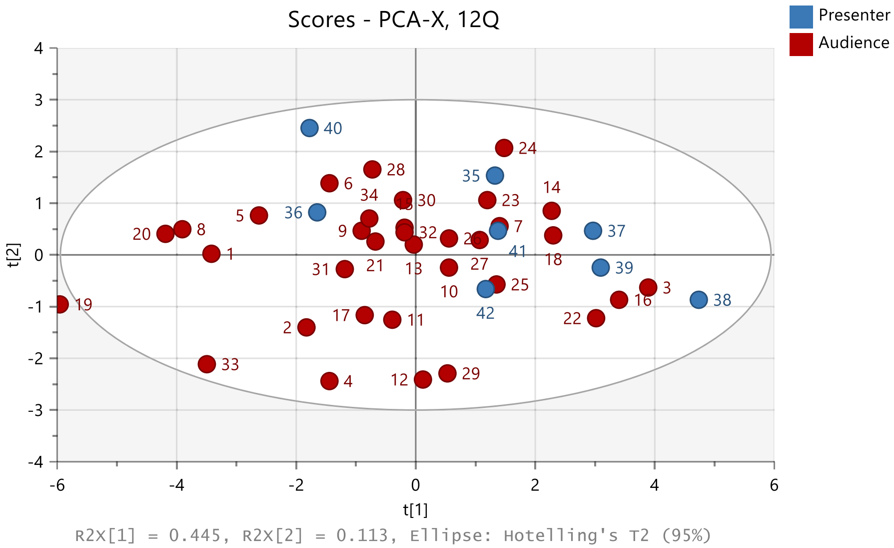
Principal component analysis

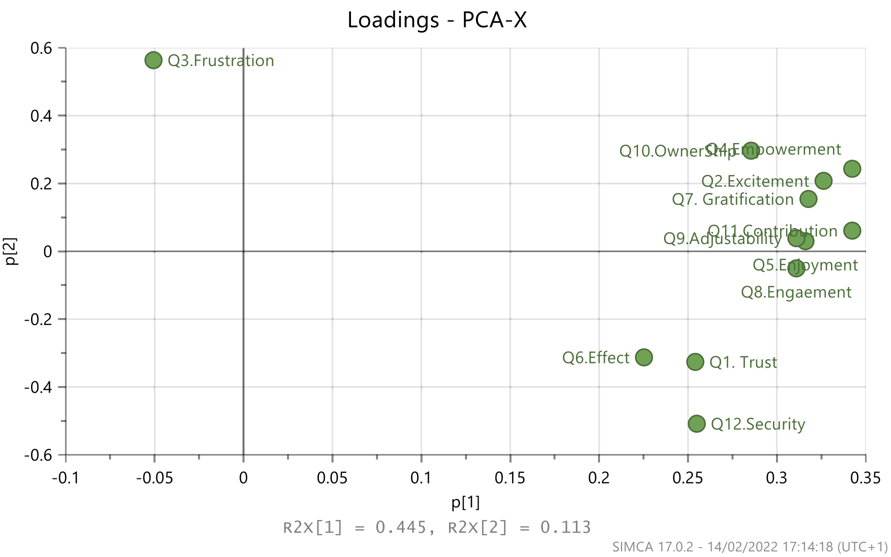
The first principal component Scores (Observation) and Loading (Variables) plots for all individuals.





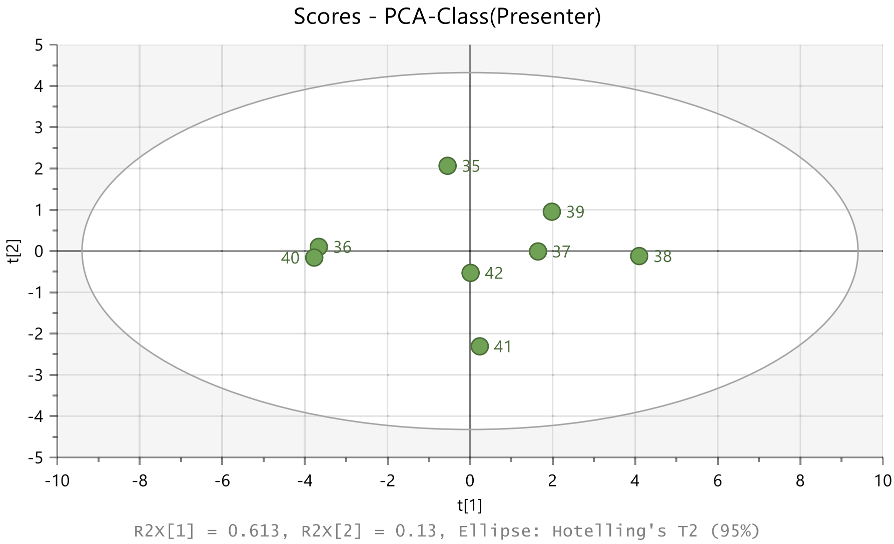
The second principal component versus the first principal component Score and Loading plots. PC1 explains 44.5% and PC2 explains 11.3% of the variations in all 42 individuals.

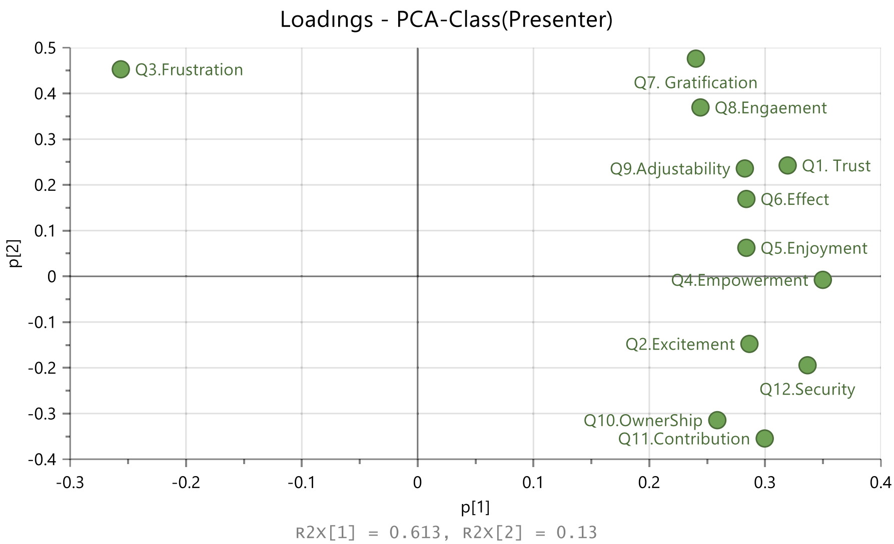




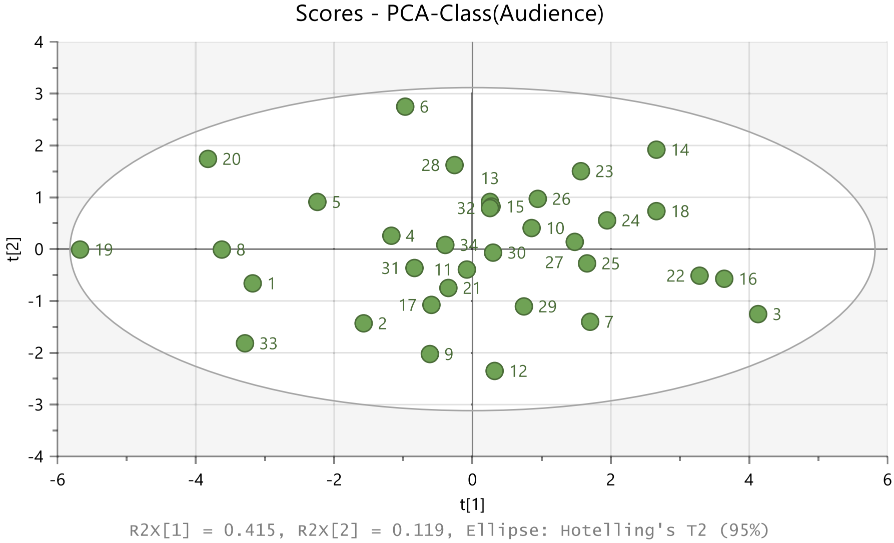
PC1 explains 61% and PC2 explains 13% of variations, in the presenters group (N=9).

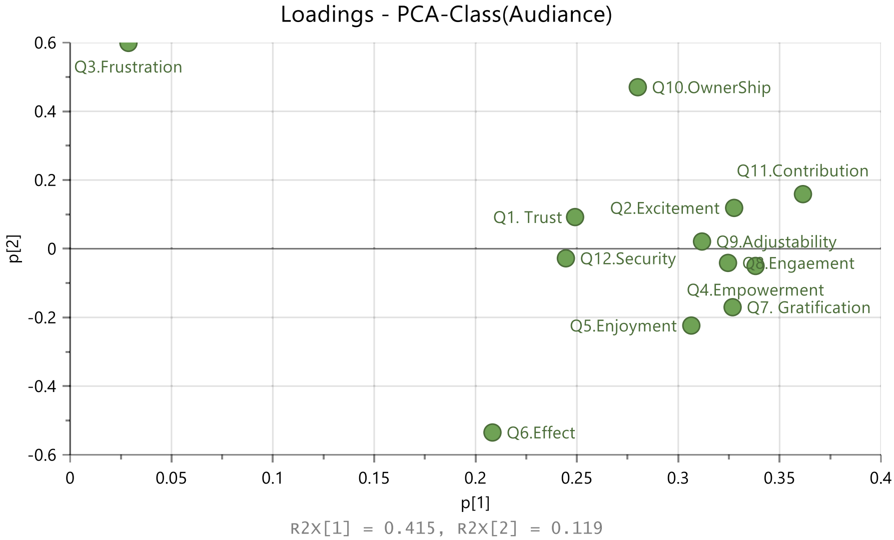
PC1 explains 61% and PC2 explains 13% of variations, in the presenters group (N=9).



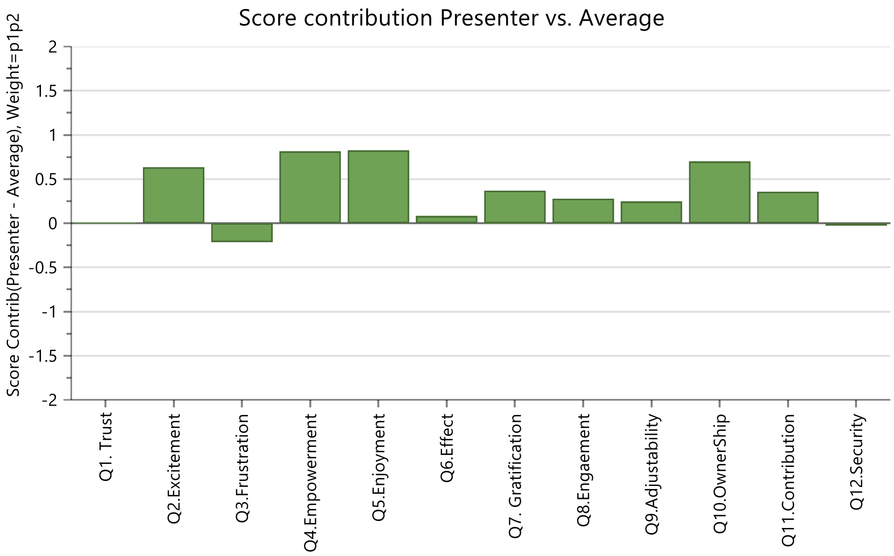


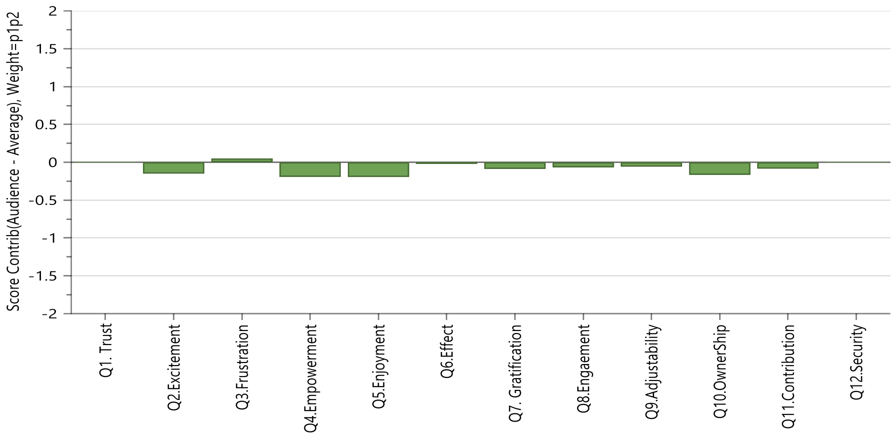
PC1 explains 41.5% and PC2 explains 11.9% of variations, in the spectators group (N = 34).

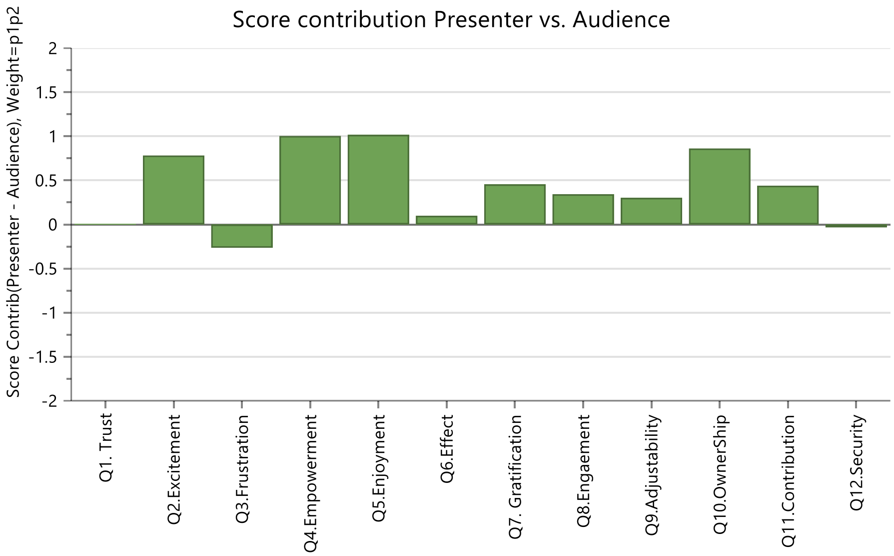




Score contributions for presenters and spectators

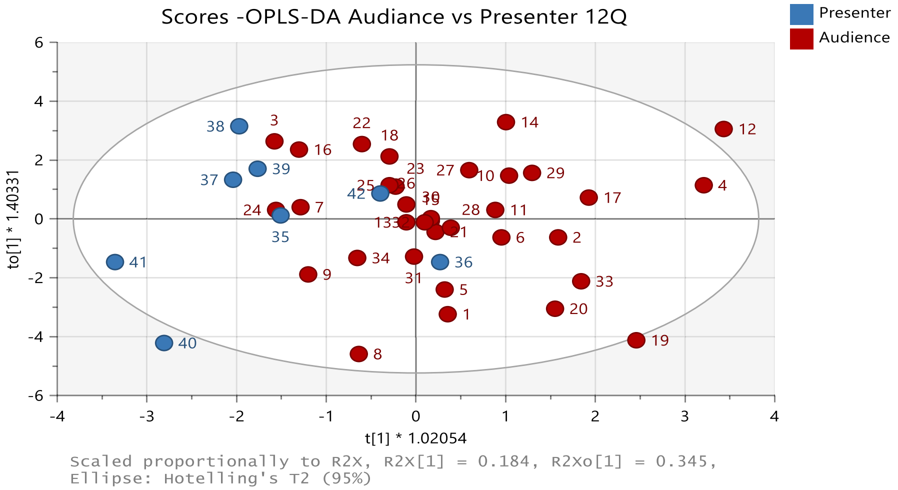


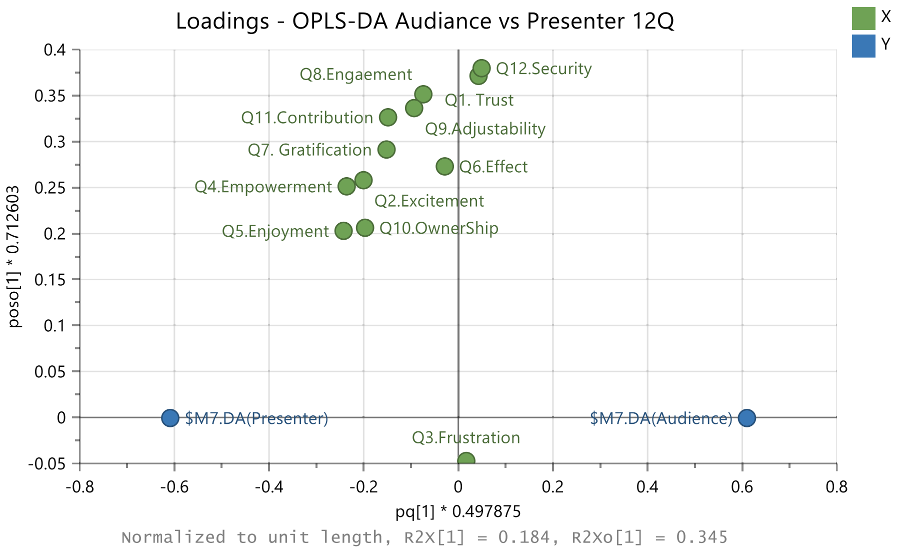


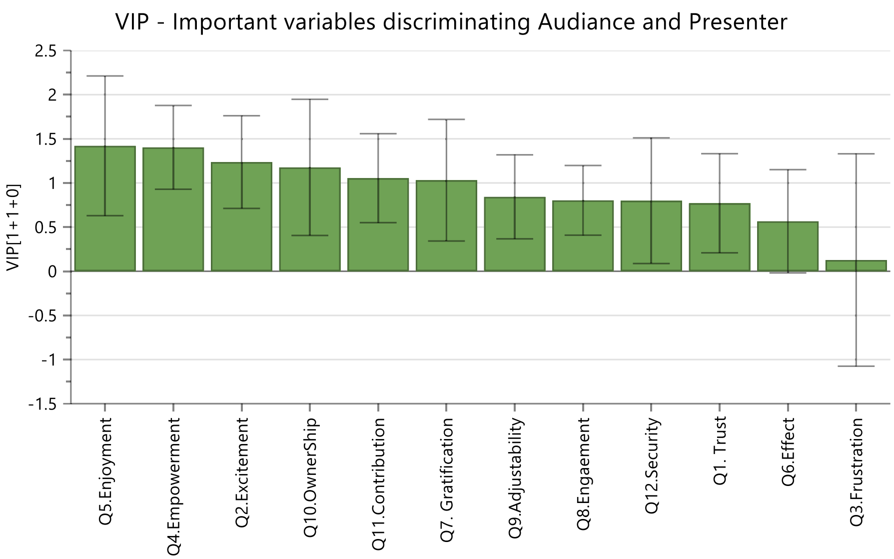


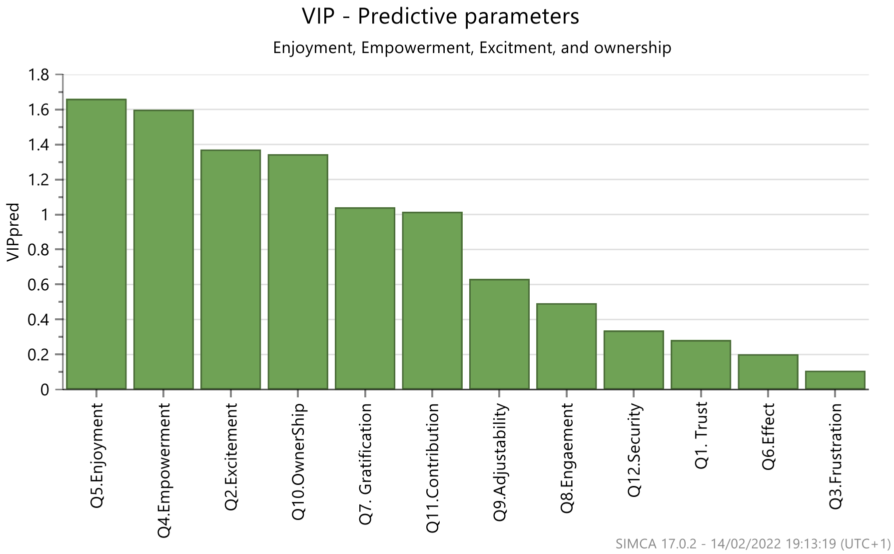
Discriminant analysis

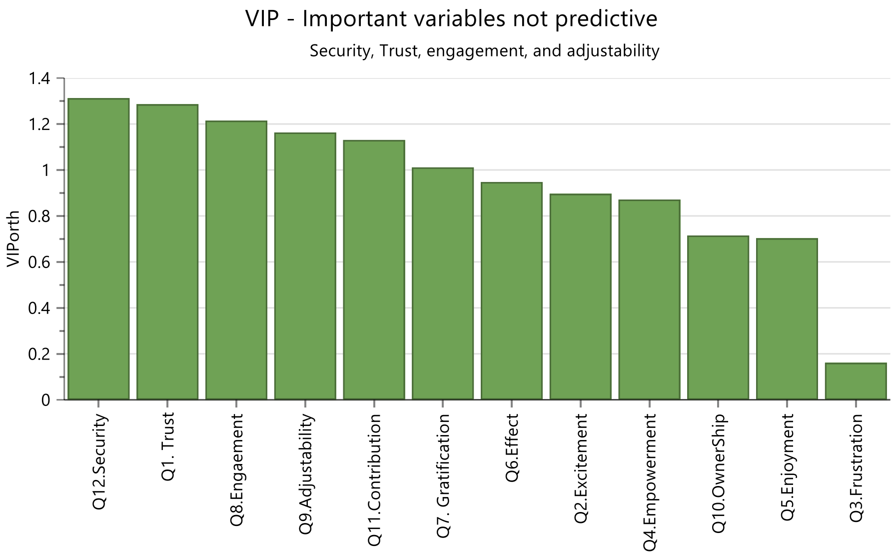
The discriminant analysis results between the presenter and spectator groups show information about 18.4% of the variations that are related to this difference and 34.5% of the variations that are orthogonal to the differences (information about the variables that are important for variation but are not predictive).




Loadings - OPLS-DA Audiance vs Presenter 12Q
X
Y
Q12.Security
Q8.Engagement
Q1. Trust
Q11.Contribution
Q9.Adjustability
Q7. Gratification
Q6.Effect
Q4.Empowerment
Q2.Excitement
Q5.Enjoyment
Q10.OwnerShip
$M7.DA(Presenter)
$M7.DA(Audience)
Q3.Frustration
poso[1] * 0.712603
pq[1] * 0.497875
Normalized to unit length, R2X[1] = 0.184, R2Xo[1] = 0.345

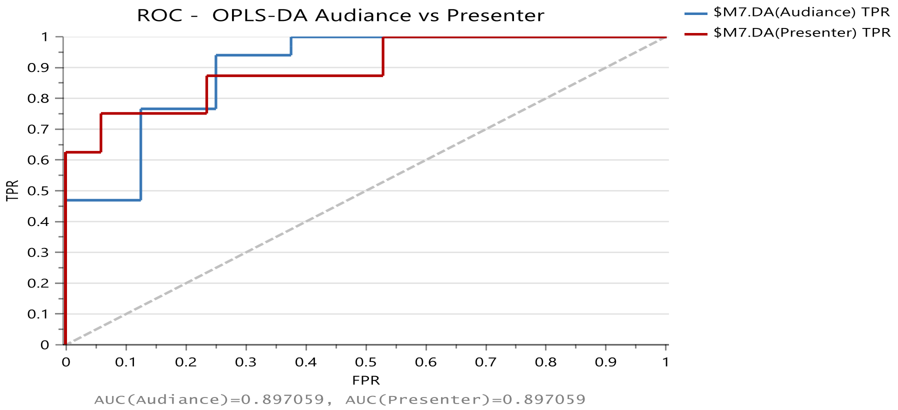

VIP - Important variables discriminating Audiance and Presenter
VIP[1+1+0]
Q5.Enjoyment
Q4.Empowerment
Q2.Excitement
Q10.OwnerShip
Q11.Contribution
Q7. Gratification
Q9.Adjustability
Q8.Engaement
Q12.Security
Q1. Trust
Q6.Effect
Q3.Frustration


VIP - Predictive parameters
Enjoyment, Empowerment, Excitment, and ownership
VIPpred
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Q5.Enjoyment
Q4.Empowerment
Q2.Excitement
Q10.OwnerShip
Q7. Gratification
Q11.Contribution
Q9.Adjustability
Q8.Engaement
Q12.Security
Q1. Trust
Q6.Effect
Q3.Frustration
SIMCA 17.0.2 - 14/02/2022 19:13:19 (UTC+1)


VIP - Important variables not predictive
Security, Trust, engagement, and adjustability
VIPorth
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Q12.Security
Q1. Trust
Q8.Engaement
Q9.Adjustability
Q11.Contribution
Q7. Gratification
Q6.Effect
Q2.Excitement
Q4.Empowerment
Q10.OwnerShip
Q5.Enjoyment
Q3.Frustration

Prediction

M7	Members	Correct	Spectator	Presenter	No class (YPred < =0)
Spectator	34	100%	34	0	0
Presenter	8	25%	6	2	0
No class	0	-	0	0	0
Total	42	85.71%	40	2	0
Fisher's prob	0.033				



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Data Availability The datasets generated during and/or analysed during the current study are available from the first author on reasonable request.

Declarations

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Conflict of Interest None.

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