Emotional Experience in Real and Virtual Environments – Does Prior VR Experience Matter?

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Abstract. Virtual reality (VR) has a great potential to induce emotions effectively and naturally. There are already existing concepts to use this technology, e.g., for the therapy of anxiety disorders or to train emotional and social skills for different user groups. Some research results show that visual stimuli are experienced emotionally different in a virtual environment than in a real environment. The aim of the study was therefore, to investigate whether a person's emotional experience (induced by affective pictures) differs between real and virtual environments. Additionally, the influence of prior experience with VR on the emotional reactions was investigated. Furthermore, in an exploratory part the effect of immersive 360° videos in VR was studied. The results indicate an effect of VR on the psychophysiological responses. The subjective assessments show that the affective pictures were able to induce significantly different emotional responses in VR. In addition, significantly different emotional responses are evident in both, the subjective and psychophysiological parameters regarding the 360° VR-videos. Overall, prior VR experience did not show a significant effect.

Keywords: Virtual Reality · Emotion Induction · Emotion Recognition · Psychophysiology

1 Introduction

The continuous development of virtual reality (VR) technologies is leading to more and more realistic, experienceable simulations [1]. Furthermore, VR has a great potential to induce emotions effectively and naturally [2]. Due to this, the technology is also increasingly used in emotion research. There are already concepts to use VR within this field of research, e.g., for the therapy of anxiety disorders [1] or to train emotional and social skills for people with ASD [3] or for managers and teams [4].

A major advantage of VR is that users focus entirely on the VR content without being distracted by visual stimuli from the real ("outside") environment [1]. This results in a VR experience with a high degree of immersion for the user. A high degree of immersion in the VR environment also leads to a higher sense of presence in VR. Presence is defined as a user's subjective feeling of actually being in the virtual environment while physically

J. Y. C. Chen et al. (Eds.): HCII 2023, LNCS 14058, pp. 190–211, 2023.
https://doi.org/10.1007/978-3-031-48050-8_14

being in another environment [5]. Several studies show that the feeling of presence in VR has an influence on the emotional reactions of the users [6–8]. To ensure this sense of presence in the simulation, it is crucial that the stimuli are perceived as natural [9].

1.1 Prior Experience with Virtual Reality

A study of Sagnier et al. [10] shows that prior experience with virtual reality can have an impact on a person's VR experience. Users with prior VR experience perceived significant more presence in VR and also assessed their performance regarding a virtual assembly task significantly better than novice users. Furthermore, users with prior VR experience rated the user experience in VR, both in terms of pragmatic quality and hedonic quality stimulation, significantly higher. These results suggest that users who have prior VR experience, feel more connected to the virtual environment than users without prior VR experience.

1.2 Emotion Induction

In order to investigate emotional responses, independent of the environment, emotions have to be induced. A review by Siedlecka and Denson [11] shows that a variety of methods have been established for emotion induction. Following the authors, using visual stimuli is the most effective method for inducing the six basic emotions anger, disgust, surprise, happiness, fear, and sadness. Since they are commonly used in emotion research, standardized databases of emotionally stimulating pictures with the corresponding valence and arousal values have been established, e.g. [12–14]. Mostly, they have been investigated by presenting the pictures in a real environment on a computer screen.

Recent research shows that VR can effectively be used for emotion induction [8]. The pictures from the standardized databases can also be integrated easily into VR [2]. However, there is a dearth of studies that have investigated the use of visual stimuli as an emotion induction method in VR. It must also be considered that the static presentation of the stimuli can lead to a lower emotional intensity compared to other induction methods in VR, such as games or videos. Dynamic stimuli can create a higher immersion than static stimuli and therefore create a more natural emotional experience. Suitable dynamic stimuli for VR are 360° videos. The use of 360° media in VR provides the possibility to view the scene in full rotation without visual distraction, providing a high level of immersion for the users. According to Somarathna et al. [2] there are only a few studies that use 360° media in VR, which can be attributed to the lack of standardised material for emotion research in VR. A first public database with immersive VR videos was published by Li et al. [15] (Virtual Human Interaction Lab of Stanford University). They provide free available 360° videos with the corresponding ratings of arousal and valence.

1.3 Emotional Experience in Real and Virtual Environments

A pilot study by Estupiñán et al. [16] gives first indications that visual stimuli are experienced emotionally different in virtual than in real environments. Affective pictures (picture categories: snakes, spiders, human concerns, animal mistreatments, positive) from the GAPED database [17] were integrated into the VR environment. The descriptive results reported by the authors, show that compared with the valence and arousal ratings provided by the standardized database, the arousal was rated higher in the virtual environment for all pictures [16]. In terms of valence, the pictures of the negative emotional categories in VR showed higher values than reported in the database.

1.4 Emotion Recognition

Measuring a person's emotional reaction is a major challenge in emotion research [18]. Therefore, various measurement methods have been established. The subjective emotional state can be assessed using interviews and questionnaires, e.g. by participants assessing their perceived valence and arousal of an emotion [12]. Psychophysiological parameters [19], such as electrodermal activity, cortisol or pupillary diameter, as well as the analysis of facial expressions [20], can be used as objective methods for emotion recognition. According to Boucsein and colleagues [21, 22], it is useful to combine subjective and objective parameters to obtain a comprehensive assessment of a person's emotional state. Therefore, our research group has developed a multidimensional measurement environment that combines subjective and psychophysiological measurements [23] and conducted a first validation study [24]. For emotion induction, different emotional pictures were shown on a computer screen. The results showed significantly different emotional responses in the subjective assessments of valence, but no evidence in the psychophysiological parameters. Another study [25] using autobiographical recall as a method for emotion induction resulted in significant responses in the subjective and psychophysiological parameters for different emotions. Nonetheless, it is important to investigate further emotion induction methods, such as virtual reality, to analyse whether a stronger emotional involvement of the participants can be evoked.

1.5 Aim of the Study

As presented before, VR can be seen as an effective medium to induce and recognize emotions [8]. Furthermore, prior VR experience and their impact on the emotional responses of the participants needs to be considered. However, to use the advantages of the possibilities of the medium "VR", dynamic stimuli with "lower" and "higher" immersive content like 360° videos should be included in the research. Also, it is necessary to include a multidimensional approach that includes also psychophysiological parameters.

Therefore, the aim of the presented study was to investigate whether a person's emotional experience differs between real and virtual environments when emotions are induced by affective pictures. Additionally, the influence of prior experience with VR on the emotional reactions was investigated. Furthermore, an exploratory part was investigated within this study, which aims to examine the effect of immersive 360° videos in a virtual environment on the emotional experience.

2 Method

A laboratory experiment with repeated measurements was chosen for this study. The study was conducted at Campus Tuttlingen of Furtwangen University. The experiment presented in this paper was part of an overall study with two different parts. In the first part of the overall study (not presented within this paper; see [25]), the influence of two different emotion induction methods, visual stimuli and autobiographical recall, on six emotional categories (anger, disgust, fear, joy, sadness, surprise) and a neutral category were investigated in real environments.

The second part of the overall study is presented within this paper. This part of the study consisted of an experimental part and an exploratory one. In the experimental part the emotional experience of four emotional categories (disgust, happiness, fear and sadness) induced by pictures was investigated in different environments. For this purpose, four of the six conditions examined in real environments in the first section of the study (see [25]) were investigated in the virtual environment as well. In the exploratory part of the study, the emotional responses to immersive 360° VR-videos were examined.

2.1 Participants

Overall, 14 women and 10 men ($N = 24$) aged between 19 and 59 years ($M = 29.25$, $SD = 11.46$) participated in the study. Grouped by the independent variable prior VR experience, 11 persons reported no prior experience with virtual reality and 13 persons reported partial or a lot of experience with VR. For the prior VR experience groups, no significant effects regarding gender, $\chi^2(1) = .24$, $p = .628$, age, $r = -.30$, $p = .157$, and affinity for technology interaction [26], $r = .26$, $p = .229$, can be shown. Informed consent was provided by all participants at the beginning of the study. The study was approved by the ethics committee of Furtwangen University.

2.2 Material

As described before, the study consists of different parts (see Sect. 2). In the experimental part the independent variables prior VR experience (with, without), environment (real, virtual) and the measurement repetition factor emotional category (disgust, happiness, fear and sadness) were examined. Within the exploratory part the prior VR experience (with, without) and the emotional category (neutral, happiness, fear; measurement repetition factor) were analysed. Following a multidimensional approach, subjective assessments and psychophysiological parameters were used as dependent variables.

Emotion Induction. Visual stimuli were used to induce the different emotions in the participants. In the experimental part, affective pictures (databases: International Affective Picture System (IAPS) [12], Emotional Picture Set (EmoPicS) [13] and Open Affective Standardized Image Set (OASIS) [14]) were used to induce the four target emotions: happiness, fear, disgust and sadness. For each emotional category, four appropriate pictures were selected from the databases. In the real environment condition the pictures were presented on a 23-in. HP screen placed on a table at a distance of 50 cm. For the virtual environment condition the laboratory room was replicated in the VR environment to provide comparability between the real and virtual environments. The same pictures as in the real environment were displayed on a wall in the virtual room. Unity [27] was used to develop the VR environment. The used VR headset was the HTC Vive Pro [28].

In the exploratory part of the study, 360° videos were investigated to induce the following three target emotions in VR: neutral, happiness and fear (see Table 1). Due to the 360° format of the video material, it could only be presented in the VR environment and not in the real environment condition. The video material was selected from the 360° VR video database from Stanford University [15] for the emotional categories neutral and happiness. Following [15], there is a lack of material with negative valence and high arousal in the database. Therefore, an additional free available video was selected for the emotional category fear. To ensure comparability of the videos, they were all shortened to a duration of 60 s.

Table 1. Description of the 360° video material used in the exploratory part of the study.

Emotional category	Video	Description
Neutral	Sunrise [29]	Beach where the sun rises over the horizon
Happiness	Dog puppies [30]	Puppies beaming in a football match
Fear	Terrifying Sea Creatures [31]	Underwater scenario with various terrifying sea creatures

Subjective Measurements. The subjective emotional state of the participants was assessed with the Self-Assessment Manikin (SAM) [32] using the two dimensions, valence and arousal (9-point scale based on the pictograms). In addition, an emotion characterization according to Ozawa [33] was used to characterize the emotions actually felt by the participants. Therefore, the participants were asked to rate the extent to which they felt each of the six basic emotions (anger, disgust, fear, happiness, sadness, surprise), and the neutral condition using a 6-point scale ranging from "not at all" (1) to "very" (6). There was also the possibility to choose the option "other emotions" and shortly describe them. The subjective assessments were completed on a *Samsung Galaxy Tab A* tablet using the online survey tool Unipark [34]. During the virtual environment condition participants gave their assessment verbally to the experimenter.

Psychophysiological Measurements. Cardiovascular (ECG) and electrodermal activity (EDA) were recorded using sensors from Movisens [35, 36]. The ECG-sensor was placed with the use of a chest strap. The EDA-sensor was attached on the inner palm (thenar and hypothenar) of the participants' non-dominant hand. For the statistical analysis the following parameters were used: ECG: Heart rate (HR) in beats per minute and heart rate variability (HRV RMSSD); EDA: Skin conductance level (SCL), amplitude of non-specific skin conductance responses (NS.SCR amp), frequency of non-specific skin conductance responses (NS.SCR freq) and mean sum amplitude (NS.SCR amp/NS.SCR freq).

2.3 Procedure

The study was conducted in a laboratory room at Campus Tuttlingen of Furtwangen University. The lighting conditions were kept constant by blinds during the whole experiment. Participants sat on a rotatable office chair in the real and the virtual environment conditions.

After a short briefing, the participants provided their informed consent and their sociodemographic data. Then, they assessed their affinity for technology with the Affinity for Technology Interaction Short Scale (ATI-S) [26], their current well-being as well as their subjectively perceived prior VR experience. Subsequently, the electrodes for the psychophysiological measurements were attached and their functionality checked, followed by a four-minute baseline measurement.

Afterwards, the first part of the overall study (affective pictures, autobiographical recall; see [25]) was examined in the real environment. Therefore, the participants' chair was placed in front of a table with a computer screen. Four affective pictures of each emotional category were presented for a total of 30 s (7.5 s each). After each emotional category, the participants rated their emotional state in terms of valence and arousal using the Self-Assessment Manikin (SAM) [32] and the items for emotion characterization. The duration of the subjective assessments was individually determined by the participants. Afterwards, a one-minute rest measurement was performed. This was followed by the investigation of the same emotional category, using the second induction method, autobiographical recall. The emotion categories were presented in permuted order. A total of seven emotional categories (anger, disgust, fear, joy, sadness, surprise, neutral) were examined, of which the four emotional categories, disgust, happiness, fear and sadness induced with affective pictures are part of the presented paper. After examining all emotional categories in front of the screen, a break of about 10 min followed.

The second part of the study started with a second measurement of the participants' current well-being. Afterwards, the chair was placed in the center of the room, giving the participants more space within the VR environment. Subsequently, the participants were instructed in the use of the VR equipment and could familiarize themselves with the virtual environment which represents a simulation of the real examination room. The investigation in the VR environment started with the emotion induction of the four emotional categories disgust, happiness, fear and sadness by using pictures [12–14]. The emotional categories were therefore presented in permuted order. The pictures and the procedure were exactly the same as in the screen condition in the real environment. The presentation of the affective pictures (30 s.) was followed by the subjective assessments and a subsequent one-minute rest measurement, which were also performed in the VR environment. Afterwards, the 360° videos [29–31] for emotion induction were examined (exploratory part). Before the first 360° video condition started, the participants were told that they could rotate their chair while watching the videos in order to look around completely in the 360° VR environment. Each of the 360° VR-videos of the three emotional categories, neutral, happiness and fear, were presented for 60 s followed by the subjective assessments and a resting measurement. The video of the neutral category was shown first to each participant. After that, the VR videos of the categories happiness and fear were presented in permuted order.

After the last resting measurement, the VR equipment was removed from the participants and they had to answer final questions regarding how they perceived their emotions in the VR environment compared to the real environment (sitting in front of the screen) and to which extent, they perceived the VR environment as suitable for evoking emotions. In addition, a third measurement of the participants' current well-being was conducted. Finally, the sensors of the psychophysiological measurements were taken off the participants. In total, the overall study lasted about 90 min for each participant.

2.4 Statistical Analysis

The psychophysiological parameters were analyzed with the software DataAnalyzer [37] from Movisens. The mean values of the psychophysiological measures were baseline-corrected. For the statistical analyses the software IBM SPSS statistics was used. The statistical procedures used were analyses of variance with repeated measures. The statistical analyses were based on a significance level of 5%.

3 Results

3.1 Experimental Part: Real and Virtual Environments

Subjective Measures

Valence. For the dimension valence, an analysis of variance with repeated measures shows significant differences of the emotional categories, $F_{HF}(2.80, 56.05) = 146.28$, $p < .001$, $\eta^2_{part.} = .880$. All other effects did not reach the level of significance (environment: $F(1, 20) = .77$, $p = .392$, $\eta^2_{part.} = .037$, prior VR experience: $F(1, 20) = 1.59$, $p = .222$, $\eta^2_{part.} = .074$, interaction emotional category x environment: $F(3, 18) = 1.22$, $p = .330$, $\eta^2_{part.} = .169$, interaction emotional category x prior VR experience: $F(3, 18) = .64$, $p = .597$, $\eta^2_{part.} = .097$, interaction environment x prior VR experience, $F(1, 20) = .77$, $p = .392$, $\eta^2_{part.} = .037$, interaction emotional category x environment x prior VR experience, $F(3, 18) = 1.83$, $p = .178$, $\eta^2_{part.} = .233$).

Post-hoc analyses (Sidak) show that the emotional category happiness was assessed significantly more positive than disgust, fear and sadness (all $p < .001$). Also, the emotional category sadness was assessed significantly more negative than disgust ($p = .010$) and fear ($p = .019$; see Fig. 1).

Arousal. An analysis of variance with repeated measures shows for the dimension arousal no significant effect of the emotional categories, $F(3, 18) = 2.41$, $p = .101$, $\eta^2_{part.} = .286$, the environment, $F(1, 20) = 1.16$, $p = .294$, $\eta^2_{part.} = .055$, nor the prior VR experience, $F(1, 20) = .67$, $p = .424$, $\eta^2_{part.} = .032$, or the interactions of them (emotional category x environment: $F(3, 18) = .83$, $p = .496$, $\eta^2_{part.} = .121$, emotional category x prior VR experience: $F(3, 18) = .25$, $p = .858$, $\eta^2_{part.} = .040$, environment x prior VR experience: $F(1, 20) = .375$, $p = .547$, $\eta^2_{part.} = .018$, emotional category x environment x prior VR experience: $F(3, 18) = .45$, $p = .721$, $\eta^2_{part.} = .070$).

Note. 9-point-scale: Negative (1) – positive (9); I … standard error of mean; * … $p < .05$

Fig. 1. Mean subjectively perceived valence of the four different emotional categories induced in real and virtual environments.

Psychophysiological Measures

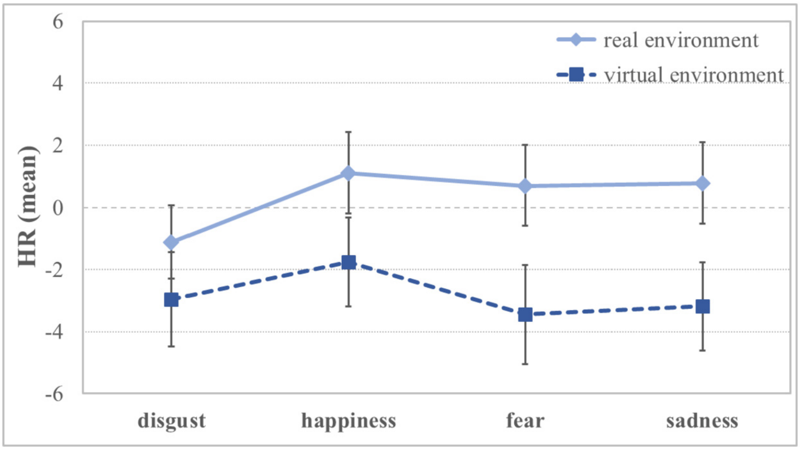
Cardiovascular Activity. Table 2 shows the results of the analyses of variance with repeated measures for the parameters of the cardiovascular activity.

Following the results presented in Table 2, a significant effect of environment was shown for the heart rate (HR). The HR was significantly higher during stimuli presentation within the real environment than in the virtual environment (see Fig. 2).

For the heart rate variability (HRV RMSSD), the results of an ANOVA with repeated measures show a significant interaction emotional category x environment. Following the results of post-hoc analyses (Sidak), the HRV was significantly higher when presenting affective pictures of the category happiness (p = .030) as well as of the category fear (p = .031) in the real than in the virtual environment (see also Fig. 3).

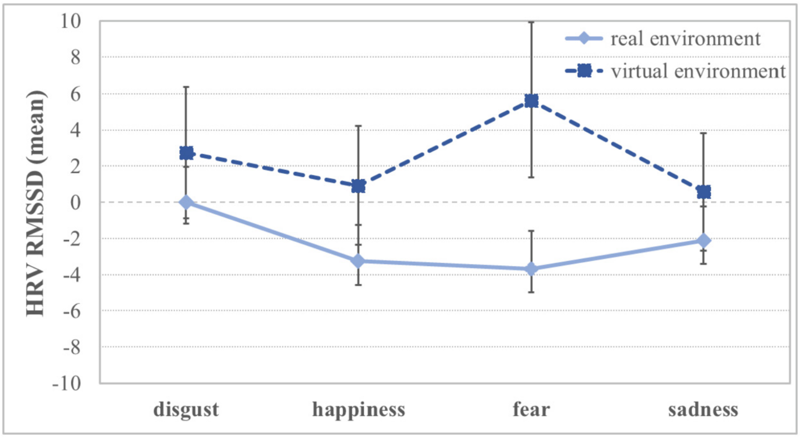
Table 2. Results of the analyses of variance with repeated measures for the parameters of the cardiovascular activity.

		F	df	df_{error}	p	$\eta^2_{part.}$
HR	Emotional category	1.20	3	17	.340	.175
	Environment	19.43	1	19	<.001	.506
	Prior VR experience	.09	1	19	.773	.004
	Emotional category x Environment	.10	1	19	.755	.005
	Emotional category x Prior VR experience	1.31	3	17	.303	.188
	Environment x Prior VR experience	.10	1	19	.755	.005
	Emotional category x Environment x Prior VR experience	2.12	3	17	.135	.273
HRV (RMSSD)	Emotional category	.76	3	17	.530	.119
	Environment	3.87	1	19	.064	.169
	Prior VR experience	.00	1	19	.957	.000
	Emotional category x Environment	3.22	3	17	.049	.362
	Emotional category x Prior VR experience	.23	3	17	.875	.039
	Environment x Prior VR experience	.09	1	19	.765	.005
	Emotional category x Environment x Prior VR experience	1.02	3	1	.409	.152



Note. Baseline-corrected mean values; I … standard error of mean

Fig. 2. Mean heart rate (HR): Four different emotional categories induced in real and virtual environments.

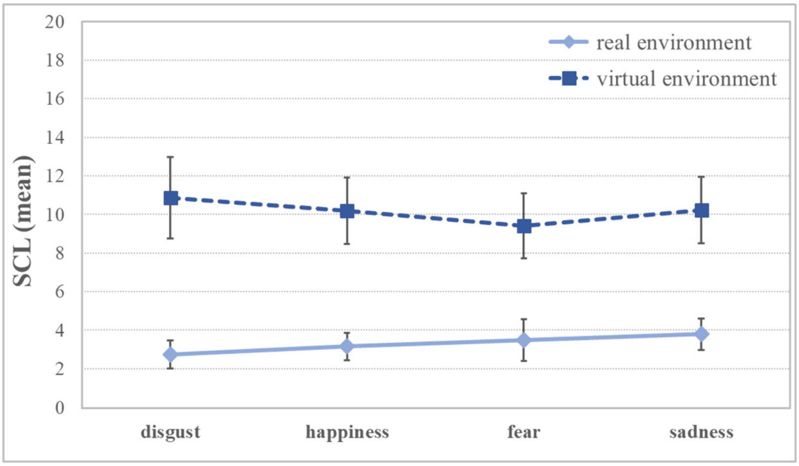


Note. Baseline-corrected mean values; I … standard error of mean

Fig. 3. Mean heart rate variability (HRV RMSSD): Four different emotional categories induced in real and virtual environments.

Electrodermal Activity. Table 3 shows the results of the analyses of variance with repeated measures for the parameters of the electrodermal activity.

As presented in Table 3 a significant effect of the environment can be shown for the skin conductance level (SCL). The SCL was significantly higher during the presentation of the affective pictures in the virtual environment than during the presentation in the real environment (see Fig. 4).



Note. Baseline-corrected mean values; I … standard error of mean

Fig. 4. Mean skin conductance level (SCL): Four different emotional categories induced in real and virtual environments.

Table 3. Results of the analyses of variance with repeated measures for the parameters of the electrodermal activity.

		F	df	df_{error}	p	$\eta^2_{part.}$
SCL	Emotional category	.14	3	17	.932	.025
	Environment	41.82	1	19	< .001	.688
	Prior VR experience	.23	1	19	.639	.012
	Emotional category x Environment	.36	3	17	.783	.060
	Emotional category x Prior VR experience	1.82	3	17	.181	.244
	Environment x Prior VR experience	.17	1	19	.687	.009
	Emotional category x Environment x Prior VR experience	2.44	3	17	.100	.301

(*continued*)

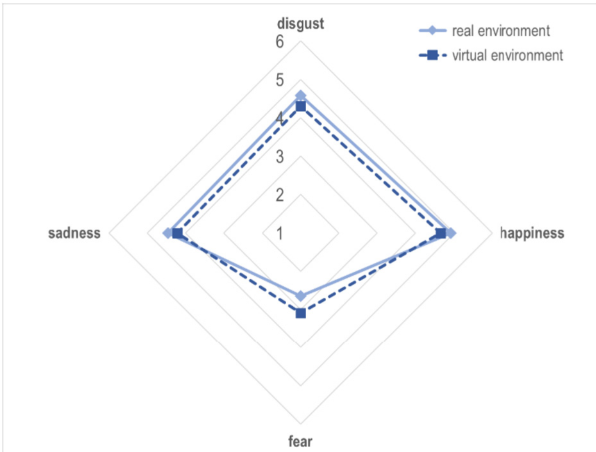
Table 3. (*continued*)

		F	df	df_{error}	p	$\eta^2_{part.}$
NS.SCR freq	Emotional category	1.20[a]	1.19	22.58	.294	.060
	Environment	.65	1	19	.429	.033
	Prior VR experience	1.79	1	19	.196	.086
	Emotional category x Environment	1.08[a]	1.27	24.08	.327	.054
	Emotional category x Prior VR experience	2.63	3	17	.083	.317
	Environment x Prior VR experience	1.74	1	19	.203	.084
	Emotional category x Environment x Prior VR experience	2.36	3	17	.108	.294
NS.SCR amp	Emotional category	1.98	3	17	.156	.259
	Environment	1.19	1	19	.289	.059
	Prior VR experience	.10	1	19	.755	.005
	Emotional category x Environment	1.96	3	17	.158	.257
	Emotional category x Prior VR experience	.46	3	17	.713	.075
	Environment x Prior VR experience	.04	1	19	.850	.002
	Emotional category x Environment x Prior VR experience	.07	3	17	.977	.012
NS.SCR amp/NS.SCR freq	Emotional category	1.19	3	17	.342	.174
	Environment	1.03	1	19	.322	.052
	Prior VR experience	1.15	1	19	.298	.057
	Emotional category x Environment	1.81[b]	2.71	51.55	.161	.087
	Emotional category x Prior VR experience	.55	3	17	.655	.088
	Environment x Prior VR experience	.41	1	19	.529	.021
	Emotional category x Environment x Prior VR experience	1.59	3	17	.228	.219

Note. [a]Greenhouse-Geisser correction, [b]Huynh-Feldt correction

Emotion Characterization

As described in 2.2, the participants rated the extent to which they felt each of the six basic emotions (anger, disgust, fear, happiness, sadness, surprise), and the "neutral" condition. Figure 5 shows the mean values of the emotion characterization, i.e. to what extent the affective visual material for emotion induction was actually able to induce the target emotions of disgust, happiness, fear and sadness in the participants.



Note. Mean values, 6-point scale: Not at all (1) – very (6)

Fig. 5. Emotion characterization of the target emotion for each emotional category induced by pictures in real and virtual environment.

The results of the statistical analyses (ANOVAs with repeated measures) are shown in Table 4.

Table 4. Results of the ANOVAs with repeated measures for the subjective emotion characterization of the four different emotional categories.

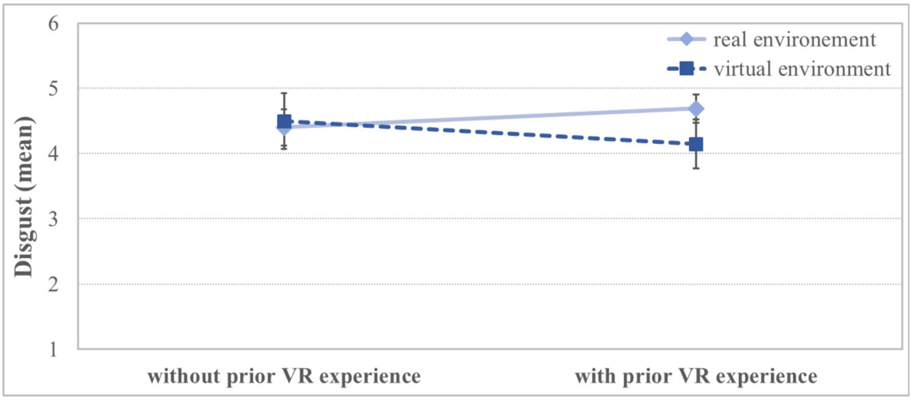
		F	df	df_{error}	p	$\eta^2_{part.}$
Disgust	Environment	1.42	1	21	.248	.063
	Prior VR experience	.00	1	21	.958	.000
	Environment x Prior VR experience	3.00	1	21	.098	.125
Happiness	Environment	.62	1	20	.441	.030
	Prior VR experience	.23	1	20	.634	.012
	Environment x Prior VR experience	2.80	1	20	.110	.123
Fear	Environment	1.17	1	19	.292	.058

(*continued*)

Table 4. (*continued*)

		F	df	df_{error}	p	$\eta^2_{part.}$
	Prior VR experience	.02	1	19	.889	.001
	Environment x Prior VR experience	1.17	1	19	.292	.058
Sadness	Environment	1.75	1	21	.200	.077
	Prior VR experience	.40	1	21	.849	.002
	Environment x Prior VR experience	1.75	1	21	.200	.077

As shown in Table 4, a tendency towards a significant interaction emotional category x prior VR experience can be shown regarding disgust. Post-hoc analyses (Sidak) show that participants with prior VR experience assessed disgusting pictures in the real environment as significantly more disgusting than in VR ($p = .038$; see Fig. 6).



Note. Mean values, 6-point scale: Not at all (1) – very (6)

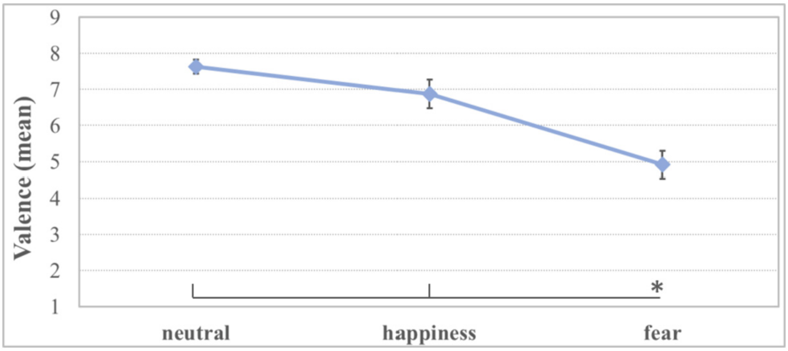
Fig. 6. Mean subjective assessments of the emotion disgust of the two prior VR experience groups in real and virtual environment.

3.2 Exploratory Part: 360° Videos in Virtual Environments

Subjective Measures

Valence. The results of an analysis of variance with repeated measures shows significant differences for the subjectively perceived valence of the emotional categories induced by the 360° videos in VR, $F(2, 21) = 21.53$, $p < .001$, $\eta^2_{part.} = .672$. All other effects did not reach the level of significance (prior VR experience: $F(1, 22) = 2.05$, $p = .166$, $\eta^2_{part.} = .085$, interaction emotional category x prior VR experience: $F(2, 21) = 3.01$, $p = .071$, $\eta^2_{part.} = .223$).

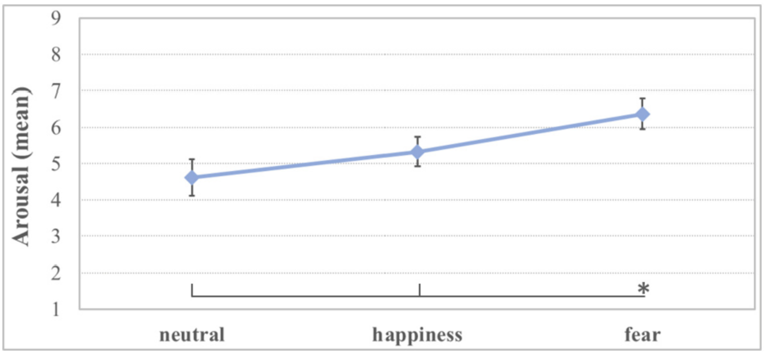
Post-hoc analyses (Sidak) show that the emotional category fear (M = 4.92, SD = 1.84) was assessed significantly more negative than the categories neutral (M = 7.63, SD = .97; p < .001) and happiness (M = 6.88, SD = 1.92; p = .001; see also Fig. 7).



Note. 9-point-scale: Negative (1) – positive (9); I … standard error of mean; * … p < .05

Fig. 7. Mean subjectively perceived valence of the three different emotional categories induced by 360° videos in VR.

Arousal. Regarding the subjectively perceived arousal, the results of an ANOVA with repeated measures indicate a significant effect emotional categories, $F(2, 21) = 7.20$, $p = .004$, $\eta^2_{part.} = .407$. Furthermore, no significant effect of the prior VR experience, $F(1, 22) = .03$, $p = .861$, $\eta^2_{part.} = .001$, and the interaction emotional category x prior VR experience, $F(2, 21) = .99$, $p = .388$, $\eta^2_{part.} = .086$, can be shown. Following the results of post-hoc analyses (Sidak) the subjectively perceived arousal was significantly higher for the emotional category fear (M = 6.37, SD = 2.08) than for the



Note. 9-point-scale: Low (1) – high (9); I … standard error of mean; * … p < .05

Fig. 8. Mean subjectively perceived arousal of the three different emotional categories induced by 360° videos in VR.

categories neutral ($M = 4.62$, $SD = 2.48$; $p = .004$) and happiness ($M = 5.33$, $SD = 1.99$; $p = .044$; see also Fig. 8).

Psychophysiological Measures

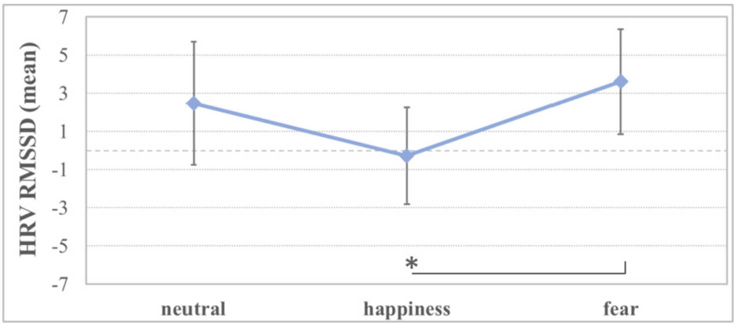
Cardiovascular Activity. Table 5 shows the results of the analyses of variance with repeated measures for the parameters of the cardiovascular activity.

Table 5. Results of the analyses of variance with repeated measures for the parameters of the cardiovascular activity.

		F	*df*	*df error*	*p*	$\eta^2_{part.}$
HR	Emotional category	2.56[b]	1.48	35.81	.101	.104
	Prior VR experience	.00	1	22	.998	.000
	Emotional category x Prior VR experience	.12	2	21	.886	.011
HRV (RMSSD)	Emotional category	4.98	2	21	.017	.322
	Prior VR experience	.08	1	22	.779	.004
	Emotional category x Prior VR experience	.22	2	21	.804	.021

Note. [b]Huynh-Feldt correction

As presented in Table 5, the results of an ANOVA with repeated measures showed a significant effect of the emotional categories for the HRV (RMSSD). Post-hoc analyses (Sidak) show significantly lower HRV (RMSSD) for the emotional category happiness ($M = -.28$, $SD = 12.41$) than for the emotional category fear ($M = 3.60$, $SD = 13.51$; $p = .033$; see also Fig. 9).



Note. Baseline-corrected mean values; I … standard error of mean; * … $p < .05$

Fig. 9. Mean heart rate variability (HRV RMSSD): Three different emotional categories induced by 360° videos in VR.

Electrodermal Activity. Table 6 shows the results of the analyses of variance with repeated measures for the parameters of the electrodermal activity.

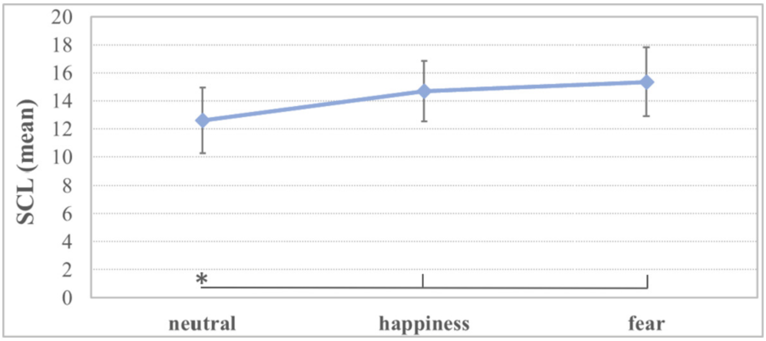
Following the results presented in Table 6, a significant effect of the emotional categories can be shown regarding the skin conductance level (SCL). Post-hoc analyses (Sidak) show a significantly lower SCL for the the neutral category ($M = 12.61$, $SD = 11.57$) than the emotional category happiness ($M = 14.68$, $SD = 10.58$; $p = .049$) as well as fear ($M = 15.35$, $SD = 12.07$; $p = .016$; see also Fig. 10).

Table 6. Results of the analyses of variance with repeated measures for the parameters of the electrodermal activity.

		F	df	df_{error}	p	$\eta^2_{part.}$
SCL	Emotional category	5.42	2	21	.013	.340
	Prior VR experience	1.39	1	22	.251	.060
	Emotional category x Prior VR experience	.83	2	21	.449	.074
NS.SCR freq	Emotional category	2.88	2	21	.079	.215
	Prior VR experience	.77	1	22	.391	.034
	Emotional category x Prior VR experience	.41	2	21	.667	.038
NS.SCR amp	Emotional category	.90	2	21	.421	.079
	Prior VR experience	.05	1	22	.824	.002
	Emotional category x Prior VR experience	1.14	2	21	.340	.098
NS.SCR amp/NS.SCR freq	Emotional category	.22	2	21	.801	.021
	Prior VR experience	.49	1	22	.491	.022
	Emotional category x Prior VR experience	.33	2	21	.720	.031

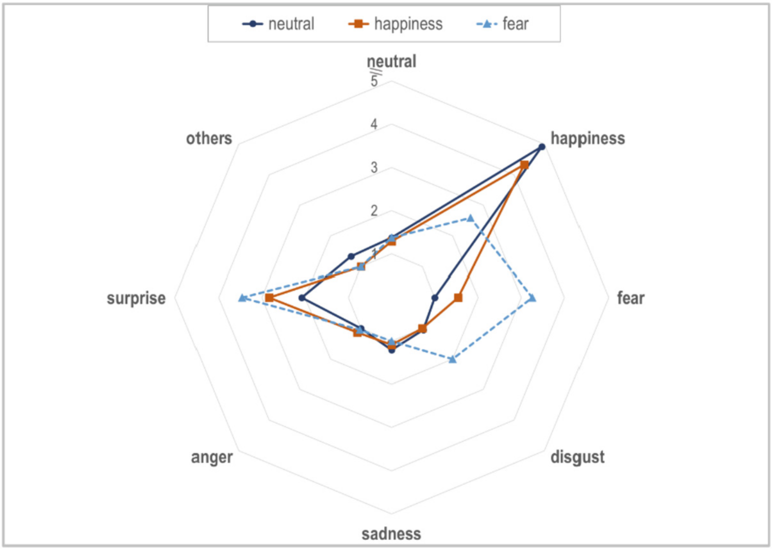
Emotion Characterization

Figure 11 shows the results of the emotion characterization for the emotion induction of the two emotions happiness and fear and the neutral category with 360° videos in VR. For each of the three categories, the assessments for the subjectively perceived emotional impression assessed with the emotions happiness, fear, disgust, sadness, anger, surprise, and the categories neutral and others are presented.



Note. Baseline-corrected mean values; I … standard error of mean; * … $p < .05$

Fig. 10. Mean skin conductance level (SCL): Three different emotional categories induced by 360° videos in VR.



Note. Mean values, 6-point scale: Not at all (1) – very (6), cut at (5)

Fig. 11. Emotion characterization of the three different emotional categories induced by 360° videos in VR.

4 Discussion

The presented paper focusses on two different parts of the study: An experimental and an exploratory one. In the first, experimental part, it was investigated whether a person's emotional experience induced with affective pictures of four emotional categories (disgust, happiness, fear and sadness), differs when presented in a real or virtual environment. Furthermore, the influence of prior experience with VR was of interest. The results indicate that the affective pictures were able to induce significantly different emotional responses. Hence, the emotional category happiness was assessed significantly more positive than the used categories disgust, fear and sadness. Sadness induced by affective pictures was assessed significantly more negative than disgust and fear. Furthermore, the results reveal significant differences in emotional responses between virtual and real environments, while prior VR experience does not significantly affect emotions. Thus, regarding the measured cardiovascular responses of the participants, the heart rate (HR) was significantly higher during the stimuli presentation in the real environment than in the virtual environment. Furthermore, the HRV was significantly higher during the presentation of affective pictures in the virtual environment than in the real environment for the categories happiness and fear. Regarding the electrodermal reactions of the participants the results show that the skin conductance level (SCL) was significantly higher during the presentation of the affective pictures in the virtual environment than during the presentation in the real environment. The psychophysiological responses give a further indication that the use of VR environments have their advantages for emotion research [cf. 2, 8]. The presentation of the affective pictures used, seems to evoke stronger emotional responses in VR than on a computer screen (real environment). At the same time, stimuli presentation in the real environment may be more mental demanding when presented on the computer screen than when presented in VR. Following the results of HRV this seems to be especially relevant for the two emotional categories happiness and fear. This is also in line with [16] who showed that visual stimuli are experienced emotionally different in virtual than in real environments.

Whereas VR-experience did not significantly affect emotions in the experimental part of the study, a tendency towards a significant interaction emotional category x prior VR experience can be shown for the emotional characterization of disgust. Here, participants with prior VR experience assessed disgusting pictures in the real environment as significantly more disgusting than in VR. One explanation for this could be that the presentation order could not be permuted due to the circumstance of being a part of an overall study (see also [25]) – the participants experienced the affective pictures first in the real environment and afterwards in the VR environment. Interestingly, the effect was only shown for participants with prior VR experience. Maybe the "novelty" of experiencing VR, masked this effect for novices. This should be further investigated in future studies.

The second, exploratory part of the study aims to examine the effect of immersive 360° videos in a virtual environment on the emotional experience (categories: happiness, fear, neutral). The results show that significantly different emotional responses are evident in both, the subjective and psychophysiological parameters. Again, VR-experience did not show a significant effect. Subjectively, the emotional category fear was assessed significantly more negative and significantly more arousing than the categories neutral and happiness. This result is also supported by the participants' emotion characterization of the three 360° videos used. The psychophysiological responses of the participants point partly in the same direction. Hence, they indicate lower emotional responses regarding the neutral category than for the emotional categories happiness and fear. Interestingly, at the same time mental strain was significantly higher during stimuli of the category happiness than while experiencing stimuli of the category fear. This can possibly be explained with the visual stimuli (360° videos) used (see also emotion characterization) and should be included in future research.

Nonetheless, the study has some limitations. As mentioned before, sequence effects could not be excluded due to the embedding in a larger (overall) study, and should therefore become part of subsequent research. Furthermore, the authors suggest to include more resting measurements during the different experimental parts for future research. Although the subjective assessments of the subjective well-being before, during and after the experiment did not show any adverse effect, it cannot be completely excluded, that the sequence of the stimuli or the duration of the experiment influenced the results. Additional resting measurements between the different experimental blocks should help to control such possible effects even better. Furthermore, according to [2], there is a lack of standardized VR video material. As the results suggest, especially the video representing the emotional category fear, could therefore be improved. Unfortunately, some data from the psychophysiological recordings were missing due to technical problems. This should be further improved for future research. Finally, the presentation via the computer screen was used to present the stimuli in a real environment. The use of this medium might not have been perceived as different enough from the presentation in VR. From our point of view, further research is needed regarding emotional reactions on "real" scenarios and virtual scenarios.

To sum it up, the results show an effect of the environment (real or virtual) on the emotional responses in the psychophysiological parameters and the subjective assessments of the participants. On this matter, VR-experienced persons do not significantly differ from VR-inexperienced persons, but a tendency towards a significance can be shown for the emotional characterization of disgust.

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