Effects of Emotion and Agency on Presence in Virtual Reality

Crescent Jicol
c.jicol@bath.ac.uk

Chun Hin Wan
chw77@bath.ac.uk

Benjamin Doling
bd373@bath.ac.uk

Caitlin H Illingworth
chi25@bath.ac.uk

Jinha Yoon
jhy33@bath.ac.uk

Charlotte Headey
ch2266@bath.ac.uk

Christof Lutteroth
c.lutteroth@bath.ac.uk

Michael J Proulx
m.j.proulx@bath.ac.uk

Karin Petrini
k.petrini@bath.ac.uk

Eamonn O'Neill
e.oneill@bath.ac.uk
University of Bath, Bath, UK

Figure 1: We manipulated emotion and agency through a 2x2 design. a) A scene in the *Happiness* park VE. b) The dog in the HNA condition. c) The dog in the HA condition interacting with the laser pointer. d) A scene in the *Fear* park VE. e) The creature in the FNA condition. f) The creature in the FA condition and the torch light.

ABSTRACT

Arguably one of the most important characteristics of virtual reality (VR) is its ability to induce higher feelings of presence. Still, research has remained inconclusive on how presence is affected by human factors such as emotion and agency. Here we adopt a novel design to investigate their effects by testing virtual environments inducing either happiness or fear, with or without user agency. Results from 121 participants showed that the dominant emotion induced by a virtual environment is positively correlated with presence. In addition, agency had a significant positive effect on presence and, furthermore, moderated the effect of emotion on presence. We show for the first time that the effects of emotion and agency on presence are not straightforward but they can be modelled by separating design factors from subjective measures. We discuss how these findings can explain seemingly conflicting results of related work and their implications for VR design.

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CCS CONCEPTS

• Interaction design → Systems and tools for interaction design; **• Human computer interaction (HCI) → HCI theory,**

concepts and models; • **Human-centered computing** → **Virtual reality**.

KEYWORDS

virtual reality, presence, emotion, agency.

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1 INTRODUCTION

In recent years, head-mounted display (HMD) VR technology has significantly improved its capability to present realistic environments and complex real life situations [18]. VR has broad applications in areas including psychological research [31, 44], emotional and behavioural therapy [41], training programmes [2], sensorimotor rehabilitation [27] and gaming [53]. A big advantage of VR over conventional media in such fields comes from its ability to facilitate user presence [74]. Presence is often defined as the psychological experience of 'being there' within a VR environment [16]. Presence is fundamental to successful VR applications as it has been shown to improve user satisfaction, enjoyability and engagement [8].

Presence is related to immersion, however, it is important to recognize them as distinct concepts. Immersion can be defined as the sensorial vividness of a virtual environment (VE) and its ability to replace real world stimuli with those from VR [10, 11, 29, 39]. Hence, immersion is closely tied to technological specifications [84]. On the other hand, presence is a cognitive construct that determines whether users feel and behave as if events experienced in VR were occurring in the real world [16, 29, 72, 88]. As remarked by Lombard and Ditton [48], presence can be defined as the "perceptual illusion of non-mediation" [48]. It is clear from these definitions that presence is fundamentally a construct of the user rather than of the technology *per se*. Thus, human factors such as emotion and agency may play major roles in the creation of presence [18, 70, 72].

The effects of emotion [3, 4, 24] and agency [34, 46, 72, 76] on presence have so far been investigated individually, and with inconclusive results. Some research suggests that different emotions lead to different levels of presence [3], while other research suggests that a wide range of emotions elicits similar levels of presence [24]. Thus, the effect of emotion on presence remains unclear. This may be due in part to the myriad of different virtual environments used and subsets of emotions studied [24]. Another possible reason is that emotions are commonly considered to have two main dimensions, yet no study on presence to date has considered both within the same design. The first dimension, *valence*, can be defined as the positive or negative nature of an emotion [5, 17, 45], while the second dimension describes its *intensity*, i.e. the extent to which a given emotion is felt by the user [15, 87]. Research suggests that the intensity of positive emotions correlates positively with presence [4] but such an effect has not been established for VEs designed to elicit negative emotions.

Similar to emotion, agency is believed to have a substantial effect on presence [18, 72, 91]. However, it has remained largely unexplored in the context of VR. Agency in VR can be defined as the perceived ability to interact with elements of a VE [76], and it varies greatly in current VR applications: many popular VR experiences such as 360° videos do not allow for user input or do not facilitate realistic interactions with the VE, while other experiences such as VR games available on high-end HMDs offer rich interactions with the VE. Importantly, emotion and agency may not only impact presence formation individually, but may interact with each other [72]. To the best of our knowledge, such interaction effects have never been investigated before.

This paper addresses gaps in the literature by systematically investigating how emotion and agency affect the formation of user presence in VR environments. To achieve this, we studied the effects of agency and both emotional valence and intensity on presence in VR within a single experimental design, using controlled VEs. 121 participants experienced a VE inducing either happiness or fear, with or without user agency, and we measured their subjective emotions and agency using established questionnaires. We addressed the following research questions:

RQ1 Is there a relationship between a user's emotion and presence in VR?
RQ2 How does the level of agency afforded to a user in VR affect their presence?
RQ3 How can we model the effects of emotion and agency on presence in VR?

In answering these questions, we shed light on how emotional valence and intensity influence the formation of presence. Furthermore, we show how agency not only impacts presence directly, but interacts with emotion to moderate the effect of emotion on presence. We propose a novel, unified model of presence that takes into account both emotion and agency, explaining the results of our experiment by separating design factors from subjective measures. Finally, we discuss how our findings inform the design of VR applications, helping designers to understand the formation of presence in their products. In summary, we make the following contributions:

(1) Evidence that both the dominant emotion induced by a virtual environment and the agency afforded by the latter are positively related to presence.
(2) Evidence that the effects of emotion on presence are moderated by agency.
(3) A structural equation model explaining the effects of emotion and agency on presence by separating design factors from subjective measures.

2 RELATED WORK

Due to the importance of presence to the success of VR applications, the factors that contribute to its formation have been investigated in a large body of literature. One factor that has received considerable attention is user emotion. Several studies have found that users experience stronger feelings of presence in VEs which induce emotional responses compared to neutral environments [1, 6, 59, 60, 64, 65, 85].

Emotional valence can be defined as the positive or negative nature of an emotion [5, 45]. For example, happiness and relaxation are positive emotions, while fear and anger are negative [45]. Emotional valence and its possible effects on presence have been addressed. For example, Felnhofer et al. [24] induced five different emotions in VR and found that levels of presence remained constant across VEs eliciting a wide range of emotions that varied in their valence. Similarly, Riva et al. [64] found that users reported significantly higher presence in VEs when they elicited either anxiety or relaxation compared to a neutral condition in which no emotion was induced.

These findings suggest that the valence of elicited emotions may not play a significant role in the formation of presence, the important factor being only that an emotion is felt. However, the studies by Riva [64] and Felnhofer [24] did not investigate the *intensity* of emotions and its role in presence creation. They did not correlate the intensity of felt emotions with presence but simply compared levels of presence between conditions eliciting different emotions. It is therefore difficult to understand how different levels of different emotions may relate to presence. For example, within each emotion users may perceive different degrees of presence depending on how intensely they feel that emotion.

A study by Baños et al. [4] attempted to investigate the relationship between emotional intensity and presence. They found that emotional intensity was positively correlated with presence in VEs that elicited relaxation or joy. Although providing intriguing results, this study did not take into account the valence of emotions. The valence of an emotion may have an impact on how its intensity correlates with presence: as a low valence (negative) emotion increases in intensity above what is enjoyable, it can break presence but this is not the case for high valence (positive) emotions [73].

Although Baños et al. [4] did measure negative emotions, they did not use a VE designed to elicit negative emotions and, unsurprisingly, their users reported levels of negative emotions considerably lower than those of positive emotions. In their study a negative emotion was never the dominant one, and we therefore cannot draw a definitive conclusion that levels of felt negative emotions in fear inducing VEs would correlate with presence. Fear is an emotion that triggers fight or flight responses [56] and as feelings of fear rise, users may feel uncomfortable and thus jeopardise presence formation. This effect could not have occurred in Baños et al.'s [4] experiment since levels of negative emotions remained low.

The uncertainty surrounding the relationship between emotion and presence in part stems from the fact that previous research has investigated either valence or intensity but never both within the same experimental design (e.g. [3, 4, 24, 64]). A comprehensive model capable of predicting presence from emotional valence and intensity is imperative to address this gap in the literature [18]. Testing the effect of valence is all the more important given that VR is widely used to induce both positive and negative emotions [24]. Many VR applications are designed to elicit fear, such as horror games. Similarly, VR is known for its ability to elicit higher levels of happiness compared to other media [4, 24]. For example, Pallavicini et al. [57] compared levels of happiness induced by playing video games on a 2D screen and VR. They found that the VR condition elicited significantly higher levels of happiness and fear (depending on the game played) compared to the 2D screen [57]. Given that these two emotions would allow us to test the effect of emotional valence and because they are highly relevant to VR applications, we chose them for the present study.

In addition, all studies that have investigated the effects of emotion on presence have used static VEs (e.g. [3, 4, 24, 64, 82]); that is, although the user can look around or even navigate the VE, it has no moving elements. This is not realistic and is not representative of most modern VR which is increasingly capable of displaying rich, realistic environments that include moving objects, animals and human avatars. Such elements may constitute a significant boost in the realism and believability of a VE, which in turn should increase presence [24, 41]. Additionally, it has been shown that attentional resources are directed towards moving elements in an environment [20, 42, 81]. If a user's attention is drawn to elements of a VE, for example by movement, then the user is more likely to feel present in that VE [18, 73]. Hence, VEs with moving elements may achieve higher levels of presence compared to static VEs. To inform creators of VR applications, it is thus important to test the relationship between emotion and presence in a dynamic VE.

Another human factor that has received attention in VR is agency. Agency represents the user's assessment of the degree to which they can control their own actions and influence events in the VE [76]. The importance of understanding the effects of agency on presence is reflected in the fact that the majority of VR applications do not support user input while others may offer minimal interaction, such as gaze pointing, but no hand or leg tracking [51, 54, 62, 83]. Clinical behavioural interventions using VR have shown higher levels of presence when the user's sense of agency is high [34, 46]. Raising the level of user agency has been found to improve spatial presence, or the feeling of being actually surrounded by landmarks in a VE [43]. Increased agency may also enhance the impression of being in the presence of other living beings [63], and the feeling that one is actually present in a VE, referred to as self-presence [12]. Nonetheless, it is unclear whether there is indeed a relationship between agency and presence in VR. A recent study by Piccione et al. [58] used a golf simulation task and found no difference in presence between a participant group playing the game and another watching it. Borrego et al. [9] used a VR stepping task meant to compare presence in VR between stroke patients and healthy individuals. Interestingly, they found no correlation between user perceived agency and presence. One possible explanation for these findings is that both studies employed relaxing tasks, which did not elicit arousing emotions such as happiness or fear. In fact, neither of these studies measured user emotions during the task. Thus, the relationship between agency and presence in VR remains unclear. Moreover, the possible effects of user emotions on this relationship remain unknown. It is therefore important to investigate the effects of agency or the lack thereof on presence in a unified, controlled study where emotions are being measured.

Users who have agency may be better able to self-regulate experienced emotions [7]. Thus, another way in which agency may impact presence is indirectly, through emotions, by moderating the intensity to which they are felt. For example, in a frightening scenario, agency could decrease the level of fear felt by users as they feel more in control of the experience. In contrast, in a happiness inducing VE, users might be expected to use their control over events to further heighten their enjoyment [7]. Thus, agency may have different effects on emotions and thereby on presence, depending on the valence of the dominant emotion in a VE. Still, due to some previous research suggesting a positive effect of agency on presence [12, 34, 43, 46], we will adopt a directional hypothesis, that agency will increase user presence.

We aim to develop a new, comprehensive model that can help us understand presence in VR based on emotion and agency. Based on previous literature, we expect that presence will be higher when VR users feel emotions more intensely. Additionally, we test whether valence has an effect on this relationship. Secondly, we expect that agency will impact presence, in that VEs which support user agency will elicit higher levels of presence. Lastly, we expect that agency will not only directly impact presence but will also moderate the effect of emotions on presence.

3 METHOD

In order to investigate RQ1 and RQ2, we conducted an experiment using a 2 x 2 between-groups design with two independent variables: $Emotion_{VE}$ describes the emotion a VE was designed to induce, with levels Fear (F) and Happiness (H); $Agency_{VE}$ describes the agency afforded by a VE, with levels Agency (A) or Non-Agency (NA). Participants were randomly assigned to one of four conditions: Happiness-Agency (HA), Happiness-Non-Agency (HNA), Fear-Agency (FA) and Fear-Non-Agency (FNA). In each condition we took subjective measures of emotion, agency and presence. In the following, we describe our VEs, measures, procedure, hypotheses and participants.

3.1 Stimuli

Rather than using pre-programmed VEs (e.g. [82]), we designed and implemented our VEs ourselves in order to retain the best possible control over their relevant characteristics. Design choices such as the type of VE to use, lighting and weather conditions, time of day etc were made based on previous mood induction research [24, 86]. Four VEs were developed, two to induce fear or happiness while supporting agency, and the other two to induce fear or happiness but with no agency. In all four VEs, participants were able to look around freely using six degrees of freedom. Participants were told not to walk around, however, as reaching the boundaries of the tracking space would have broken presence. Participants had no VR body represented in the VE in order to avoid introducing potential confounding variables such as body ownership [78]. Each condition lasted exactly three minutes. This timing was chosen as it has been shown to be the optimal duration to induce VR presence while precluding boredom [92].

3.1.1 Visuals. The Happiness VEs consisted of a park environment during a sunny day. Parks have been successfully used in literature investigating the relationship between emotion and presence [3, 4, 24, 64]. Participants were accompanied by a dog which walked around the participant, in a scripted pattern of movement and with semi-random actions that were all friendly and not threatening (e.g. sniffing, playing, jumping in the air). The dog and its movements were screened by pilot participants and were all found to be friendly and non-threatening. In the HNA condition, participants could only observe the dog performing the scripted movements. These were designed so that the dog would eventually go around the participant, which would make the user turn and experience the entire park. The dog approached the participant four times during the experience, each time performing a friendly action. In the HA condition, participants were able to direct a virtual laser pointer by moving a tracked VR hand controller. If the participant flashed the pointer in front of the dog on the ground, it attracted the dog's attention and interrupted the scripted movement pattern temporarily. The dog would respond by barking in a friendly way, jumping to catch the pointer or following it.

The Fear VEs were designed to mimic the Happiness VEs as closely as possible while changing only the elements designed to induce the corresponding emotions. Instead of the friendly dog, a menacing looking wolf with dark fur appeared in this condition. This creature maintained the main body characteristics of the dog, such as locomotion, size and shape. The same park VE was used but it was darkened in order to appear as night time. Fog was added to mask the movements of the creature, which was designed to add to the fear and discomfort felt by users. The wolf followed the same scripted pattern of movements as the dog in the Happiness VE. This consistency was maintained to minimize differences in user movement across conditions. The wolf approached the user four times, at the exact same times as those for the friendly dog. The wolf, however, jumped and attacked the user each time it approached, after which it retreated and circled the user again. In the FNA condition, participants had no way to defend themselves from these attacks. In contrast, in the FA condition participants could direct a flashlight using the hand controller which, if directed in the face of the approaching wolf, would make it retreat. The laser pointer in the HA condition and the flashlight in the FA condition used similar virtual light beams. They were designed so that the user's interaction with the controller was identical in the agency conditions.

Our VE design ensured that afforded agency was similar in the Happy (HA) and Fear (FA) conditions. In both FA and HA there were consequences for remaining passive: while the Fear wolf would attack, the Happy dog would distance itself. The movements of the wolf and dog were similar, and affected to similar degrees by a user's interaction, but in opposite ways. Thus, in both FA and HA, users were able to exert a substantial degree of influence on the animal, and this was controlled so as to be as similar as possible. Log data of the interactions were collected to determine the number of times users interacted with the animal in each of the agency conditions.

3.1.2 Audio. Royalty-free music was sourced online for audio accompanying each VE. We conducted a pilot study with 12 participants to validate our VEs and the audio pieces used. Five happy and five fear inducing pieces were chosen by the experimenters. These were played in conjunction with our VEs and they were scored on the levels of happiness and fear they induced. The pieces with the highest scores were chosen for the study. The pilot study also confirmed that the fear scores in the Fear VE were significantly higher than the happiness scores in that VE, and vice versa for the Happiness VE. The track "Happy Sandbox" was chosen for the Happiness conditions [49]. For the Fear conditions, "Dark Ambient Music 3" was used [90]. Each piece spanned the duration of the VR experience.

3.1.3 Apparatus. An HTC Vive HMD was used to display the VEs. The headset had a refresh rate of 90Hz and dual OLED panels with a density of 1080 x 1200 pixels per eye. For enhanced sound quality, Sennheiser HD 380 Pro headphones were connected to the HMD. These were powered by a desktop computer running Windows 10 with an Intel i7-9900k processor, an RTX 2080Ti GPU and 64GB of RAM. These specifications align with recent studies using similar VR stimuli and Unity recommendations [50].

3.2 Measures

We used the comprehensive "User Experience in Immersive Virtual Environments" questionnaire proposed by Tcha-Tokey et al. [80], which has been validated by the authors for use with VR and showed good reliability and sensitivity. The *Presence* subscale is based on the presence subscale of Witmer and Singer's Presence Questionnaire [89], which has been widely used for measuring presence in VEs.

We also compiled a subjective *Agency* subscale from three items present in Tcha-Tokey et al.'s [80] questionnaire. These were chosen so that they specifically refer to control over events in the VE and of the avatar, which aligns with the common definition of agency as the degree to which a user perceives they have the ability to interact with elements of an environment and control their actions [76]. All items in the questionnaire were assessed on 10-point Likert scales (1 = Strongly Disagree, 10 = Strongly Agree). A Cronbach's alpha internal reliability analysis was conducted and this yielded a value of .623, which is considered as acceptable [37]. Removing any of the three items reduced Cronbach's alpha below the accepted threshold of .600.

When investigating the emotion-presence relation, Riva et al. [64] found that using direct questions to assess emotion was a reliable measure. Replicating their methodology, levels of happiness and fear were assessed via simple questions immediately after completing the VR experience: "For the following emotions (happiness, fear), how intensely did you feel them during the VR experience?". Responses were measured on Likert scales from 1 (lowest) to 10 (highest), as Baños et al. [3] demonstrated this to be reliable when assessing emotional intensity pertaining to VR experiences. Happiness and fear are typically characterised by high arousal. Choosing high intensity emotions allowed us to focus on differences in valence. We take the intensity of an emotion to be the subjective appreciation by the user of how much they feel that emotion, whereas arousal refers to the physiological reactions in the human body when an emotion is felt [19]. Thus, the items assessing emotions were intended to measure emotional intensity and not arousal (i.e. we measured how much fear a user felt as opposed to whether their physiological state aligned with the high arousal of fear).

In the following, *Happiness* denotes the intensity of perceived happiness, *Fear* the intensity of perceived fear, and *Intensity* denotes the intensity of the dominant emotion induced by its corresponding VEs; i.e. it measures the intensity of *Happiness* in the happiness inducing VEs and the intensity of *Fear* in the fear inducing VEs. Thus, *Intensity* is not a composite variable of *Happiness* and *Fear* but is simply the *Happiness* values from the happiness inducing VEs (HA and HNA), and the *Fear* values from the fear inducing VEs (FA and FNA).

3.3 Procedure

Participants were greeted by the experimenter and asked for consent after reading an information sheet describing the study. All questionnaires were displayed and completed using the Qualtrics online questionnaire system.

Participants completed a pre-task demographics questionnaire in Qualtrics and were given a description of the type of VE they would experience, including whether or not they would have agency and either that the VE was designed to be fear inducing or happiness inducing (depending on their respective condition). None of the participants was aware of the other conditions in the study. Participants were assisted to wear the HTC Vive. Then participants underwent a calibration phase during which the Vive HMD was adjusted until they were able to read the smallest text size presented. This process also served the role of familiarizing participants with the HMD's head-tracking and VR-specific distance compression [26]. If assigned to one of the agency conditions (HA or FA), participants were told how to use the hand controller.

After the experimental condition, participants removed the HMD and used Qualtrics on a computer screen to complete the questionnaires assessing subjective emotion intensities, presence and other measures. The questions assessing *Happiness* and *Fear* were completed first, immediately after the VR experience ended. At the end of the study, participants were debriefed and compensated for their time. An experimental session took on average 30 minutes to complete.

3.4 Hypotheses

Based on the findings of previous related work, we posed the following *a priori* hypotheses:

- **H1** The intensity of the dominant emotion in each VE (*Intensity*) will correlate positively with *Presence*.
- **H2** *Presence* will be significantly higher in environments where participants have *Agency*.
- **H3** *Agency* will moderate the effect of *Emotion* on *Presence*.

3.5 Participants

We had 121 participants (39 males, 86 females), aged 18-45 (M = 21.4, SD = 4.40). Participants were randomly assigned to one of four conditions: FA (n = 30), FNA (n = 29), HA (n = 31) or HNA (n = 31). The sample size for each group was calculated with an *a priori* power analysis for a between-factors ANOVA for main factors and interaction by using G*Power 3.1 [23]. For the estimation we used a partial eta-squared η_p^2 of 0.06 (for a medium effect size), a level of power of 0.80, 4 groups, 1 numerator df (degree of freedom; for main factor $2 - 1 = 1$, for interaction $(2 - 1) \times (2 - 1) = 1$), and an α-level of 0.05. This analysis returned a sample size of 31 per group. Through an initial questionnaire, participants were screened through exclusion criteria for history of neurological disease, use of medication for psychological or emotional issues, epilepsy or use of medical devices (e.g. heart pump). Additionally, they were screened for cynophobia (fear of dogs). Their level of experience with VR was also assessed. All participants had normal or corrected to normal vision and normal hearing. Participants were paid £5 for participation. This study was approved by the Department of

Psychology Ethics Committee at the University of Bath (Ethics code: UG 19-017).

4 RESULTS

We confirmed that the data satisfied the assumptions of a repeated measures analysis of variance (ANOVA). We used two-way repeated measures ANOVAs to compare the effects of our design variables ($Emotion_{VE}$ and $Agency_{VE}$). Paired t-tests with Holm correction were used for all pairwise comparisons between conditions. We used independent samples t-tests for all other between or within group comparisons as the data were normally distributed. All tests for significance were made at the $\alpha = 0.05$ level. In this section we mark a p-value below .05 with '*' and one less than or equal to .01 with '**'. The error bars in the graphs show the 95% confidence intervals of the means. We tested for differences in VR experience between our participant groups. A one-way ANOVA showed that the 4 participant groups did not significantly differ in their level of VR experience ($F(1, 117) = 0.106, p = .746$). A Pearson correlation also showed that there was no correlation between VR experience and Presence ($r(119) = .080, p = .38$).

4.1 Manipulation Check

First, we verified that the VEs elicited the desired emotions. Results showed that *Happiness* was significantly higher in the Happiness VEs compared to the Fear VEs ($t(114.8) = -6.384, p < .001^{**}, d = -1.162$). Similarly, *Fear* was significantly higher in the Fear VEs compared to the Happiness VEs ($t(115.754) = 6.742, p < .001^{**}, d = 1.227$). Secondly, we tested whether in the Happiness VEs happiness was indeed felt more strongly than fear and vice versa in the Fear VEs. Paired-samples t-tests showed that in the Happiness VEs *Happiness* ($M = 5.85, SD = 2.11$) was significantly higher compared to *Fear* ($M = 4.41, SD = 2.67$), ($t(60) = 2.544, p = .011^{*}$). For the Fear VEs, as expected, *Fear* ($M = 5.97, SD = 2.56$) was significantly higher than *Happiness* ($M = 4.33, SD = 2.26$), ($t(59) = 3.002, p = .004^{**}$). These results confirm that our manipulations of emotion worked as intended in the VEs design.

An independent samples t-test was run to compare *Agency* between agency and non-agency VEs. This showed that the agency VEs ($M = 6.56, SD = 1.91$) indeed led to significantly increased *Agency* compared to non-agency VEs ($M = 4.94, SD = 1.70$), ($t(119) = 4.921, p < .001^{**}$). In order to validate the three questionnaire items for measuring *Agency*, we conducted a Confirmatory Factor Analysis which showed that all three factors correlated and significantly contributed to the *Agency* variable ($p < .001^{**}$).

Last, we analysed the user interaction log data and used a paired samples t-test to compare the number of times users interacted with the wolf in the FA condition to the number of interactions with the dog in the HA condition. Results showed that the number of interactions in HA ($M = 9.13, SD = 3.39$) was significantly higher than that in FA ($M = 4.17, SD = .38$), ($t(29) = 7.910, p < .001^{**}$).

4.2 Emotion and Presence

One-tailed Pearson correlations showed that *Presence* and *Happiness* were significantly positively correlated in the Happiness VEs ($r = .371, p = .002^{**}$). Furthermore, *Fear* did not significantly correlate with *Presence* in these happiness inducing VEs ($r = -.106, p = .207$). One-tailed Pearson correlations showed that, as expected, *Presence* and *Fear* were significantly positively correlated in the Fear VEs ($r = .244, p = .030^{*}$). Furthermore, *Happiness* did not significantly correlate with Presence in these fear inducing VEs. We therefore accept H1.

4.3 Agency and Presence

To test H2, that having agency would significantly increase *Presence*, a between-groups analysis of variance (ANOVA) was conducted. The ANOVA tested the effect of experimental condition (HA, FA, HNA, FNA) on *Presence* and found main effects for $Emotion_{VE}$ ($F(1, 117) = 7.946, p = .006^{**}, eta_p^2 = .056$) and $Agency_{VE}$ ($F(1, 117) = 7.168, p = .008^{**}, eta_p^2 = .050$). A significant interaction effect was found between $Emotion_{VE}$ and $Agency_{VE}$ ($F(1, 117) = 10.569, p = .002^{**}, eta_p^2 = .074$). Post-hoc tests using Holm correction found that presence was significantly greater in FA compared to FNA ($M = 1.14, SE = 0.27, p < .001^{**}$), HA ($M = 1.17, SE = .0.27, p < .001^{**}$) and HNA ($M = 1.06, SE = 0.27, p < .001^{**}$). No other comparisons between conditions reached significance ($p > .05$). These results mean that H2 can be partially accepted, since *Presence* was higher when users had agency but only in the fear inducing condition.

We also ran a Pearson correlation and found an overall strong positive correlation between *Agency* and *Presence* ($r(119) = 0.686, p < .001^{**}$). That is, the more agency a user felt in the VE, the more present they felt.

4.4 Agency, Emotion and Presence

The interaction effect between $Emotion_{VE}$ and $Agency_{VE}$ found in our ANOVA for *Presence* was due to *Presence* levels being significantly different between FA and FNA but not between HA and HNA. This suggests that there exists a relationship between $Emotion_{VE}$ and $Agency_{VE}$, in that $Agency_{VE}$ had an effect on *Presence* only when the dominant emotion was *Fear*. This indicates that $Emotion_{VE}$ moderates the effects of $Agency_{VE}$, which in turn influence presence, validating H3. To better understand the interaction between $Emotion_{VE}$ and $Agency_{VE}$, we ran two ANOVAs, one comparing *Intensity* (see Fig. 3b) across conditions and the other comparing *Agency* (see Fig 3c).

For *Intensity*, we found a main effect for $Emotion_{VE}$ ($F(1, 117) = 11.611, p < .001^{**}, eta_p^2 = .086$) and an interaction effect between $Emotion_{VE}$ and $Agency_{VE}$ ($F(1, 117) = 6.154, p = .015^{*}, eta_p^2 = .046$). Post-hoc tests using Holm correction found that the only significant difference in *Intensity* was between FNA ($M = 5.23, SD = 2.24$) and HNA ($M = 7.43, SD = 1.55$)($p < .001^{**}$). These results mean that *Fear* was not significantly different between FA and FNA and, similarly, *Happiness* was not different between HA and HNA (see Fig 3b).

The ANOVA for *Agency* yielded main effects for $Emotion_{VE}$ ($F(1, 117) = 12.553, p < .001^{**}, eta_p^2 = .075$) and $Agency_{VE}$ ($F(1, 117) = 28.990, p < .001^{**}, eta_p^2 = .174$). Additionally, a significant interaction effect was found between $Emotion_{VE}$ and $Agency_{VE}$ ($F(1, 117) = 9.863, p = .002^{**}, eta_p^2 = .059$). Post-hoc tests using Holm correction found a difference in *Agency* between

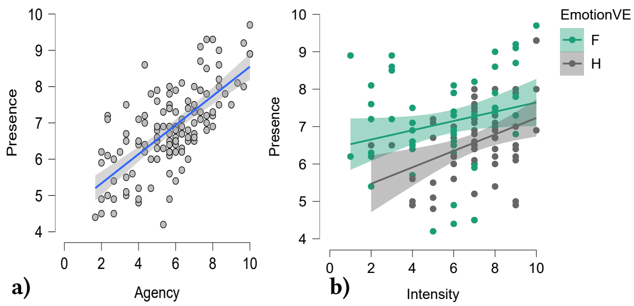

Figure 2: a) Correlation scatter plot between *Presence* and *Agency* for the happiness and fear-inducing VEs. b) Correlation scatter plot for *Presence* and *Intensity*. *Intensity* is the variable defining the dominant emotion in each VE (*Fear* for FA and FNA and *Happiness* for HA and HNA).

the FA ($M = 7.59, SD = 1.43$) condition and FNA ($M = 5.00, SD = 1.54, p < .001^{**}$), HA ($M = 5.56, SD = 1.79, p < .001^{**}$) and HNA ($M = 4.88, SD = 1.87, p < .001^{**}$) respectively (see Figure 3c).

5 MODELLING THE EFFECTS OF EMOTION AND AGENCY ON PRESENCE

In order to describe and explain the effects of emotion and agency on the formation of presence, we constructed a structural equation model (SEM) based on the hypotheses accepted in our experiment. We call our model the Presence, Emotion and Agency (PEA) model. SEM [36] is an established methodological framework that allows researchers to describe how concepts of interest affect each other, i.e. to model a network of causal effects between variables characterising these concepts. SEM models can predict how variables will likely affect each other, and the quality of a SEM model can be validated in terms of how well the model describes the effects observed in a data set (the *model fit*).

For the PEA model, we separated the factors relating to the design of our VEs ($Emotion_{VE}$ and $Agency_{VE}$) from the subjective measurements of felt emotion and agency (*Intensity* and *Agency*). As SEM models are quantitative and based on linear regressions between variables, we encode $Emotion_{VE}$ as emotional valence with values +1 for Happiness and -1 for Fear, and $Agency_{VE}$ as a binary variable with values 1 for Agency and 0 for Non-Agency.

The structure of a SEM model specifies how variables affect each other in a linear fashion. This can be illustrated as a directed graph, with rectangles representing variables and arrows representing the effects between them, as shown in Fig. 4. We first specify the direct relationships between the design factors $Emotion_{VE}$ and $Agency_{VE}$ and corresponding subjective measures *Intensity* and *Agency*. If a VE is designed to elicit emotion, then it will affect the emotional intensity perceived by a user, hence the arrow from $Emotion_{VE}$ to *Intensity*. Similarly, if a VE is designed to afford agency to a user, then it will affect the level of agency perceived by a user, hence the arrow from $Agency_{VE}$ to *Agency*. In our experiment we have determined that there are interaction effects between $Emotion_{VE}$ and $Agency_{VE}$ on subjective measures of *Intensity* and *Agency*. In SEM models such interaction is modelled as the product of the two interacting variables $Emotion_{VE} \times Agency_{VE}$, with arrows to the variables affected by the interaction. Finally, *Presence* is affected by both our subjective measures.

5.1 Model Evaluation

In order to estimate coefficients (also called parameters) for the linear effects between the variables and evaluate the SEM model using goodness of fit measures, we used the SEM maximum likelihood estimator provided by the R package lavaan [67]. According to the fit measures reported by lavaan, the model has a good fit to our experimental data, as indicated by the following four comparisons [69]: (1) the p-value associated with the χ^2 value comparing the covariance matrices of our model with the covariance matrix of our experimental data $p = .47$ is larger than .05, indicating that the model can be regarded as compatible with the data; (2) the Standardised Root Mean Square Residual $SRMR = .04$ and the Root Mean Square Error of Approximation $RMSEA < .01$, which are measures of difference between the covariance matrices, are below .05; (3) the 90% confidence interval of the RMSEA $[0, 0.11]$ contains 0; and (4) the Comparative Fit Index and Tucker-Lewis Index are greater than .97, indicating that our model fits much better to the data than a baseline model without the specified relationships.

5.2 Model Applications

Similar to simple linear regression, the model in Fig. 4 specifies two numbers on each arrow: the unstandardised coefficient for the linear relationship between the participating variables, and the standardised coefficient in parentheses. The unstandardised coefficient allows us to estimate effects in terms of the scales used by the participating variables. For example, affording agency to the user of a VE ($Agency_{VE} = 1$) is estimated to increase *Agency* by 1.64 on its 10-point Likert scale. The standardized coefficients are independent of the scale of the participating variables; they specify how many standard deviations the target variable will change per standard deviation increase in the predictor variable. For example, the standardised coefficients tell us that *Agency* has a much stronger positive effect on *Presence* than *Intensity* does. Similar to regression analysis, all linear relationships between variables in the SEM can be tested for significance. In our model, all of them are significant ($|z| \geq 2.52, p \leq .01^{**}$). The regression of *Intensity* ($R^2 = .13$) has a medium effect size, and the regressions of *Agency* ($R^2 = .30$) and *Presence* ($R^2 = .51$) have large effect sizes [14].

By considering the coefficients of the model, it is possible to estimate not only the direct effects along a single arrow, but also the indirect effects along a model path. For example, let us consider the strengths of the effects the design factors $Emotion_{VE}$ and $Agency_{VE}$ have on *Presence*. The standardised direct effect of $Emotion_{VE}$ on *Intensity* is 0.51 and the standardised direct effect of *Intensity* on *Presence* is 0.20. The indirect standardised effect of $Emotion_{VE}$ on *Presence* is the product of the two, i.e. $0.51 \times 0.20 \approx 0.10$. Analogously, the indirect standardised effect of $Agency_{VE}$ on *Presence* is $0.42 \times 0.69 \approx 0.29$. So if the other of the two respectively stays constant, the effect of $Agency_{VE}$ on *Presence* is almost three times as strong as that of $Emotion_{VE}$, which can explain why experiments

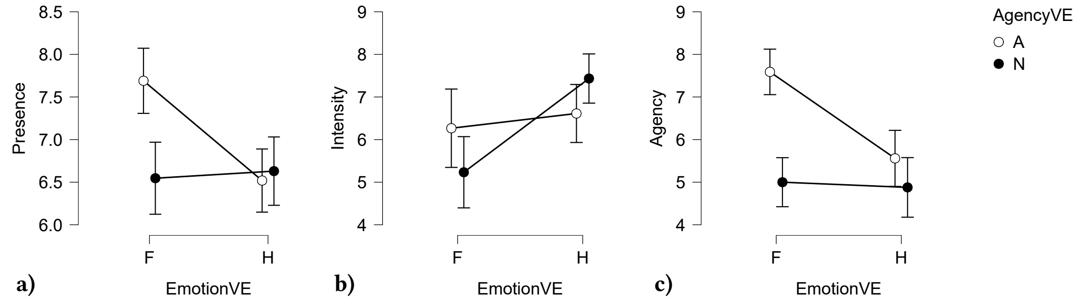

Figure 3: a) Levels of *Presence* reported in all conditions, as manipulated through $Emotion_{VE}$ and $Agency_{VE}$. b) *Intensity* reported in all conditions, as manipulated through $Emotion_{VE}$ and $Agency_{VE}$. *Intensity* is the variable defining the dominant emotion in each VE (*Fear* for FA and FNA and *Happiness* for HA and HNA). c) Levels of *Agency* reported in all conditions, as manipulated through $Emotion_{VE}$ and $Agency_{VE}$. Error bars represent confidence intervals in all three graphs.

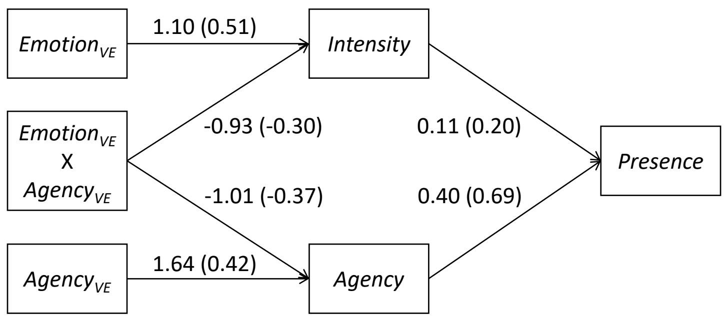

Figure 4: Structural equation model describing the indirect effects of the VE design factors $Emotion_{VE}$ and $Agency_{VE}$ and the direct effects of subjective measures of *Intensity* and *Agency*. The labels are unstandardised regression coefficients, and standardised coefficients in brackets.

not controlling for agency across VEs may find spurious relationships between emotions and presence that are in fact caused by differences in agency.

In order to analyse the total effect of a variable on another, the effects of all paths between them must be summed. So the total effect on *Presence* of the interaction between the VE design factors emotion and agency $Emotion_{VE} \times Agency_{VE}$ is $-0.30 \times 0.20 - 0.37 \times 0.69 \approx -0.32$. The sign of $Emotion_{VE} \times Agency_{VE}$ is determined by the valence of the emotion the VE is designed to elicit. Thus, designing a VE to induce the negative emotion of fear ($Emotion_{VE}$ = -1) while providing affordances for agency ($Agency_{VE}$ = 1) is estimated to increase *Presence* with a standardised effect of 0.32. This is quite large compared to the standardised separate effects on *Presence* of $Emotion_{\ VE}$ (0.10) and $Agency_{VE}$ (0.29), which is why not considering this interaction in experiments about presence may again lead to spurious results.

In order to calculate the magnitude of effects in terms of the measurement scales used, analogous calculations can be performed with the unstandardised coefficients. For example, consider two VEs that are compared with regard to their effect on presence: the first elicits a negative emotion and the second elicits a positive emotion, but the first of the VEs affords agency to the user and the second does not. The difference in *Presence* caused only by differences in the emotion inducing design of the VEs, $Emotion_{VE}$, can be estimated as $(+1) \times 1.10 \times 0.11 - (-1) \times 1.10 \times 0.11 \approx 0.24$ scale points. The difference caused by $Agency_{VE}$ alone can be estimated as $0 - 1.64 \times 0.40 \approx -0.66$ scale points, and the difference caused by the interaction of $Agency_{VE}$ and $Emotion_{VE}$ as $(0-(-1)) \times (-0.93 \times 0.11 - 1.01 \times 0.4) = -0.51$. Then the overall difference in *Presence* between the VEs can be estimated as $0.24 - 0.66 - 0.51 = -0.93$. By contrast, if $Agency_{VE}$ had been controlled, then the difference in *Presence* between the VEs would have been estimated as 0.24 if neither of the VEs afforded agency and as -0.77 if both VEs afforded agency. This illustrates that the results of experiments can be strongly confounded by $Agency_{VE}$, potentially leading to erroneous conclusions about the effects on presence of emotions elicited by VEs.

6 DISCUSSION

6.1 Effects of Emotion on Presence

This study investigated relations between emotion, agency and presence in VR. Our first research question asked simply if there is a relation between a user's emotions and presence. Testing H1 confirmed that there is indeed such a relation, specifically that emotional intensity is a major factor in the formation of presence. Furthermore, our structural equation model showed that this is mainly due to the emotional intensity that people actually feel in the VE, and it is less influenced by the valence of the emotion that the VE was designed to induce, $Emotion_{VE}$. Our SEM nonetheless showed that the design level factor, $Emotion_{VE}$, had a significant impact on the dominant emotion in each VE.

This was confirmed by the manipulation checks which showed that, similar to previous research [64, 71, 82], our VEs achieved their intended purpose. That is, the fear inducing VEs elicited significantly higher *Fear* than *Happiness*. An inverse effect was observed for the happiness inducing VEs, which scored significantly higher *Happiness*. This validation of the VE designs in turn gives us confidence in the validity of our findings based on those designs.

As expected, *Happiness* positively correlated with *Presence* in the happy conditions, which is in line with the findings of Baños et al. [4], and *Fear* positively correlated with *Presence* in the fear conditions. Fear had not been investigated as a dominant emotion in Baños et al.'s [4] study, so we show here for the first time that even when a negative emotion, such as fear, is predominant in a VR environment, higher levels of the emotion are associated with increased presence.

Most previous research has looked mainly at the design of VEs with regard to valence and has not explicitly considered emotional intensity [3, 18, 24, 25, 64]. Our SEM also showed that *Intensity*, i.e. the intensity of the dominant emotion in each VE, impacts *Presence*. In particular, *Happiness* levels predicted *Presence* in the happiness inducing conditions but *Fear* did not. An inverse pattern of results was found for the fear inducing conditions, whereby *Fear* levels predicted *Presence* but *Happiness* did not. This is in contrast to Baños et al. [4] who found that negative emotions correlated with presence, even in VEs that were designed to elicit positive emotions (joy and relaxation). A possible explanation for this difference in results is that we specifically assessed happiness and fear, whereas Baños et al. [4] employed the PANAS measure of affect which contains multiple negative emotions, such as distress, nervousness, shame and guilt. It is therefore not possible to tell which of these negative emotions may have driven their correlation. In this regard, our study provides a more targeted assessment of the exact emotion that was most elicited by a given VE.

Our results show no difference in the relationship between, on one hand, the intensity of happiness in the happiness inducing VE and *Presence* and, on the other hand, the intensity of fear in the fear inducing VE and *Presence*. A possible explanation for this is that in some contexts, such as watching a horror movie or taking a rollercoaster ride, feeling fearful is interpreted at a cognitive level as a pleasurable emotion because it matches the intended purpose and design of the experience [13]. Indeed, some participants reported that they enjoyed the fear inducing VE because of its excitement. Still, it should be noted that the effect size for the correlation between *Fear* and *Presence* was much smaller than that between *Happiness* and *Presence*. This may suggest that some detachment effect did occur in the fear conditions but was not strong enough to make the correlation non-significant.

6.2 Effects of Agency on Presence

Our second research question asked how the level of agency afforded to a user affected presence. We hypothesised (H2) that presence will be higher in VEs where participants have agency and (H3) that agency moderates the effect of emotion on presence. In other words, we expected that *Agency* would have a direct effect on *Presence* and that there would be an interaction effect between *Intensity* and *Agency* which would lead to an indirect effect on *Presence*.

Our results showed that *Agency* is indeed a major factor that has a direct effect on the formation of *Presence*. This is something others have found but never in a rich VR environment that depicted a realistic location (see [34, 43, 46, 91]). Furthermore, *Agency* and *Intensity* interact strongly in their effect on *Presence*. The important implication is that we have to look at both of them together, or carefully control for one or the other, in order to see clear effects. Otherwise the effects of these two factors will be confounded. For example, we cannot be sure whether affording agency to users would have an effect on *Presence* without controlling for the dominant emotion that the VE is eliciting.

Comparing the fear inducing conditions, FA scored higher levels of *Presence* than FNA. This result shows, for the first time, that agency is beneficial to presence formation within a realistic VR environment. However, this was not the case for the happiness inducing conditions (HA and HNA), which scored similar levels of *Presence*. The lack of an effect of $Agency_{VE}$ on *Presence* in the happy conditions is surprising and means that H2 can be only partially accepted.

This result may be explained by the special status of fear amongst all other emotions. Fear benefits from cognitive and perceptual priority which stems from its evolutionary role in survival functions [52]. It is reasonable to assume that our fear conditions triggered a fight or flight response, which is a powerful survival instinct when one is faced with a threat [56]. Such responses are known to be especially triggered by wild animals such as snakes, tigers and wolves, such as the one used in our design [38]. Moreover, such fears are considered 'universal', due to their evolutionary nature, meaning that they are experienced by all humans [61].

A fight or flight response in turn requires agency to act upon it. Hence, in our fear inducing VEs, benefiting from agency became a stronger factor than felt emotions as it was instrumental to 'survival'. Having agency is known to heighten the believability and naturalness of a VE [41], as well as preoccupying the user with defending themselves. First, this means that users were likely more engaged with the VE, which is known to drive presence [18, 39]. Secondly, directing users' attentional and cognitive resources towards defence from the creature may have meant that they were less likely to observe imperfections in design or graphics characteristics of the VE (e.g. shadows, resolution etc). This again would have had a positive impact on presence [16].

Importantly, although $Agency_{VE}$ did lead to higher *Presence* in the FA condition compared to FNA, there was no difference in *Fear* between FA and FNA. This finding is novel and shows for the first time an important dissociation between *Fear* intensity and *Presence*, whereby it seems that agency felt by users is a better predictor of the latter. Indeed, when comparing levels of *Agency* across the four conditions, an identical pattern of results to that for *Presence* can be observed (Fig 3c). We see a difference in *Agency* between FA and FNA but not between HA and HNA.

An intriguing finding is the lack of an effect of $Agency_{VE}$ on *Intensity*. Previous research has suggested that agency can offer users a mechanism to regulate emotions experienced in VR [66]. This involves implicit or explicit attempts to modify the intensity of felt emotions [33, 35]. Based on this evidence, we might have expected participants benefiting from agency to increase their feelings of *Happiness* in the happiness inducing conditions, because happiness is a positive and desirable state, and to limit the intensity of their fear because it is negative. Applied to our VEs, being able to interact with the dog in the HA condition should therefore have led to increased happiness. On the other hand, users being able to defend themselves against the creature in the FA condition would have reduced *Fear* because they would have felt more in charge of the situation. However, neither of these effects occurred as *Happiness* was similar across HA and HNA, and so was *Fear* across FA and FNA. This suggests that implementation of agency in VR applications should not be based on the assumption that it always leads to higher levels of felt emotions.

Another finding is that users in the HA condition, although provided with the possibility of interacting with the dog, did not report a perceived increase in *Agency* compared to HNA. In contrast, within the fear inducing VEs, participants did report increased agency for FA compared to FNA. This effect being due to a difference in agency afforded by the VEs can be excluded. Our log data show that both conditions were successful in motivating all users to interact, either to avert fear (negative motivation) or to experience playful interaction (positive motivation). The perceived lesser agency in HA cannot be explained by fewer interactions, as users interacted significantly more often with the animal in HA than in FA. In fact, within the HA condition the dog would stay visible to the user for longer while interacting. Observations and comments made by our participants also showed clearly that they were aware of the afforded agency in HA, and that they were literally 'happy' about being able to interact, as opposed to HNA. Thus, the lack of an increase in perceived *Agency* in the HA condition cannot be due to a failure of the system to afford said agency.

Instead, the explanation for this effect may lie in the nature of the studied emotions. It is more likely that the 'fight or flight' response elicited by the wolf made agency relevant for survival in the FA condition, since participants could make use of the torch to defend themselves. A previous study by Jeunet et al. [40] found that agency is divided into two components, namely the feeling and the judgement of agency. It was previously argued that feeling agency in a VE may not necessarily lead to that agency being consciously acknowledged and reported (referred to as judgement) [22, 30, 40, 79]. This could explain why users may have judged that they did not have agency in the HA condition when in fact agency was available to them. Our results suggest that perhaps agency is consciously acknowledged (judged) only when it is necessary for the task at hand. In the happy scenario, users did not depend on agency to defend themselves but could use it at their leisure potentially to increase their enjoyment of the VE. In contrast, in the FA condition the fight or flight instinct meant that agency was essential [38, 52, 56] and that may have made it consciously acknowledged and reported in the questionnaire. Hence, implementing agency in a VR application should be prioritised only in cases where it makes a meaningful contribution to the narrative and context of the experience. Otherwise, it may remain unrecognised and unused by the user.

6.3 The Presence, Emotion and Agency (PEA) Model

Our third research question asked how we can model the effects of emotion and agency on presence. To address this question, we constructed and applied a structural equation model based on our empirical data. Our SEM, known as PEA, allowed us to separate $Emotion_{VE}$ and $Agency_{VE}$ as VE design factors from emotional intensity (*Intensity*) and agency (*Agency*), which are user experience variables (i.e. actually felt by users). By doing this, we are for the first time able to clarify the formation of felt emotional intensity and felt agency based on VE design, and in turn the influence of felt emotional intensity and felt agency on the formation of presence.

Our model is able to explain the effects of confounding the VE design factors emotion and agency. It explains why empirical investigations of the effects on presence of emotion and agency in isolation, without controlling for the other, can lead to spurious results (i.e. differences that are not really there but result from the confounds) and can also mask real differences (i.e. effects on presence that are just not visible because of the confounds).

We agree with R1 that once a VE has been designed, its perceived intensity and agency are (on average) implicit and fixed values. In line with this, our model helps designers to predict how their VE will be perceived based on how emotion and agency were 'designed into them'. We will clarify that to support the model, our conditions used different VE designs; they did not compare how one design was influenced by other factors.

It should also be acknowledged that once a VE has been designed, its perceived intensity and agency are (on average) implicit and fixed values. In line with this, our model helps designers to predict how their VE will be perceived based on how emotion and agency were 'designed into them'. Here we did not investigate how perception of a VE was influenced by other factors as we were strictly focusing on the impact of user agency and emotions.

The observed dissociation between emotion and presence is also reflected in the SEM, in that the regression coefficient for the effect of *Agency* on *Presence* (0.69) is much higher compared to that of *Intensity* (0.20). This suggests that emotional intensity is able to predict presence in VR to a lesser extent than agency is.

Overall, these results point to an even more important effect: that agency and emotion interact in the presence creation process. This is a significant finding since studies so far have only investigated either emotion [3, 4, 24] or agency on their own [12, 34, 43, 46]. *Agency* does not always have an effect on *Presence*. Instead, there seems to be an interaction between the two whereby only if the dominant emotion in a VE is *Fear* does agency enhance *Presence*. This is reflected in the SEM (see Fig 4). Our two design factors, $Emotion_{VE}$ and $Agency_{VE}$, interact and they have an effect on both *Intensity* and *Agency* separately. The latter two factors then have an impact on *Presence*. This is a novel finding and one of great importance for the design of VR applications. For the first time, we are able to understand the contribution of perhaps the two most relevant human factors to presence. Our model enables experimenters to gain insight on the formation of presence based on emotion and agency. Furthermore, it gives VR designers a tool to predict the effects of their design choices and thereby optimise designing for presence.

Ultimately, it becomes apparent from the SEM that controlling only emotions or only agency in VR cannot suffice for ensuring presence. Instead, the interrelations between emotion and agency and their influence on presence mean that VR designers need to prioritise agency in the right circumstances while designing the VE to elicit high levels of emotions.

6.4 Limitations

One potential limitation in our study is the use of non-human agents (the dog and creature). Previous definitions of presence have emphasized feeling a sense of 'togetherness' with other social actors [47]. Additionally, studies have shown that emotions have higher social salience when elicited by facial features [52, 56]. Thus, the use of non-human agents may have somewhat reduced *Presence*. However, the use of non-human agents was intentional in the present study because human agents would have introduced a host of confounding variables that impact emotion, such as their height [28], race[32], realism [68] and facial features [75]. Building on our study, future studies could use anthropomorphic or human avatars to investigate the effects of such factors on presence [55].

Several other factors that can impact presence were not investigated here as they were beyond the scope of the study. One such example is the impact that a user's past experiences may have on the level of presence achieved. For example, being more familiar with dogs' behaviour could have reduced the credibility of the dog avatar in the Happiness conditions. Non-human factors such as the level of graphical fidelity, the field of view and sound quality can also impact presence [16]. Our VEs were specifically controlled so as to minimise the impact of these factors by maintaining all such characteristics identically across conditions.

Another possible limitation could arise from the duration of our VR experiences (three minutes), which was chosen because it has been shown to be optimal for the creation of presence while not allowing boredom to set in [92]. In the non-agency conditions, participants knew they could not interact with the VE and all that was expected of them was to observe the dog or the creature. Similarly, in the HA condition, agency was afforded but the experience did not provide participants with a specific goal or task. This in turn may reduce engagement with a VE [77] and thus negatively affect presence [18, 39]. The condition that could perhaps have been treated differently is FA, due to it having a clear purpose: defending oneself against the creature. This characteristic could have been used to gamify the experience and provide participants with a purpose that they could feel invested in. This may partially explain why FA scored higher *Presence* compared to all other conditions.

Although user levels of *Happiness* and *Fear* reported within each condition look close, they were significantly different from each other with a medium effect size, which is consonant with other studies that elicited multiple emotions in VR (e.g. [24, 64]). Moreover, qualitative feedback from participants confirmed that each emotion was felt intensely in the VE that was designed to elicit that emotion. Eliciting strong emotional differences in VR is challenging due to the novelty of the medium for many users. It is possible that this novelty could lead to reported happiness being high due to the excitement of using VR and regardless of the emotion elicited by the content itself.

It should be noted that our PEA model will not always predict perceived *Intensity*, *Agency* and *Presence* accurately as those variables are influenced by many design, user and context-related factors. In addition, the model considers the design factors $Emotion_{VE}$ and $Agency_{VE}$ only at their extreme values, as binary variables, while they are usually changing on a continuous scale. However, our model was created based on data from representative VEs and is capable of explaining important phenomena that have previously been unexplained. The model is a useful tool for designers if its predictions are considered with due regard to these limitations.

Lastly, while our assessment of emotions was shown to be effective, real-time measurements of arousal levels could potentially provide additional useful information. They could allow for the pairing of events within the VE (e.g. the wolf attacking) with physiological reactions such as skin conductance and heart rate, which have been argued to be good indicators of emotions [19]. Much work needs to be conducted in this area, however, as research so far has been unable to reach a consensus on the usability of physiological measures in assessing VR presence (see [19, 21, 24]).

6.5 Conclusion

We developed and used a set of custom VEs to test, for the first time, the combined effect of emotion and agency on presence in VR. First, we tested the effect of both emotional valence and intensity on presence. Previous research has provided some evidence that both agency and emotion may affect presence but no study so far has investigated their interrelations and how they contribute together to the sense of presence in VE. Our results begin to demonstrate the implications of affording agency to users in VR, and the potentially complex relations that exist between human factors in the creation of presence. We propose a new model of presence that incorporates both emotion and agency, and illustrate its utility with our data. This model can be used by researchers to control for both emotion and agency when designing VR studies, while VR content creators can use the model to prioritise either eliciting emotions or affording agency, depending on the nature of the VE, with the ultimate goal of maximising presence.

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REFERENCES

[1] Ivan Alsina-Jurnet and José Gutiérrez-Maldonado. 2010. Influence of personality and individual abilities on the sense of presence experienced in anxiety triggering virtual environments. *International journal of human-computer studies* 68, 10 (2010), 788–801.

[2] Asit Arora, Loretta YM Lau, Zaid Awad, Ara Darzi, Arvind Singh, and Neil Tolley. 2014. Virtual reality simulation training in Otolaryngology. *International Journal of Surgery* 12, 2 (2014), 87–94.

[3] Rosa María Baños, Cristina Botella, Mariano Alcañiz, Víctor Liaño, Belén Guerrero, and Beatriz Rey. 2004. Immersion and emotion: their impact on the sense of presence. *Cyberpsychology & behavior* 7, 6 (2004), 734–741.

[4] Rosa M Baños, Cristina Botella, Isabel Rubió, Soledad Quero, Azucena García-Palacios, and Mariano Alcañiz. 2008. Presence and emotions in virtual environments: The influence of stereoscopy. *CyberPsychology & Behavior* 11, 1 (2008), 1–8.

[5] Lisa Feldman Barrett. 1998. Discrete emotions or dimensions? The role of valence focus and arousal focus. *Cognition & Emotion* 12, 4 (1998), 579–599.

[6] Manon Bertrand and Stéphane Bouchard. 2008. Applying the technology acceptance model to VR with people who are favorable to its use. *Journal of Cyber Therapy & Rehabilitation* 1, 2 (2008).

[7] Philippe Bertrand, Jérôme Guegan, Léonore Robieux, Cade Andrew McCall, and Franck Zenasni. 2018. Learning empathy through virtual reality: multiple strategies for training empathy-related abilities using body ownership illusions in embodied virtual reality. *Frontiers in Robotics and AI* 5 (2018), 26.

[8] Corey J Bohil, Bradly Alicea, and Frank A Biocca. 2011. Virtual reality in neuroscience research and therapy. *Nature reviews neuroscience* 12, 12 (2011), 752–762.

[9] Adrián Borrego, Jorge Latorre, Mariano Alcañiz, and Roberto Llorens. 2019. Embodiment and presence in virtual reality after stroke. A comparative study with healthy subjects. *Frontiers in neurology* 10 (2019), 1061.

[10] Emily Brown and Paul Cairns. 2004. A grounded investigation of game immersion. In *CHI'04 extended abstracts on Human factors in computing systems*. 1297–1300.

[11] Paul Cairns, Anna L Cox, Matthew Day, Hayley Martin, and Thomas Perryman. 2013. Who but not where: The effect of social play on immersion in digital games. *International Journal of Human-Computer Studies* 71, 11 (2013), 1069–1077.

[12] Joon Hao Chuah, Andrew Robb, Casey White, Adam Wendling, Samsun Lampotang, Regis Kopper, and Benjamin Lok. 2012. Increasing agent physicality to raise social presence and elicit realistic behavior. In *2012 IEEE Virtual Reality Workshops (VRW)*. IEEE, 19–22.

[13] Mathias Clasen. 2017. *Why horror seduces*. Oxford University Press.

[14] Jacob Cohen. 1992. A power primer. *Psychological Bulletin* 112, 1 (1992), 155.

[15] Tiziano Colibazzi, Jonathan Posner, Zhishun Wang, Daniel Gorman, Andrew Gerber, Shan Yu, Hongtu Zhu, Alayar Kangarlu, Yunsuo Duan, James A Russell, et al. 2010. Neural systems subserving valence and arousal during the experience of induced emotions. *Emotion* 10, 3 (2010), 377.

[16] James J Cummings and Jeremy N Bailenson. 2016. How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology* 19, 2 (2016), 272–309.

[17] Jelle Demanet, Baptist Liefooghe, and Frederick Verbruggen. 2011. Valence, arousal, and cognitive control: a voluntary task-switching study. *Frontiers in psychology* 2 (2011), 336.

[18] Julia Diemer, Georg W Alpers, Henrik M Peperkorn, Youssef Shiban, and Andreas Mühlberger. 2015. The impact of perception and presence on emotional reactions: a review of research in virtual reality. *Frontiers in psychology* 6 (2015), 26.

[19] Darragh Egan, Sean Brennan, John Barrett, Yuansong Qiao, Christian Timmerer, and Niall Murray. 2016. An evaluation of Heart Rate and ElectroDermal Activity as an objective QoE evaluation method for immersive virtual reality environments. In *2016 Eighth International Conference on Quality of Multimedia Experience (QoMEX)*. IEEE, 1–6.

[20] Howard E Egeth and Steven Yantis. 1997. Visual attention: Control, representation, and time course. *Annual review of psychology* 48, 1 (1997), 269–297.

[21] Martin Ervik. 2017. *Contributing Factors of Immersion in Interactive Digital Storytelling-Evaluation of Heart Rate as a Parameter for Immersion in QoE assessment of Interactive Storytelling*. Master's thesis. NTNU.

[22] Chlöé Farrer and Chris D Frith. 2002. Experiencing oneself vs another person as being the cause of an action: the neural correlates of the experience of agency. *Neuroimage* 15, 3 (2002), 596–603.

[23] Franz Faul, Edgar Erdfelder, Albert-Georg Lang, and Axel Buchner. 2007. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods* 39, 2 (2007), 175–191.

[24] Anna Felnhofer, Oswald D Kothgassner, Mareike Schmidt, Anna-Katharina Heinzle, Leon Beutl, Helmut Hlavacs, and Ilse Kryspin-Exner. 2015. Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios. *International journal of human-computer studies* 82 (2015), 48–56.

[25] Marta Ferrer-Garcia, Jose Gutierrez-Maldonado, Alejandra Caqueo-Urizar, and Elena Moreno. 2009. The validity of virtual environments for eliciting emotional responses in patients with eating disorders and in controls. *Behavior Modification* 33, 6 (2009), 830–854.

[26] Daniel J Finnegan, Eamonn O'Neill, and Michael J Proulx. 2016. Compensating for distance compression in audiovisual virtual environments using incongruence. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. 200–212.

[27] Gerard G Fluet and Judith E Deutsch. 2013. Virtual reality for sensorimotor rehabilitation post-stroke: the promise and current state of the field. *Current physical medicine and rehabilitation reports* 1, 1 (2013), 9–20.

[28] Jonathan Freeman, Jane Lessiter, Katherine Pugh, and Ed Keogh. 2005. When presence and emotion are related, and when they are not. In *Proceedings of the 8th annual international workshop on presence (PRESENCE 2005)*. International Society for Presence Research, 213–219.

[29] Philippe Fuchs, Guillaume Moreau, and Pascal Guitton. 2011. *Virtual reality: concepts and technologies*. CRC Press.

[30] Shaun Gallagher. 2012. Multiple aspects in the sense of agency. *New ideas in psychology* 30, 1 (2012), 15–31.

[31] Evelyn Glotzbach-Schoon, Regina Tadda, Marta Andreatta, Christian Tröger, Heike Ewald, Christian Grillon, Paul Pauli, and Andreas Mühlberger. 2013. Enhanced discrimination between threatening and safe contexts in high-anxious individuals. *Biological psychology* 93, 1 (2013), 159–166.

[32] Victoria Groom, Jeremy N Bailenson, and Clifford Nass. 2009. The influence of racial embodiment on racial bias in immersive virtual environments. *Social Influence* 4, 3 (2009), 231–248.

[33] James J Gross. 2015. The extended process model of emotion regulation: Elaborations, applications, and future directions. *Psychological Inquiry* 26, 1 (2015), 130–137.

[34] Olga Gutiérrez-Martínez, José Gutiérrez-Maldonado, and Desirée Loreto-Quijada. 2011. Control over the virtual environment influences the presence and efficacy of a virtual reality intervention on pain.

[35] Scott H Hemenover and Nicholas D Bowman. 2018. Video games, emotion, and emotion regulation: Expanding the scope. *Annals of the International Communication Association* 42, 2 (2018), 125–143.

[36] Rick H Hoyle. 1995. *Structural equation modeling: Concepts, issues, and applications*. Sage.

[37] Charles Hulin, Richard Netemeyer, and Robert Cudeck. 2001. Can a reliability coefficient be too high? *Journal of Consumer Psychology* 10, 1/2 (2001), 55–58.

[38] Maarten H Jacobs. 2012. Human emotions toward wildlife. *Human Dimensions of Wildlife* 17, 1 (2012), 1–3.

[39] Charlene Jennett, Anna L Cox, Paul Cairns, Samira Dhoparee, Andrew Epps, Tim Tijs, and Alison Walton. 2008. Measuring and defining the experience of immersion in games. *International journal of human-computer studies* 66, 9 (2008), 641–661.

[40] Camille Jeunet, Louis Albert, Ferran Argelaguet, and Anatole Lécuyer. 2018. "Do you feel in control?": towards novel approaches to characterise, manipulate and measure the sense of agency in virtual environments. *IEEE transactions on visualization and computer graphics* 24, 4 (2018), 1486–1495.

[41] M Carmen Juan and David Pérez. 2010. Using augmented and virtual reality for the development of acrophobic scenarios. Comparison of the levels of presence and anxiety. *Computers & Graphics* 34, 6 (2010), 756–766.

[42] Hacer Karacan and Mary M Hayhoe. 2008. Is attention drawn to changes in familiar scenes? *Visual Cognition* 16, 2-3 (2008), 356–374.

[43] Konstantina Kilteni, Raphaela Groten, and Mel Slater. 2012. The sense of embodiment in virtual reality. *Presence: Teleoperators and Virtual Environments* 21, 4 (2012), 373–387.

[44] Michail D Kozlov and Mark K Johansen. 2010. Real behavior in virtual environments: Psychology experiments in a simple virtual-reality paradigm using video games. *Cyberpsychology, behavior, and social networking* 13, 6 (2010), 711–714.

[45] Jeonghun Ku, Hee Jeong Jang, Kwang Uk Kim, Jae Hun Kim, Sung Hyouk Park, Jang Han Lee, Jae Jin Kim, In Y Kim, and Sun I Kim. 2005. Experimental results of affective valence and arousal to avatar's facial expressions. *CyberPsychology & Behavior* 8, 5 (2005), 493–503.

[46] Elise Lallart, Xavier Lallart, and Roland Jouvent. 2009. Agency, the sense of presence, and schizophrenia. *Cyberpsychology & behavior* 12, 2 (2009), 139–145.

[47] Kwan Min Lee and Clifford Nass. 2003. Designing social presence of social actors in human computer interaction. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 289–296.

[48] Matthew Lombard, Theresa B Ditton, and Lisa Weinstein. 2009. Measuring presence: the temple presence inventory. In *Proceedings of the 12th annual international workshop on presence*. 1–15.

[49] Mativve. 2018. Happy Sandbox. (2018).

[50] Hanna McCabe-Bennett, Richard Lachman, Todd A Girard, and Martin M Antony. 2020. A Virtual Reality Study of the Relationships Between Hoarding, Clutter, and Claustrophobia. *Cyberpsychology, Behavior, and Social Networking* 23, 2 (2020), 83–89.

[51] Vangelis Metsis, Grayson Lawrence, Mark Trahan, Kenneth S Smith, Dan Tamir, and Katherine Selber. 2019. 360 Video: A prototyping process for developing virtual reality interventions. *Journal of Technology in Human Services* 37, 1 (2019), 32–50.

[52] Maarten Milders, Arash Sahraie, Sarah Logan, and Niamh Donnellon. 2006. Awareness of faces is modulated by their emotional meaning. *Emotion* 6, 1 (2006), 10.

[53] Diego Monteiro, Hai-Ning Liang, Yuxuan Zhao, and Andrew Abel. 2018. Comparing event related arousal-valence and focus among different viewing perspectives in vr gaming. In *International Conference on Brain Inspired Cognitive Systems*. Springer, 770–779.

[54] Erica E Nason, Mark Trahan, Scott Smith, Vangelis Metsis, and Katherine Selber. 2020. Virtual treatment for veteran social anxiety disorder: A comparison of 360 video and 3D virtual reality. *Journal of Technology in Human Services* 38, 3 (2020), 288–308.

[55] Kristine L Nowak and Frank Biocca. 2003. The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in

virtual environments. *Presence: Teleoperators & Virtual Environments* 12, 5 (2003), 481–494.

[56] Arne Öhman. 2009. Of snakes and faces: An evolutionary perspective on the psychology of fear. *Scandinavian journal of psychology* 50, 6 (2009), 543–552.

[57] Federica Pallavicini, Alessandro Pepe, and Maria Eleonora Minissi. 2019. Gaming in virtual reality: What changes in terms of usability, emotional response and sense of presence compared to non-immersive video games? *Simulation & Gaming* 50, 2 (2019), 136–159.

[58] Joseph Piccione, James Collett, and Alexander De Foe. 2019. Virtual skills training: the role of presence and agency. *Heliyon* 5, 11 (2019), e02583.

[59] Matthew Price and Page Anderson. 2007. The role of presence in virtual reality exposure therapy. *Journal of anxiety disorders* 21, 5 (2007), 742–751.

[60] Matthew Price, Natasha Mehta, Erin B Tone, and Page L Anderson. 2011. Does engagement with exposure yield better outcomes? Components of presence as a predictor of treatment response for virtual reality exposure therapy for social phobia. *Journal of anxiety disorders* 25, 6 (2011), 763–770.

[61] Pavol Prokop. 2016. Universal Human Fears. *TK Shackelford, VAWeekes-Shackelford Encyclopedia of Evolutionary Psychological Science Cham: Springer International Publishing* (2016).

[62] Virginia Puyana-Romero, Lilian Solange Lopez-Segura, Luigi Maffei, Ricardo Hernández-Molina, and Massimiliano Masullo. 2017. Interactive soundscapes: 360°-video based immersive virtual reality in a tool for the participatory acoustic environment evaluation of urban areas. *Acta Acustica united with Acustica* 103, 4 (2017), 574–588.

[63] Giuseppe Riva. 2002. The sociocognitive psychology of computer-mediated communication: The present and future of technology-based interactions. *Cyberpsychology & behavior* 5, 6 (2002), 581–598.

[64] Giuseppe Riva, Fabrizia Mantovani, Claret Samantha Capideville, Alessandra Preziosa, Francesca Morganti, Daniela Villani, Andrea Gaggioli, Cristina Botella, and Mariano Alcañiz. 2007. Affective interactions using virtual reality: the link between presence and emotions. *CyberPsychology & Behavior* 10, 1 (2007), 45–56.

[65] Geneviève Robillard, Stéphane Bouchard, Thomas Fournier, and Patrice Renaud. 2003. Anxiety and presence during VR immersion: A comparative study of the reactions of phobic and non-phobic participants in therapeutic virtual environments derived from computer games. *CyberPsychology & Behavior* 6, 5 (2003), 467–476.

[66] Alejandro Rodríguez, Beatriz Rey, Miriam Clemente, Maja Wrzesien, and Mariano Alcañiz. 2015. Assessing brain activations associated with emotional regulation during virtual reality mood induction procedures. *Expert Systems with Applications* 42, 3 (2015), 1699–1709.

[67] Yves Rosseel. 2012. Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). *Journal of statistical software* 48, 2 (2012), 1–36.

[68] Daniel Roth, Jean-Luc Lugrin, Dmitri Galakhov, Arvid Hofmann, Gary Bente, Marc Erich Latoschik, and Arnulph Fuhrmann. 2016. Avatar realism and social interaction quality in virtual reality. In *2016 IEEE Virtual Reality (VR)*. IEEE, 277–278.

[69] Karin Schermelleh-Engel, Helfried Moosbrugger, Hans Müller, et al. 2003. Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of psychological research online* 8, 2 (2003), 23–74.

[70] Thomas W Schubert. 2009. A new conception of spatial presence: Once again, with feeling. *Communication Theory* 19, 2 (2009), 161–187.

[71] Berenice Serrano, Cristina Botella, Rosa M Baños, and Mariano Alcañiz. 2013. Using virtual reality and mood-induction procedures to test products with consumers of ceramic tiles. *Computers in Human Behavior* 29, 3 (2013), 648–653.

[72] Anil K Seth, Keisuke Suzuki, and Hugo D Critchley. 2012. An interoceptive predictive coding model of conscious presence. *Frontiers in psychology* 2 (2012), 395.

[73] Dong-Hee Shin. 2017. The role of affordance in the experience of virtual reality learning: Technological and affective affordances in virtual reality. *Telematics and Informatics* 34, 8 (2017), 1826–1836.

[74] Mel Slater. 2009. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, 1535 (2009), 3549–3557.

[75] Harrison Jesse Smith and Michael Neff. 2018. Communication behavior in embodied virtual reality. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–12.

[76] Alexander Smolentsev, Jessica E Cornick, and Jim Blascovich. 2017. Using a preamble to increase presence in digital virtual environments. *Virtual Reality* 21, 3 (2017), 153–164.

[77] Jiyeon So. 2013. A further extension of the extended parallel process model (E-EPPM): Implications of cognitive appraisal theory of emotion and dispositional coping style. *Health communication* 28, 1 (2013), 72–83.

[78] Anthony Steed, Sebastian Frlston, Maria Murcia Lopez, Jason Drummond, Ye Pan, and David Swapp. 2016. An 'in the wild'experiment on presence and embodiment using consumer virtual reality equipment. *IEEE transactions on visualization and computer graphics* 22, 4 (2016), 1406–1414.

[79] Matthis Synofzik, Gottfried Vosgerau, and Albert Newen. 2008. Beyond the comparator model: a multifactorial two-step account of agency. *Consciousness and cognition* 17, 1 (2008), 219–239.

[80] Katy Tcha-Tokey, Emilie Loup-Escande, Olivier Christmann, and Simon Richir. 2016. A questionnaire to measure the user experience in immersive virtual environments. In *Proceedings of the 2016 virtual reality international conference*. 1–5.

[81] Steven P Tipper, Jamie C Brehaut, and Jon Driver. 1990. Selection of moving and static objects for the control of spatially directed action. *Journal of Experimental Psychology: Human perception and performance* 16, 3 (1990), 492.

[82] Alexander Toet, Marloes van Welie, and Joske Houtkamp. 2009. Is a dark virtual environment scary? *CyberPsychology & Behavior* 12, 4 (2009), 363–371.

[83] Huyen TT Tran, Nam Pham Ngoc, Cuong T Pham, Yong Ju Jung, and Truong Cong Thang. 2017. A subjective study on QoE of 360 video for VR communication. In *2017 IEEE 19th international workshop on multimedia signal processing (MMSP)*. IEEE, 1–6.

[84] Spyros Vosinakis and Panayiotis Koutsabasis. 2018. Evaluation of visual feedback techniques for virtual grasping with bare hands using Leap Motion and Oculus Rift. *Virtual Reality* 22, 1 (2018), 47–62.

[85] Helene S Wallach, Marilyn P Safir, Roy Samana, Idan Almog, and Reut Horef. 2011. How can presence in psychotherapy employing VR be increased? Chapter for inclusion in: Systems in health care using agents and virtual reality. In *Advanced Computational Intelligence Paradigms in Healthcare 6. Virtual Reality in Psychotherapy, Rehabilitation, and Assessment*. Springer, 129–147.

[86] Rainer Westermann, Kordelia Spies, Günter Stahl, and Friedrich W Hesse. 1996. Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of social psychology* 26, 4 (1996), 557–580.

[87] Maxine Gallander Wintre and Denise D Vallance. 1994. A developmental sequence in the comprehension of emotions: Intensity, multiple emotions, and valence. *Developmental psychology* 30, 4 (1994), 509.

[88] Werner Wirth, Tilo Hartmann, Saskia Böcking, Peter Vorderer, Christoph Klimmt, Holger Schramm, Timo Saari, Jari Laarni, Niklas Ravaja, Feliz Ribeiro Gouveia, et al. 2007. A process model of the formation of spatial presence experiences. *Media psychology* 9, 3 (2007), 493–525.

[89] Bob G Witmer and Michael J Singer. 1998. Measuring presence in virtual environments: A presence questionnaire. *Presence* 7, 3 (1998), 225–240.

[90] Xanco123. 2014. Dark Ambient Music 3. (2014).

[91] Pavel Zahorik and Rick L Jenison. 1998. Presence as being-in-the-world. *Presence* 7, 1 (1998), 78–89.

[92] Chenyan Zhang, Aud Sissel Hoel, Andrew Perkis, and Saman Zadtootaghaj. 2018. How Long is Long Enough to Induce Immersion?. In *2018 Tenth International Conference on Quality of Multimedia Experience (QoMEX)*. IEEE, 1–6.