**“Give Me Some Space!”:**

**The Transformative Effects of Spatial Distance in an Immersive VR Learning Environment**

**Abstract**

This study explores this very question with a 2 (Proxemic Distance) X 2 (Virtual Instructor Gender) between subject design. In this experiment, participants (N=118) actively engage in a learning task with a male/female virtual instructor that provides negative feedback while either standing close to or far from participant. Based on the different deliveries of the negative feedback, the study aimed to identify the sources of variations in participant reactions to the negative feedback, namely patterns of attribution and both behavioral and physiological measurements of emotions.

**Introduction**

**Virtual Environments**

Virtual environments (VE) have been widely explored in the context of learning and pedagogy. Utilizing virtual environments as an educational tool has long been discussed, Virtual environments have been investigated as educational tools that encourage active participation and individualization (Pantelidis, 1993) and that foster a constructivist educational approach (Bricken, 1990; Winn, 1993).

Bailenson and colleagues (2008a) conceptualize immersive virtual environment (IVE) as one that “perceptually surrounds the user, increasing his or her sense of presence or actually being within it” (p. 104). A simple example of an IVE is a virtual reality (VR) environment. Relative to conventional virtual environments, the sensory and perceptual cues within an IVE are more salient and engaging while actual sensory information outside of the IVE (real-world) is minimized.

**Embodied Pedagogical Agents**

While research examining learning within virtual environments have mostly made use of computer-driven embodied agents (Bailenson & Blascovich, 2004). To have optimal learning effects using virtual agents, studies have underscored the need to integrate socio-emotional and relational variables such as embodiment and nonverbal behavior (Krämer & Bente, 2010).

These studies have traditionally focused on the effects of positive feedback from virtual agents in a virtual learning environment (Krämer et al., 2010; Krämer et al., 2016; Gratch et al., 2006; Wang et al., 2009). For instance, Wang et al. (2008) found that an agent who uses polite requests had a more positive impact on learning than a more direct agent. Further, Krämer et al. (2016) found a significant improvement on participant's performance when interacting with same-gender virtual agents that rapidly respond to the participants with positive non-verbal behavior. Departing from these previous works, Feng et al., (2017) focused on students' direct response to purely negative feedback from virtual instructors, and found thatstudents attribute greater self-blame (internal attribution) for their purported poor performance when interacting with the female virtual instructor than when interacting with the male virtual instructor.

**Negative Feedback**

First introduced by Dweck (1975), the effects of negative feedback in educational contexts have long been debated. Some argue that negative feedback benefits learning (Kluger et al., 1996) while others argue that it leads to a “learned helplessness” that hampers learning (Dweck et al., 1978). At a fundamental level, negative feedback has been shown to lower motivation (Vallerand et al., 1984). That said, students may employ strategies to counteract the negative feedback, such as increasing effort (Carver et al., 1998) and lowering goals and expectations (Kluger et al., 1996). Such goal regulation strategies have been observed both for legitimate and manipulated feedback (Ilies et al., 2005). Further, negative feedback has been observed to act as a motivator for tasks that are required (Hattie et al., 2007).

**Attribution**

A crucial response to negative feedback in an educational context is one's attribution of blame or responsibility. That is, does the student attribute blame to their own poor abilities or do they attribute blame to the instructor's poor teaching abilities? Attribution theory has long been discussed in the field of education (Weiner et al., 1978). While students' success is often attributed to the self, failures are typically attributed to others (Klein et al., 2001). In fact, students tend to ignore negative feedback that contrasts with their own assessments of their performance (Campbell et al., 1983).

What remains to be seen, however, is an understanding of how negative feedback transforms and shifts students’ attribution tendencies based on the gender of a teacher and the interpersonal distance between the student and the teacher.

**Proxemics**

Proxemics, or interpersonal distance between communicators, highly impacts the perception of meaning in all forms of human social interaction. Hall (1966) identified 4 types of interpersonal distance zones with varying distances and social meaning: the intimate zone (0–45 cm), the personal–casual zone (45–120 cm), the socio-consultive zone (120–360 cm), and the public zone (360–750 cm).

Management of and responses to interpersonal distance has also been extended to non-human agents such as virtual characters (Bailenson et al., 2001, 2003; Gillath et al., 2008; Llobera et al., 2010; Wilcox et al., 2006) and robotics (Gockley, Forlizzi, & Simmons, 2007; Pacchierotti, Christensen, & Jensfelt, 2005; Walters et al., 2005). As Bailenson et al (2001) note, studies about proxemics have historically been wrought with issues of reliability and validity across participants. Virtual environments offer an opportunity to reliably test precisely defined proxemics while also maximizing realism (Loomis et al.,1999; Bailenson et al., 2001; Blascovich et al., 2002).

**Hypotheses**

We anticipate the proxemic distance of the virtual instructor to have a wide impact on participants’ experiences in this virtual learning environment. Specifically, we expect the closer interpersonal distance to be associated with poorer evaluations of performance, greater negative affect, lower attributional control, external attributional tendencies, greater head movements (HMD). Instructor gender has previously been linked with varying attributional tendencies. This study will further examine these gender effects in a negative feedback-based virtual learning environment. Specifically, we will explore the role of instructor gender, and potential interaction effects of instructor gender with both instructor proxemic distance and student gender (participant) as they impact the above outcomes.

**Method**

**Participants**

118 students from two universities (54 men and 64 women), with an average age of 20.94 (SD = 2.77) participated in this study and were randomly assigned to one of 4 conditions in a 2 (Virtual Instructor Gender) \* 2 (Close/Far) between-subjects design. The distribution of participants across conditions was as follows: There were 28 participants in condition 1(Male Close), 24 participants in condition 2 (Female Close), 30 participants in condition 3 (Male Far), and 36 participants in condition 4 (Female Far).

**Measures**

**Positive and Negative Affect Schedule-Expanded Form (PANAS-X).** The general dimension PANAS-X scales of positive affect and negative were included in this study scale (Watson & Clarke, 1999). Items were measured on a 5-point Likert scale ranging from (1) *Very slightly or not at all* to (5) *Extremely*. Positive affect items included active, alert, attentive, determined, enthusiastic, excited, inspired, interested, proud, and strong. Negative affect items included afraid, scared, nervous, jittery, irritable, hostile, guilty, ashamed, upset, and distressed. Participant responses were collected pre and post the experiment. For the current study, each item of the PANAS-X scale will be analyzed at the univariate level.

**Causal Dimension Scale II.** The Revised Causal Dimension Scale (CDSII) (McAuley, Duncan, & Russell, 1992) was used to measure assignment of causal attributions after the conclusion of the experiment. The CDSII consists of four individual dimensions, “locus of causality” (internality), “stability”, “personal control”, and “external control”. Responses are made on 9-point semantic differential scale with anchoring statements at either end of the scale. In addition to the original items grouped under each dimension of the scale, items tailored for this experiment were included as slight modifications to the existing items. A complete list of items included in this modified scale can be found in the appendix.

**Ad-Hoc Items.** Upon completion of the experiment, participants were also asked to respond to a series of ad-hoc items designed to attain a more holistic understanding of participants’ experiences with the task, the instructor, and the feedback they received. We first asked the participants to evaluate the virtual human regarding valance (e.g. likable), dominance, activity, attributions of the professor's behavior (e.g. due to his/her personality or participants' underperformance). As these items do not represent a scale or combined measure, each item will be analyzed at the univariate level.

**Head Mounted Display (HMD) Movements.** To reiterate, this study involved the use and application of a three-dimensional virtual environment, which was essentially a model of a superordinate space. In this three-dimensional space, the environment was not designed to appear bounded to a specific space, such as an enclosed room. Rather, the characters in the virtual environment appeared and interacted with the participants in a seemingly limitless environment, with every point in the space identified by three coordinates (x, y, and z), with each point representing a specific data point for analysis. The movement of each participant's head along the x, y, and z planes in this study was tracked by a three-axis sensing system integrated within the head mounted display.

**Materials**

**Virtual Environment Design.** A mismatch between resources and demands can create threat states that can potentially account for performance outcomes (Blascovich et al.,, 1999). The inability to satisfy the person of power in this interaction is suggested to lead to feelings of helplessness and lack of motivation, key components of negative feedback. Using this scenario as a template, we created a virtual environment in which individuals are assigned to a task that they are incapable of completing to the satisfaction of an instructor. This system enables the researchers to develop a keener understanding of how participants respond, both verbally and physiologically, to the experience of negative feedback. This information can then be used to create intervention strategies to ``buffer" participants against the instructor's negative feedback: These student tactics could be taught through successive iterations of the virtual scene. Thus, the first step before constructing such an intervention is to create a specific learning context where the instructor provides negative feedback and within which participants' responses can be assessed.

Specifically, the interactive virtual environment here simulated an acting class scenario. One of the virtual characters was designed to be the instructor in the scene. Each participant and other non-player characters (NPC) were students who were asked to rehearse 'Romeo and Juliet: Act 3, Scene 3'. The researcher told the participants that their goal is to finish their rehearsal in a limited amount of time. Each time the participant finished reading a line, the virtual instructor provided negative feedback in several ways including harsh language, negative non-verbals, encroaching on personal space, and ridiculing the participants' performance. Although the negative feedback from virtual instructor were scripted and identical for all participants, participants were told the feedback was tailored based on their performance and they should follow the instructor's directions to the best of their ability. After the experiment, participants were debriefed about the scripted and non-authentic nature of the ``feedback".

To invoke negative affect, the system utilized social interaction and an impossible task framework as mechanisms. All feedback given by the virtual instructor, regardless of actual performance, were designed to be negative and variable in nature. For example, ``Woah woah woah, stop. You are sounding way too excited. Let us do it again, and tone it down. Casual-like.", ``Ugh, stop. You sound like a dead fish... Let's do it again, and put a little more energy into it.", ``Hang on. You are giving it too much energy. Try bringing it down a notch, okay?". In order to get the participants engaged in the experiment, the participants were given a time limit for each line they read. They would be interrupted by the virtual instructor if they could not finish it in time.

The nonverbal behavior such as gesture, facial expression, gaze and posture of the virtual agents are generated by Cerebella (Lhommet & Marsella, 2013) to convey negative affect. Cerebella is an intelligent framework which can take a communicative intent as input and generates a multimodal nonverbal behavior commands using the Behavior Markup Language (BML). Taking advantage of the 3D environment, the proxemics between virtual characters could also be manipulated.

**Apparatus.** The 3D virtual environment was developed using Unity3D. The framework of virtual human and character animation is developed based on the Virtual Human Toolkit. The head mounted display (HMD) is Oculus Rift Development Kit 2.

**Experiment Procedure**

Prior to arrival, participants were randomly assigned to one of four conditions (Male Close, Female Close, Male Far, Female Far). As they began to read the informed consent form, participants were fitted with the E4/ skin conductance measure bracelet. After completing this briefing session, participants were asked to fill out the PANAS-X (pre-test) and the Rosenberg Self-Esteem Scale. After completing those two questionnaires, participants were fitted with the HMD and headphones at an appropriate distance of about 5 feet from the HMD sensor. Upon completing the experiment, the participants responded to additional questionnaire measurements including the PANAS-X (post-test) and the CDS II. Each session for a given participant lasted no more than 30 minutes. More detailed information on the experimental procedure may be found elsewhere (Feng et al., 2017).

**Results**

**Data Preparation**

**CDS II.** Factor analysis was conducted on individual subscales that make up the Causal Dimension Scale II. Five items under the “Locus of causality” dimension of the CDSII were examined via principal components analysis using varimax rotation as the primary purpose was to establish and compute composite variables for each subscale of the CDSII. All five items loaded onto one factor and were retained under a “locus of causality” composite measure (Cronbach’s α = .86). Three items under the “personal” dimension of the CDSII were examined via principal components analysis and were all found to load on one factor (Cronbach’s α = .87). Three items under the “stability” dimension of the CDSII were examined via principal components analysis using varimax rotation, and all loaded on one factor (Cronbach’s α = .73). Six items under the “external” dimension of the CDSII were examined via principal components analysis using varimax rotation. Three items did not load on the first factor and were dropped from the composite “external” measure (Cronbach’s α = 76).

**Head-Mounted Display (HMD).** HMD data coordinates for x-, y-, and z-axes were recorded at 25 separate time points over the course of the actual acting experiment. HMD movement analyzed for both aggregate movement (bi-directional) and for movement direction (uni-directional).

***Aggregate HMD Movement.*** Head movement was calculated by summing up the absolute values of the differences between each pair of the sequential data points. In other words, the absolute value of the difference between time 1 and time 2 was added with the absolute value of the difference between time 2 and time 3, and so on up to the absolute value of the difference between time 24 and time 25. By summing up the absolute values of each time point for each axis, we computed aggregate movement variables for each axis. The formulas for the movement variables of each axis are depicted below.

***HMD Movement Direction.*** HMD movement direction was calculated by summing the non-absolute differences between each pair of sequential data points. The output generated by this formula represents the aggregate movement direction that the participants tended to move towards over the course of the experiment for each x-,y-, and z- axes. The formulas for the movement direction variables are depicted below.

**Manipulation check**

**Negative Affect.** Manipulation checks were performed to verify manipulations were being interpreted accurately and as intended. Critical to the present study was the impact and reception of the negative feedback messages from the Virtual Instructor. As such, we tested the effectiveness of the negative feedback by determining the level of negative affect that the feedback generated. We conducted a series of paired samples t-tests to examine this emotional impact of the negative feedback message. Significant mean differences between pre- and post-test measurements of PANAS-X were observed for the negative affect items of Upset, *t(*114) = -5.74, p < .001, Guilty, *t(*114) = -2.252, *p =* .026, Hostile, *t(*114) = -4.041, p < .001, Irritable, *t(*114) = -2.52, *p =* .013, Ashamed, *t(*114) = -4.54, p < .001, and Nervous, *t(*114) = 3.495, *p =* .001. Here, we see clear indication that the experimental negative feedback was generally successful in communicating its meaning and intent. Significant mean differences were also observed for the positive affect items of Enthusiastic, *t(*114) = 2.62, *p =* .01, Proud, *t(*114) = 2.82, *p =* .006, but the direction of the mean differences indicate a decrease in enthusiasm and pride, providing further support for that the “negativity” of the feedback was accurately perceived.

**Experiment Authenticity.** Another significant factor in the present study was the degree to which participants truly believed that the negative feedback they were receiving was tailored and specific to each person. Although efforts were made to make the virtual environment and authentic, some participants could pick up on the actual non-intelligent nature of the virtual environment. That is, although participants were (falsely) told that the virtual instructor would be tailoring their feedback to the participants’ performance, not all participants deemed the virtual environment to be authentic. As such, a manipulation check was delivered to the participants in the form of two items on a 7-point Likert scale (anchors *extremely inauthentic* and *extremely authentic*): “*To what extent did you feel that the instructor's feedback was authentic/real?*” and “*To what extent did you feel that the virtual environment was authentic/real?*”

Both items were normally distributed and no outliers were identified, enabling all participants to be included for analysis. Participants generally were mixed in their judgments of the authenticity of the instructor feedback (M= 3.92, SD = 1.7) and generally felt the virtual environment was more authentic than inauthentic (M = 4.43, SD= 1.5). Further, the medians for each of the two items were 5, which corresponds to “Slightly authentic” on the 7-point Likert scale.

A dichotomous Feedback Authenticity variable was constructed by splitting the responses at the median and examined in a 2-way MANOVA with the original independent variables of Proxemic Distance and Virtual Instructor Gender. A main effect of Feedback Authenticity was observed on multiple Ad-hoc items, including task difficulty, *F(*6,89) = 6.624, *p =* .012, feedback helpfulness, *F(*6, 89) = 15.99, p < .001, feedback accuracy, *F(*6, 89) = 22.126, p < .001, affected by professor’s reactions, *F(*6, 89) = 4.57, *p =* .036, feedback attributed to own underperformance, *F(*6, 89) = 12.433, p < .001, and feedback attributed to professor having a bad day, *F(*6, 89) = 4.83, *p =* .031.

Table  
*MANOVA of Feedback Authenticity on Ad-hoc items*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Independent Variable(s) | Dependent Variable | *Df* | Mean Square | *F* | Sig. |
| Feedback Authenticity | Difficulty of task | 1 | 6.542 | 6.624 | .012 |
| Helpfulness of feedback | 1 | 9.836 | 15.999 | .000 |
| Accuracy of feedback | 1 | 13.464 | 22.126 | .000 |
| Affected by feedback | 1 | 3.758 | 4.565 | .036 |
| Attribute to own underperformance | 1 | 25.367 | 12.433 | .001 |
| Attribute to professor having a bad day | 1 | 9.770 | 4.843 | .031 |
| Proxemic Distance \* Feedback Authenticity | Difficulty of task | 1 | 4.069 | 4.120 | .046 |
| Proxemic Distance \* Feedback Authenticity \* Virtual Instructor Gender | Helpfulness of feedback | 1 | 3.504 | 5.700 | .019 |
| Affected by feedback | 1 | 8.333 | 10.124 | .002 |

A univariate interaction effect was observed between Feedback Authenticity and Proxemic Distance on ratings of task difficulty, *F(*6,89) = 4.120, *p =* .046. That is, participants in the Far condition who deemed the feedback to be low in authenticity reported low difficulty, whereas participants in the Far condition who deemed the feedback to be high in authenticity reported high difficulty. This was in contrast with the Close condition participants, who regardless of judgments of Feedback Authenticity, did not vary significantly in reported difficulty of the task. This result makes intuitive sense, because those who are not convinced in the authenticity of the “automated” feedback clearly are not as concerned about the difficulty of the task as those who have fully “bought in” to the task. *#Further, we do expect higher ratings of difficulty in the Far condition than in the Close condition. #Why?*

**Statistical Analysis**

**CDSII**. Before examining the proxemics-based and gender-based effects of the negative feedback on students’ attributional tendencies, we explored the effects of participants’ expectations of their performance entering the study and their assessments of their performance after completing the experiment on attributional tendencies.

***Expectations and Self-Assessments.*** Immediate effects of Proxemic Distance were observed on participants’ self-assessments of their own performance, *F(*1, 114) = 9.60, *p =* .002. In other words, instructors at a close distance led to significantly poorer self-assessments than instructors at a far distance. Further, one’s own self-assessment significantly predicted external attribution (locus of causality), *F(*1, 114) = 4.314, *p =* .003.

Table X

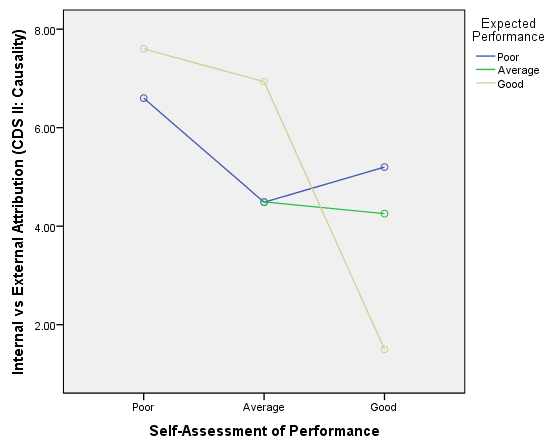
*2-way MANOVA Effects of Self-Expectation, Self-Assessment on CDS II (Attributions)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Independent Variable(s) | Dependent Variable | Type III Sum of Squares | df | F | Sig. |
| Self-Expectation | CDS Causality | .170 | 2 | .037 | .964 |
| CDS External | 16.136 | 2 | 3.316 | .041 |
| CDS Stability | 1.998 | 2 | .393 | .676 |
| CDS Personal | 1.410 | 2 | .374 | .689 |
| Self-Assessment | CDS Causality | 20.034 | 2 | 4.383 | .016 |
| CDS External | 10.496 | 2 | 2.157 | .122 |
| CDS Stability | 13.863 | 2 | 2.729 | .071 |
| CDS Personal | 15.062 | 2 | 4.000 | .022 |
| Expectation \* Assessment | CDS Causality | 30.829 | 3 | 4.496 | .006 |
| CDS External | 19.506 | 3 | 2.673 | .053 |
| CDS Stability | 9.431 | 3 | 1.238 | .301 |
| CDS Personal | 13.193 | 3 | 2.336 | .080 |

To further examine the effects of expectation and one’s self-assessment of performance, a 2-way MANOVA was conducted examining the effects of participants’ pre-test self-expectations and post-test self-assessments on the factor analyzed composite CDS II dimensions (Locus of Causality, Personal Control, Stability, and External Control). As can be seen in Table X, main effects were observed for self-expectations on CDS External Control, *F*(2, 81) = 3.32, *p* = .041. Main effects were also observed for self-assessments on CDS Causality, *F*(2, 81) = 4.38, *p* = .016, and CDS Personal Control, *F*(2, 81) = 4.00, *p* = .022. Finally, an interaction effect of self-expectation and self-assessment was observed for CDS Causality, *F*(3, 81) = 4.50, *p* = .006. As can be seen in Figure X, participants who expected to do “Good”, and felt they performed “Good”, reported low Causality (internal attribution). Among the same participants with high expectations, however, those who felt they performed “Poor”, reported high Causality (external attribution). In general, participants who felt they performed “Poor”, tended to externally attribute for their performance, reflecting a regulatory strategy in response to feedback that conflicts with one’s self concept.

Figure X

*Interaction effect of Self-Expectation and Self-Assessment on Internal vs. External Attribution (CDS Causality)*



***Proxemics and Gender.*** A 2-way MANOVA was conducted examining the effects of Proxemic Distance with the Gender of the Virtual instructor on the factor analyzed composite CDS II Dimensions of Locus of Causality, Personal Control, Stability, and External Control. A multivariate main effect of Proxemic Distance on the CDS Dimensions was observed, *F(*4, 117) = 7.15, p < .001. No other main effects or interaction effects were found. Univariate main effects of Proxemic Distance were observed for Stability, *F(*3, 117) = 20.69, p < .001, Personal Control, *F(*3, 117) = 4.88, *p =* .029, and External Control, *F(*3, 117) = 7.91, *p =* .006. No other main effects or interaction effects were observed. As each independent variable was limited to 2 levels, post-hoc tests were not conducted.

Regardless of Virtual Instructor Gender, those who interacted with a Close instructor reported significantly higher levels of External Control. In other words, the participants in the Close conditions tended to report that people outside of themselves (the professor) had a more impactful role in their performance. Further, those who interacted with a Close instructor reported significantly lower levels of personal control, or one’s own ability to regulate and manage one’s performance, as well as significantly higher levels of stability, deeming the current situation of negative feedback to be more permanent, stable, and unchangeable.

Table X

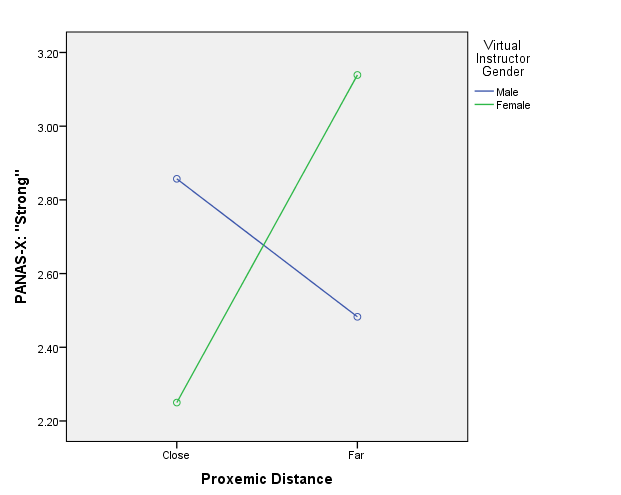
*Main effect for Proxemic Distance on CDS Stability, Personal Control, and External Control*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dependent Variable | Type III Sum of Squares | *df* | Mean Square | *F* | Sig. |
| CDS Stability | 61.322 | 1 | 61.322 | 20.686 | .000 |
| CDS Causality | 1.127 | 1 | 1.127 | .382 | .538 |
| CDS Personal | 20.418 | 1 | 20.418 | 4.879 | .029 |
| CDS External | 25.829 | 1 | 25.829 | 7.910 | .006 |

**PANAS-X.** A 2-way MANOVA conducted to examine the effects of Proxemic Distance and Gender of the Virtual Instructor on individual post-test measurements of PANAS-X yielded no significant effects. That is, there were no marked differences in the emotional responses of different groups of participants to the negative feedback. There was a small, yet nonsignificant main effect of Proxemic Distance on “Guilty”, *F(*3, 117) = 3.37, *p =* .069, meaning Close distance elicited slightly more guilt than Far distance. The only reportable effect in this model was an interaction effect between Proxemic Distance and Virtual Instructor Gender for Strong, *F(*3, 117) = 8.414, *p =* .004. See Figure X. Interestingly, the male virtual instructor had the effect of raising ratings of “Strong” at a Close distance, whereas the female virtual instructor had the inverse effect of raising ratings of “Strong” at a Far distance. A rather loose interpretation of this result is that participants felt less empowered and more marginalized by a female instructor delivering negative feedback at a close distance.

Figure X

*Interaction effect of Proxemic Distance and Virtual Instructor Gender on PANAS-X: “Strong”*

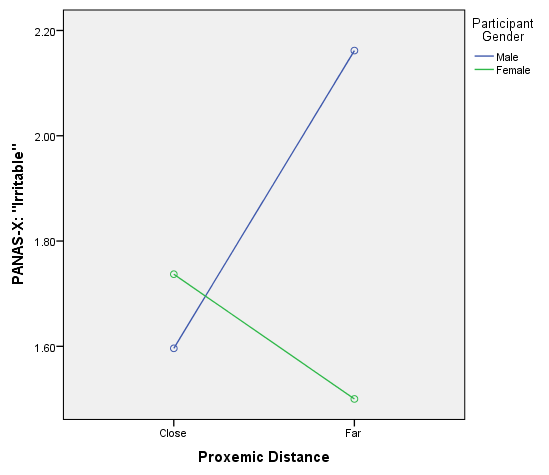


***Ad-hoc analyses.*** In order to provide further insight into the role of emotion in the present study an ad-hoc analysis was conducted few ad-hoc analyses was conducted. Participant Gender was added to the above MANOVA model to examine the 3-way effects of Proxemic Distance, Gender of the Virtual Instructor, and Participant Gender on the individual post-test measurements of PANAS-X. As each independent variable was limited to 2 levels, post-hoc tests were not conducted. Univariate main effects of Participant Gender were found on Interested, *F(*3, 117) = 4.52, *p =* .036, Excited, *F(*3,117) = 7.46, *p =* .007, Enthusiastic, *F(*3, 117) = 4.135, *p =* .044, Inspired, *F(*3, 117) = 8.39, *p =* .005, Determined, *F(*3, 117) = 8.68, *p =* .004, and Active, *F(*3,17) = 13.96, p < .001. That is, male participants in general reported being more interested, excited, enthusiastic, determined, and active than female participants after receiving the negative feedback. *This indicates a presence of a gender-based pattern in which male participants seemingly “bounce-back” in reaction to harsh negative feedback.*

Further, an interaction effect between Proxemic Distance and Participant Gender was observed for Irritable, *F(*3, 117) = 5.57, *p =* .02. As can be seen in Figure X, male participants were far more irritated by the instructor at a Far distance than were female participants.

Figure X

*Interaction effect of Proxemic Distance and Participant Gender on PANAS-X: “Irritable”*

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**Ad-Hoc Analyses**

**Ad-Hoc Items.** A 3-way MANOVA was conducted examining the effects of Proxemic Distance, Virtual Instructor Gender, and Participant Gender on the individual Ad-hoc items. As the Ad-hoc items did not constitute a composite measurement scale, each item was examined at the univariate level. Univariate main effects of Proxemic Distance were observed for the helpfulness of the feedback, *F(*3, 117) = 7.69, *p =* .007, the likability of the professor, *F(*3, 117) = 23.74, p < .001, and the level of effort put into the task, *F(*3, 117) = 27.46, p < .001. That is, participants in the Close condition perceived the feedback to be less helpful, the professor to be less likable, and tried harder to complete the task than participants in the Far condition did. Further, participants in the Close condition attributed the professor’s reactions to his/her personality more so than those in the Far conditions, *F(*3.117) = 28.23, p < .001.

Table X

*Main effect for Proxemic Distance on Ad-hoc items*

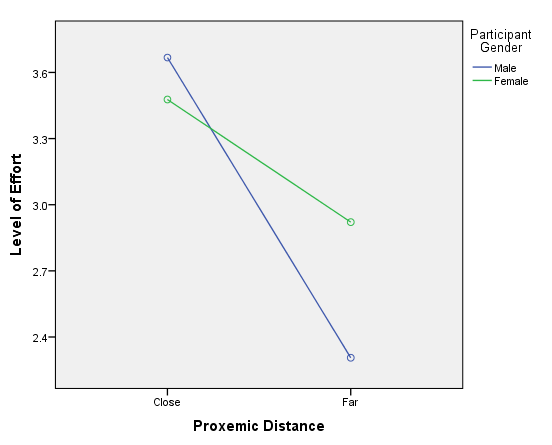
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Dependent Variable | *df* | Mean Square | *F* | Sig. |
| Helpfulness of feedback | 1 | 9.078 | 7.687 | .007 |
| Accuracy of feedback | 1 | 2.676 | 2.928 | .090 |
| Attribute to professor’s personality | 1 | 88.264 | 28.226 | .000 |
| Attribute to professor having a bad day | 1 | 5.398 | 2.424 | .122 |
| Level of Effort | 1 | 23.509 | 27.460 | .000 |
| Likability of professor | 1 | 39.971 | 23.738 | .000 |

An interaction effect of Participant Gender and Proxemic Distance was observed for the level of effort placed on the acting task, *F(*3, 117) = 5.304, *p =* .023. That is, male participants in the Close condition tried much harder on the task than the males in the Far condition. The difference in effort between Close and Far conditions was not as pronounced for the female participants.

See figure below. *Interpretation: the close distance seems to play the role of raising the degree of accountability in the task – particularly for male participants, who demonstrate a sizable drop off in effort when interacting with a far virtual instructor.*

Figure

*Interaction effect of Participant Gender and Proxemic Distance on effort put into the task*

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**Head-Mounted Display (HMD)**

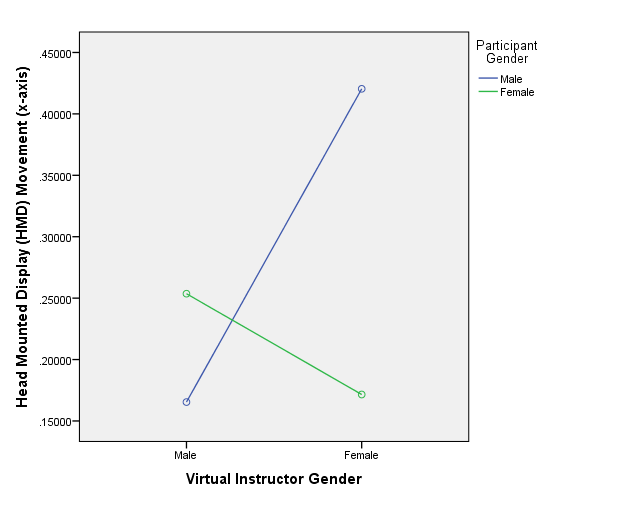
**HMD Aggregate Movement.** A 3-way MANOVA was conducted examining the effects of Proxemic Distance, Virtual Instructor Gender, and Participant Gender on the separate measurements of HMD movement on the *x*, *y*, and *z* axes. A multivariate main effect for Proxemic Distance was observed for HMD movement, *F(*3, 105) = 2.983, *p =* .035. Further, a 2-way multivariate interaction effect was observed between Participant Gender and Virtual Instructor Gender, *F(*3, 105) = 5.334, *p =* .002. Finally, a 3-way multivariate interaction effect was observed for Proxemic Distance, Participant Gender, and Virtual Instructor Gender, *F(*3, 105) = 2.994, *p =* .034.

Univariate analyses revealed main effects of Proxemic Distance on x-axis movement, *F(*1, 115) = 8.498, *p =* .004, and z-axis movement, *F(*1, 115) = 4.105, *p =* .045. In other words, there was a significant difference in side-to-side movement (x) and front-back movement (z) depending on the Virtual Instructor’s Proxemic Distance. Proxemic Distance also impacted the up-down movement (y), but this main effect was not significant, *F(*1, 115) = 3.069, *p =* .083.

A univariate 2-way interaction effect between Participant Gender and Virtual Instructor Gender was observed on only the x-axis movement, *F(*1,115) = 9.598, *p =* .002. As seen on Figure X, male participants’ x-axis head movements shot up in response to interacting with a female virtual instructor, whereas female participants’ x-axis head movement declined when interacting with a male virtual instructor. No other significant univariate main effects or interaction effects were observed.

Figure X

*Interaction effect between Participant Gender and Virtual Instructor Gender the x-axis movement (HMD)*

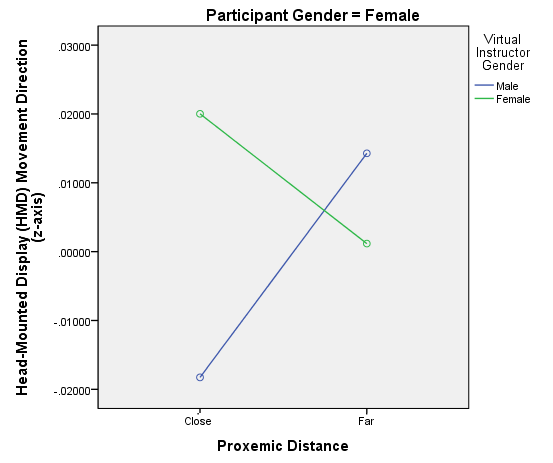
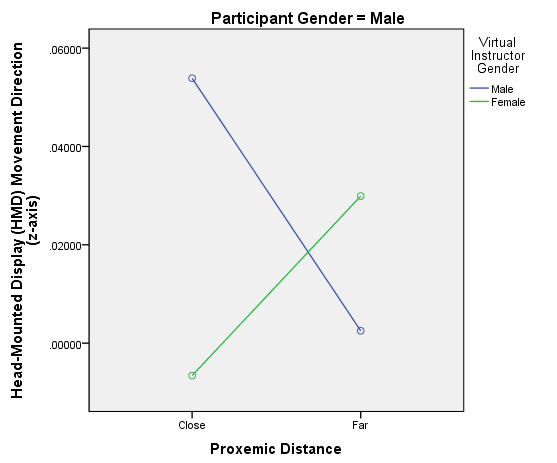
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**HMD Movement Direction.** A 3-way MANOVA was conducted examining the effects of Proxemic Distance, Virtual Instructor Gender, and Participant Gender on the separate measurements of HMD movement direction on the *x*, *y*, and *z* axes. A univariate main effect was observed for Proxemic Distance on HMD y-axis (up-down) movement direction, *F(*1,115) = 4.461, *p =* .037. In other words, participants tended to sink down in response to the Close distance conditions relative to the Far distance conditions.

Further, a univariate 3-way interaction for Proxemic Distance, Virtual Instructor Gender, and Participant Gender was observed on HMD z-axis (towards-away) movement direction, *F(*1, 115) = 5.41, *p =* .022). In other words, a two-way interaction varies across different levels of a third variable. Figure X depicts the 2-way interaction for Proxemic Distance and Virtual Instructor Gender for Male participants and Figure Y depicts the 2-way interaction for Proxemic Distance and Virtual Instructor Gender for Female participants. As can be seen in Tables X, male participants tended to move forward when they interacted with a male virtual instructor at a close distance relative to those who interacted with a male virtual instructor at a far distance. Conversely, male participants interacting with a female virtual instructor at a close distance tended to move backwards relative to male participants interacting with a female virtual instructor at a far distance. As shown in Figure Y, this identical pattern of forward-movement in response to same-gendered virtual instructors and backward-movement in response to cross-gendered virtual instructors at a close distance was also observed among female participants. No other main effects or interaction effects were observed for the above variables.

Figure X and Y

*2-way Interaction for Proxemic Distance and Virtual Instructor Gender across Male and Female Participants (3-way Interaction)*

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**Discussion**

**Summary of Findings**

**Attribution.**  The most compelling finding in this study must be the transformative effects of Proxemic Distance. Manipulating a controlled negative feedback message according to Far or Close distance had the effect of categorically transforming the social perception of the message. Specifically, delivering a series of negative feedback messages from a close distance had the effect of lowering one’s sense of personal control and ability to change the present situation while simultaneously raising a sense of the critic’s (the Virtual Instructor) control.

This finding has tremendous implications for learning and pedagogy, suggesting that a unique pattern of attribution exists in response to criticism and negative feedback delivered at different proxemics distances. Quite simply, negative feedback delivered at a proximal distance appears to have the effect of stripping the student of a sense of control and agency, thus debilitating the student from making the necessary adjustments needed to address the purported root of the negative feedback.

**Affect.** The most compelling affect-based findings in the present study were the male participants’ distinct tendency as students to “bounce-back” in response to the negative feedback from the virtual instructor, reporting significantly higher levels of interest, excitement, enthusiasm, determined, and activity. As observed in the initial manipulation check of the negative feedback, the harshly critical nature of the negative feedback had the effect of reducing various positive affect items and raising various negative feedback items from pre to post. That said, male participants exhibited a curiously unexpected pattern of asserting what must be categorized as a defiant resilience, and a refusal to be negatively impacted by the criticisms. This pattern of behavior must be explained by the tendency of negative feedback to enforce a sense of accountability, thereby generating the attention and motivation needed to complete the task successfully. This suggests male participants may require a straightforward, even harsh negative feedback in a learning situation as opposed to a teaching strategy that simply complimenting and reinforcing the student.

An additional interaction effect was observed across Proxemic Distance and Participant gender on ratings of “Irritable”. Specifically, male participants seemed to report feeling far more irritated by instructors providing negative feedback at a far distance than close distances, whereas the inverse effect was seen among female participants. The male effect may be attributable to the cognitive dissonance experienced with an extremely critical message coupled with a perception of a less engaged body language (far distance). This irritation experienced by male participants is likely associated with the tendency for male participants to try harder on the task in the close conditions. This effect is discussed further in the following section.

**Ad-hoc items.** The results of the ad-hoc items demonstrated that the interpersonal distance of the professor had clear impact on perceptions of the likability of the professor, the helpfulness of the feedback, as well as the subsequent effort put into the task. Although participants in the close conditions perceived the instructor to be less likable and the feedback to be less helpful, they did report trying harder in the task than did participants in the far condition. The close distance seems to play the role of raising the degree of accountability in the task – particularly for male participants, who demonstrate a sizable drop off in effort when interacting with a far virtual instructor. This pattern of behavior somewhat corroborates the above tendency for the male participants to be being more interested, excited, enthusiastic, determined, and active in response to the instructor’s negative feedback.

**Social Presence.** Proxemic Distance also revealed a clear effect when it came todegree of presence felt by participants across distance conditions. Specifically, participants in the close conditions reported feeling significantly greater feelings of physical transportation into the virtual environment, ability to observe subtle cues such as body language, and a sense of immersion and engagement.

**Head Movements.** Close distance resulted in significantly greater side-to-side movement (x) and front-back movement (z) than far distance. Further, male participants’ x-axis head movements shot up in response to interacting with a female virtual instructor, whereas female participants’ x-axis head movement declined when interacting with a male virtual instructor. The male participants’ head movements corroborated their defiant “bounce-back” tendencies as evidenced in their PANAS ratings. Female participants, on the other hand, responded in a more expected fashion, as one might expect participants receiving criticisms to sink their heads in discouragement.

Further research should be done into examining the specific gender-specific patterns observed here. While questionnaire items are admittedly subjective, HMD data is definitively objective. The objective gender-specific pattern observed here may have greater implications for how we study face to face human interaction.

**Implications and Limitations**

The present study has major implications for educational technology, the design of virtual agents, and for presence researchers.

**Teaching Style.** Design of the negative feedback was scripted following the model of cinematic arts courses that invoke a great deal of repetition and straight-forward feedback. In post experiment interviews, many subjects reported feeling that the degree of repetition had an annoying effect. In other words, the participants felt that the repetition was not helpful from a pedagogical standpoint of learning “why” and “how” to improve. The experiment of course, was designed to deny success.

**Suspending Disbelief**. By the end of the experiment, most participants had some inkling of the non-intelligent design of the experiment stimuli. That is, whether due to limitations in the design of the messages or the design of the environment, most came to a gradual realization that the feedback could not be entirely legitimate or authentic. What some participants reported in post-experimental interviews, however, was they could not suppress their emotions regardless of this realization. Indeed, the various effects observed in this study highlight the participants’ inabilities to suspend disbelief over the medium – a significant issue in the presence research. Although presence measures were originally included in this experiment to test for the immersiveness of the virtual environment, an overlooked aspect of the experiment was the presence-based effects of the feedback messages themselves. In other words, the negative feedback in this experiment was designed under the assumption that they would be received at face value. The general sharpness and quick eye of participants to pick up on the inauthentic and non-tailored nature of the feedback in effect revealed an interesting finding about the permanence of negative feedback and negative affect: That is, even in the face of denial and rejection of the legitimacy of the negative feedback, participants ultimately reacted in the expected patterns of causality and emotion associated with authentic negative feedback.

**Distance and Authenticity.** One interesting absent effect was the lack of any distinguishable pattern among the independent variables of distance, participant gender, and instructor gender in dictating the perception of feedback and/or environment authenticity. That is, there were no significant differences in perception of feedback or environment authenticity for any of the independent variables. The lack of a significant difference between close and far conditions was rather surprising as one would intuitively anticipate that the close distance would elicit a more realistic perception of the interaction and in turn, the feedback. What is even more surprising however, was when simply comparing the ratings of feedback authenticity/realism, participants in the far condition rated to the feedback to be greater in authenticity than participants in the close condition. Although the difference is nonsignificant, the perception of greater realism of the far instructor conditions may have two possible explanations.

First, the farther virtual instructor is displayed completely in terms of physical orientation, movements, and gestures whereas the closer virtual instructor requires intentional movement of the head-mounted display to observe different parts of the instructor’s physical orientation and gestures. The full representation of the body and all its inference-generating affordances may have provided participants with a greater sense that the instructor’s feedback was authentic.

Second, the farther virtual instructors may be representing a step prior to reaching the uncanny valley, while the close virtual instructors – with their more closely depicted graphical features—may be representing the uncanny valley itself. When the virtual characters are farther away, some participants noted that they could not make out the facial expressions of the characters. Others noted that the farther characters could not necessarily be definitively identified as virtual characters, suggesting a possibility that the characters may represent an actual human displayed in the virtual environment. In other words, the far distance may have had the unintended effect of eliciting perceptions of greater realism simply by virtue of their lack of realism. As a result of this relative lack of realism in the far conditions, participants would have also had to “fill in” the facial expressions of characters and fixate more-so on the speech and gesture of the character. Essentially, any confounding effect of the uncanny valley of the close distance characters on the perception of the negative feedback message (“This is obviously just a virtual character, so the feedback is probably not real”) would have been nullified by the far distance.

**Conclusion**

The results of the present study have numerous implications for the design of virtual agents for learning outcomes as well as the methodological design of studies utilizing virtual agents in virtual environments. The simple difference of manipulating the interpersonal distance between a participant and a virtual agent had the effect of transforming the attributional, affective, immersiveness, effort, and even head-movement reactions of the participants in a virtual environment. As mentioned earlier, social situations in human-human communication naturally fluctuate in valence and nature. The results of the present study demonstrate evidence that distinct response patterns exist among female and male users of virtual environments and these differences should be accounted for when designing games and interventions that simulate negatively-valenced and/or emotionally-charged social situations.

This project has numerous implications for classroom learning and teaching, mental health, decision-making, skill-based training, and AI/machine learning. Since the effects of negative feedback on learning have been well-established, teachers and educators tend to avoid negative feedback in the learning process. That said, this does not preclude all educators from employing negative feedback in their teaching. Some teachers have bad days and some teachers are quite simply ineffective teachers. By simulating a negative feedback teaching situation in a virtual environment, we present the potential for a more precise understanding of the effects of negative feedback on students' learning, emotional state, attribution patterns, and even their nonverbal reactions to the negative feedback.

The benefits of using immersive VR in this domain of research is that it allows the reliable and precise replication of any social context while maximizing physical and social realism.  For obvious reasons, it simply would not be practical or feasible to test for these effects of negative feedback in an actual teaching environment. Although many studies using VR target prosocial themes and goals, real world social interactions, certainly involve a wider spectrum of contexts that are by no means exclusively positive. VR environments allow us to test the specific patterns in which people respond and react in these negatively valenced contexts and offer the potential for designing interventions and training programs for positive social and health outcomes.

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