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The effects of appearance and motion of virtual characters on emotional reactivity

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ABSTRACT

The aim of this study was to examine the influence of appearance and motion of virtual characters on students' emotional reactions. We used four different virtual reality (VR) conditions with different combinations of appearance and motion: that is, a regular-male and zombie-male virtual character each assigned to low- and high-amplitude motion. Participants were asked to wear a head-mounted display (HMD) and observe the virtual content. Immediately after viewing each of the four stimuli, participants were asked questions about their emotional reactions in terms of reactivity (intensity) and subjective valence. Both the appearance and the motion of the virtual characters significantly affected participants' (a) emotional valence in a dynamic pattern and (b) emotional intensity, with reactions to subjectively aversive and/or active stimuli as more negative than reactions to neutral and/or passive stimuli. Females showed significantly higher levels of negative emotional intensity to all virtual characters and negative emotional valence (lower likeability) to aversive characters. Implications for further research, and gender and cultural considerations are discussed.

1. Introduction

It has been suggested that to the extent to which users can be immersed into a virtual world, VR blurs the line between real and virtual experience to the point that the distinction may become ambiguous to some people (Billinghurst, Kato, & Poupyrev, 2001; Bowman & McMahan, 2007; Ropolyi, 2016). Reality and fantasy can be blurred and commingled, and this may have cognitive and social implications (Andersen, 2017).

In addition, the transition to an age of mixed actual and virtual reality can be accompanied by anxiety toward technological innovation, which could take several forms. For example, it is possible for people to be hesitant about this new kind of VR contacts and/or interactions. Thus, in this study, we focus on university students, who we theorize may be more amenable than other portions of population to VR contacts. We examine the extent to which their emotional reactivity (intensity) change when they are exposed to variations of VR.

Immersive virtual environments allow simulation of real-world scenarios that would be difficult or impossible to experience otherwise, either because of technical feasibility or cost (Gallagher et al., 2005; Maran & Glavin, 2003; Mujber, Szecsi, & Hashmi, 2004; Zyda, 2005). With the rapid development of low-cost VR technologies, users will progressively contact and/or interact with virtual worlds and characters. Technologies like Microsoft's Kinect, which tracks a user's whole body, are able to not only capture the movement of the user, but also to transfer his or her movements into the virtual scene (Zhang, 2012), creating the sense that the user is, and belongs, in the VR environment both mentally and physically (Dourish, 2004; England, 2011). In addition, the widely spread of low-cost VR display technologies (e.g., HMDs such as the Oculus Rift or HTC's Vive) is enhancing users' emotional reactions, when compared to more common monitors, such as computer screens.

VR environments and simulations have several applications in many fields, including neuroscience, medicine, psychology, education, human communication, and marketing and advertising. The accessible and easy acquisition of three-dimension (3D) graphics content using low-cost 3D scanning technologies (Izadi et al., 2011; Tong, Zhou, Liu, Pan, & Yan, 2012) in conjunction with either computational methods that provide variations of the 3D content (Kalogerakis, Chaudhuri, Koller, & Koltun, 2012; Xu et al., 2010) or user-friendly interfaces for designing and editing the 3D content

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oneself (Chaudhuri, Kalogerakis, Giguere, & Funkhouser, 2013; Yu, Yeung, & Terzopoulos, 2016) all make it easier and faster the process to produce variations of visual stimuli. In this way, limitations of studies (Loomis, Blascovich, & Beall, 1999; Sanchez-Vives & Slater, 2005) of emotional perception and reactivity (intensity) that use traditional, non-VR methods, including over-generalized visual stimuli (e.g., photographs of faces and scenes) (Sabatinelli et al., 2011), can be overcome. VR provides vividness and tangibility to virtual emotional reactions by assimilating the social contact of the real world.

In virtual reality, games, and animation movies, a virtual character is the representation of a human or humanoid that corresponds to a particular person or creature within the virtual context (Brogan, Metoyer, & Hodgins, 1998; McDonnell, Breidt, & Bülthoff, 2012). Virtual characters can either be represented in 2D or 3D forms depending on the context (e.g., video games, animated movies) (Fink, 1999; Lessig, 2009). Virtual characters not only transfer information to humans on a cognitive-analytical processing level, but they can also be perceived as social agents that can influence human functioning at an emotional processing level (Astrid, Krämer, Gratch, & Kang, 2010; Bailenson, Blascovich, Beall, & Loomis, 2003; Fox et al., 2015; Pertaub, Slater, & Barker, 2002). It has been shown that humans are able to understand a social interaction with a virtual character and that VR characters may even evoke a sense of social presence (Biocca, Harms, & Burgoon, 2003; Fox et al., 2015), especially when represented in an anthropomorphic way (Astrid et al., 2010; Fox et al., 2015; Nowak & Biocca, 2003). Humans' ability to closely relate to VR characters makes the evaluation of possible variations in emotional intensity as a function of distinct features of the VR stimuli necessary.

Considering the large amount of VR content available (especially games and 360 videos), its accessibility, and the spread of low-cost VR hardware (for example, smartphones can be converted into HMDs for less than $100 by placing them inside Google's cardboard headset or Samsung's GearVR headset), we believe that a better understanding of VR users' emotional reactions to virtual characters is vital. In this study, we developed four experimental conditions for examining the emotional reactivity to the appearance and motion of virtual characters. Emotional reactivity (intensity) has been defined as the tendency to experience emotional arousal in response to visual stimuli (Astrid et al., 2010; Clark, Watson, & Mineka, 1994; Fox et al., 2015; Karrass et al., 2006; Stevens & Hamann, 2012). In a VR context, emotional intensity can be defined as an instantaneous reaction by a user contacting with a VR stimulus. In our view, emotional intensity can be operationalized in several ways, including (a) the intensity of the emotional arousal, that is, the ease with which a human becomes emotionally aroused and the comfort in the contact with a VR character, and (b) psychological readiness to interact with a virtual character. In our experiment, emotional reactivity (intensity) refers to a spontaneous reaction (e.g., uneasiness to easiness, uncomfortableness to comfortableness, and unreadiness to readiness to interact) experienced by an individual as the result of the presence of a virtual stimulus, which is designed to be either neutral or aversive, and with two different levels of activity. Finally, like most studies (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Clark et al., 1994; Huang & Hu, 2009; Spinrad et al., 2004; Stevens & Hamann, 2012), our study is primarily focused on negative emotional reactions.

1.1. The current study

Emotional reactivity (intensity) is the central concept of this study and is defined in terms of emotional reaction to a virtual stimulus. To understand how emotional intensity relates to features of virtual stimuli, we examined two basic dimensions: the appearance (neutral vs. aversive) and motion (low amplitude vs. high amplitude) of a virtual character, and the combination of these factors (2×2). We selected two virtual character models: a male human-like character and a male zombie-like character. We used two types of idle motion: low amplitude and high amplitude. In low-amplitude motion, the angle range of the character's body joints is more constrained; that is, body joints do not rotate that much; on the other hand, high-amplitude motion means that the angle range of the character's body joints is less constrained; that is, body joints rotate more (Neff & Fiume, 2008). Idle motion (Egges, Molet, & Magnenat-Thalmann, 2004) refers to the type of motion assigned to a character that retains its global position without moving in the 3D environment. The research hypotheses of this study were as follows:

- RQ1: Aversive characters with high-amplitude motion have a greater impact on emotional reactivity (intensity) than regular characters with low-amplitude motion.
- RQ2: Females have higher levels of emotional reactivity (intensity) to virtual characters than males.
- RQ3: Participants with prior virtual reality experiences have lower emotional reactivity to virtual characters compared to those without prior experiences.
- RQ4: Features of appearance and motion of virtual characters have a dynamic (moving and changing) impact on emotional valence.
- RQ5: Females have more negative emotional valence (lower likeability) to aversive (zombie) virtual characters than males.

2. Theoretical framework and related work

Emotions are complex phenomena of subjective experiences, and this is reflected in different and often opposing theories of emotion (Fuchs & Koch, 2014). Psychopathology, and extreme psychological conditions can provide a key to understanding emotion complexity. According to the biphasic theory of emotion, the emotional reactional system has two major dimensions: (a) emotional valence, (b) emotional reactivity or intensity (Berenbaum, Raghavan, Le, Vernon, & Gomez, 2003; Hillman, Rosengren, & Smith, 2004; Lang, 2000; Lang & McTeague, 2009; Lang, Bradley, & Cuthbert, 1990). Emotional valence refers to pleasant (positive/appetitive) emotions or unpleasant (negative/aversive) emotions, which are typically related to the presence of corresponding stimuli. One common type of unpleasant/aversive emotions is the distress emotions such as fear, anxiety and disgust (Berenbaum et al., 2003; Hillman et al., 2004; Lang, 2000; Lang & McTeague, 2009; Lang et al., 1990). Emotional reactivity (or intensity or arousal) refers to the human organism's disposition to react with varying degrees of energy (Berenbaum et al., 2003; Hillman et al., 2004; Lang, 2000; Lang & McTeague, 2009; Lang et al., 1990). Both emotional hyperreactivity and hyporeactivity are related psychopathological conditions (Lang et al., 1990). For example, there is evidence for hyperactivity towards aversive stimuli (excessive levels exhibited by individuals) such as anxiety disorders (Berenbaum et al., 2003), phobias (e.g., cynophobia) (Suied, Drettakis, Warusfel, & Viaud-Delmon, 2013), and skin-picking disorder (Wabnegger, Übel, Suchar, & Schienle, 2018), as well as hyporeactivity (flattening levels of reaction) especially for positive/pleasant stimuli (e.g., depression) (Berenbaum et al., 2003). In the current study, we focus on reactivity (varying degrees of reactivity) towards aversive stimuli, in particular, fear and embarrassment/disgust.

Two characteristics of stimuli that can arouse reactions towards aversive emotions are: (a) physical appearance, and (b) movement.

Physical appearance is commonplace in most aversive experiments (e.g., using fearful, disgusting stimuli) in non-virtual environments (Atkinson, Dittrich, Gemmell, & Young, 2004; Hare et al., 2008). In virtual environments, the appearance (face and body appearance varied by the modification of the character's texture) can influence emotions (Hodgins et al., 1998, 2010; Inkpen & Sedlins, 2011; McDonnell, Jörg, McHugh, Newell, & O'Sullivan, 2009; Nowak, 2001; Nowak & Biocca, 2001).

Motion and emotion are intrinsically connected. Emotion is often prompted by movement, which at the same time can move a human organism (via expression, action tendency; hence, e-motion) (Fuchs & Koch, 2014; Hillman et al., 2004). Motion in combination with physical appearance has greater ecological validity than static images, because both faces and bodies have an impact on emotional intensity in authentic social interactions (Atkinson et al., 2004; Hodgins et al., 2010; McDonnell et al., 2009). The geometry of the 3D model (virtual character) may affect the characteristics of motion applied to a virtual character (Hodgins et al., 1998). Higher sensitivity to changes in motion has been found when applied to a polygonal model than a stick figure (Hodgins et al., 1998).

Several studies have tried to understand the intersection between the motion and the appearance of virtual characters (Hodgins et al., 1998, 2010). Hodgins et al. (Hodgins et al., 2010) conducted perceptual experiments to investigate how degradation of human motion affects the emotional response of participants to an animation. They found that removal of the facial animation changed emotional reactivity (intensity). Animations with no facial animation conveyed emotional content and reactions, but less effectively (Hodgins et al., 2010).

This is a pilot study, part of a broader project for studying emotional reactivity (intensity) in atypical populations (e.g., individuals with autism spectrum disorders, phobias, depression). Specifically, we hypothesized that in normal young adult participants virtual environments can elicit varying degrees of negative emotional reactions about virtual characters with vivid motion, when environments through aversive stimuli induce anxiety or embarrassment. This may be considered commonsensical, but the *uncanny valley* phenomenon suggests uncertainty about actual emotional reactions before their careful investigation (Tinwell, 2014, pp. 173–186). The uncanny valley theory predicts that an entity (android) appearing almost human can elicit cold, eerie feelings in viewers (MacDorman & Ishiguro, 2006). It has been found that reducing realism consistency in human replicas increased the uncanny valley effect (MacDorman & Chattopadhyay, 2016). It is noteworthy that Geller (Geller, 2008) claimed that this can also happen with realistic virtual characters, which may receive negative reactions when their appearance and motion is uncomfortably realistic. However, the possibility of the uncanny valley effect has not been extensively investigated with virtual characters (Tinwell, Grimshaw, Nabi, & Williams, 2011).

Age-related differences have been observed in emotional reactivity among typical developing populations. Thus, adolescents show increased emotional reactivity compared with children and adults (Hare et al., 2008).

No consensus has been reached regarding gender differences in emotional reactivity (intensity). Overall, men and women differ in the processing of emotional content (Deng, Chang, Yang, Huo, & Zhou, 2016; Fischer, Rodriguez Mosquera, Van Vianen, & Manstead, 2004; Gohier et al., 2013). These gender differences in emotion may be culturally mediated (Codispoti, Surcinelli, & Baldaro, 2008; Deng et al., 2016; Fischer et al., 2004). However, some studies have shown that the gender differences in response to a specific type of emotional stimuli cannot be taken for granted (Codispoti et al., 2008; Deng et al., 2016; Fischer et al., 2004). In this study, we focus on aversive stimuli. Some studies using pictorial material have found that women respond to aversive pictures with greater defensive intensity –measured either physiologically (women responded with more cardiac deceleration when viewing unpleasant pictures) or with evaluative judgments– regardless of the specific content (e.g., human attack, animal attack, mutilation, accident) (Bradley et al., 2001; Hillman et al., 2004). However, gender-related differences in emotional reactivity (intensity) regarding aversive characters in non-pictorial environments are far from being conclusive (Deng et al., 2016; Gohier et al., 2013). For example, Deng et al. (Deng et al., 2016) found no gender difference in heart rate (an actual *physiological experience*), when their participants watched videos that induced *fear* and *disgust*; however, women reported higher arousal than men (*emotional expressivity*) (Deng et al., 2016). In general, when watching videos that induce an emotional response, men tend to have more intense emotional experiences, whereas women tend to have higher emotional expressivity for negative emotions (Codispoti et al., 2008; Deng et al., 2016). Thus, gender differences in emotional intensity may depend on specific types/content of emotion, and not so much on valence (positive or negative or neutral), as well as on the method of measurement (e.g., heart rate recording or reactivity reporting), sustained attention, and action preparation of participants (Codispoti et al., 2008; Deng et al., 2016). Thus, for some, physiological and emotional experiences are two different reactions systems (Deng et al., 2016; Evers et al., 2014). In the current study, we focused on spontaneously reported emotional reactivity (intensity) towards stimuli meant to induce fear and embarrassment/disgust (versus neutral stimuli) in a virtual environment.

3. Materials and methods

3.1. Participants

We conducted an *a priori* power analysis to determine the sample size, using G*Power3.10 software (Cohen, 1988, pp. 20–26). The calculation was based on 95% power, a medium-effect size of 0.25 (Faul, Erdfelder, Buchner, & Lang, 2009) and four (2×2) groups with four repeated measures, a non-sphericity correction $\varepsilon = .60$, and an $a = 0.05$. The analysis resulted in a recommended sample size of 72 participants.

In this study, the participant group was comprised of 72 volunteers, undergraduate and graduate students at a Midwest U.S. university. Of the sample, 16 (22.2%) were female and 56 (77.8%) were male. Forty-eight (66.7%) participants were majoring in computer science, 12 (16.7%) in English literature, five (6.9%) in computer engineering, and seven (9.7%) in other social science and humanities departments. The sample's computer-related and humanities/social science ratio was designed to be about 3:1, in an effort to include enough students with VR experience. Students' ages ranged from 18 to 47, with a mean of 23.24 ($SD = 5.18$). Forty-two (58.3%) students had never experienced VR before, whereas 30 (41.7%) students had experienced it at least once.

3.2. Physical and virtual environment

The study took place in a computer science research lab. The lab was 26 ft long, 16 ft wide, with a ceiling height of 8 ft. This lab was free of unnecessary objects or obstacles, and is a space typically used for conducting VR-related experiments. The virtual characters were placed in an empty virtual environment designed in the Unity game engine. The environment was empty in order to give participants the sense that they were allowed to move freely into the

virtual world.

3.3. Virtual reality application

The application was developed in Unity 5.5. The VR hardware used was the Oculus Development Kit 2. The Oculus Utilities for Unity 5 package for the Oculus integration into Unity was used. The application consisted of one scene with five available buttons for the experimenter: four to change between the different experiment conditions, and one to change the virtual characters' position. The buttons were available from the Unity's inspector panel and each made one of the following appear: regular-male character with low amplitude, regular-male character with high amplitude, zombie-male character with low amplitude, and zombie-male character with high amplitude. The fifth button changed the character's position (for either character). The four conditions used in our experiment are shown in Fig. 1. The models used to represent the regular male and zombie male came from Mixamo and CG River. We used Unity's Mechanism animation engine to assign movements to the virtual characters. The motion data used in our experiment were downloaded from Unity's asset store.

The use of a modern HMD that allows users to navigate within the virtual environment was able to provide users with the ability to not only immerse themselves in it but also navigate within it. According to Slater (Slater, 2009) scenarios that allow users to interact with the virtual environments (in our case it is the freedom that is given to the users to navigate into the virtual environment) positively affect the feeling of presence that users have when navigating in virtual reality scenarios. In addition, according to Steed et al. (Steed et al., 2016) having a self-avatar should have a positive impact on presence. Thus, following Slater and Wilbur's (Slater & Wilbur, 1997) definition for presence, it can be claimed that both the navigation freedom and the self-avatar provide positive levels of presence.

3.4. Measures: emotional reactivity and emotional valence

Participants rated their emotional reaction (uneasiness vs. easiness, non-comfortableness vs. comfortableness, non-readiness vs. readiness for interaction) to the presence and motion of a virtual character. The emotional reactivity (intensity) scale consists of six items on a seven-point Likert scale ranging from one (i.e., not uneasy at all) to seven (i.e., totally uneasy) (see Appendix 1). All questions included a negative adjective (uncomfortable, uneasy, unready to interact). High values on the scale mean strong negative emotional reactivity. The six-item scale yielded good to very good reliability coefficients for the emotional reactivity to virtual stimuli. Specifically, the Cronbach's alpha coefficient of the intensity was $\alpha = .87$ for the low-amplitude regular-male character, $\alpha = .90$ for the high-amplitude regular-male character, $\alpha = .82$ for the low-amplitude zombie-male character, and $\alpha = .92$ for the high-amplitude zombie-male character. No removal of items would enhance these reliability measures.

For the valence dimension, participants evaluated the appearance and motion. Specifically, each characteristic (face, body, size, motion) of every virtual character was rated on a 1-7-point scale (1 for dislike - 7 for like). The Cronbach's alpha coefficient for the subjective valence was $\alpha = .67$ for the low-amplitude regular-male character, $\alpha = .76$ for the high-amplitude regular-male character, $\alpha = .62$ for the low-amplitude zombie-male character, and $\alpha = .70$ for the high-amplitude zombie-male character. Removal of items would not enhance these reliability measures.

3.5. Procedure

An original emotional reaction questionnaire, developed for the needs of this study, was provided to participants. Our measure addressed the two dimensions of the emotional reaction system: (a) reactivity (intensity) and (b) emotional valence, that is, the subjective ratings of valence that followed the measurement of intensity. The questionnaire consisted of two sections, one demographic and another experimental section. The total duration of the whole procedure lasted on average 40 min. The reactivity (intensity) questions are listed in Appendix 1. Participants were first

Fig. 2. A participant wearing the Oculus Rift HMD during the experiment.

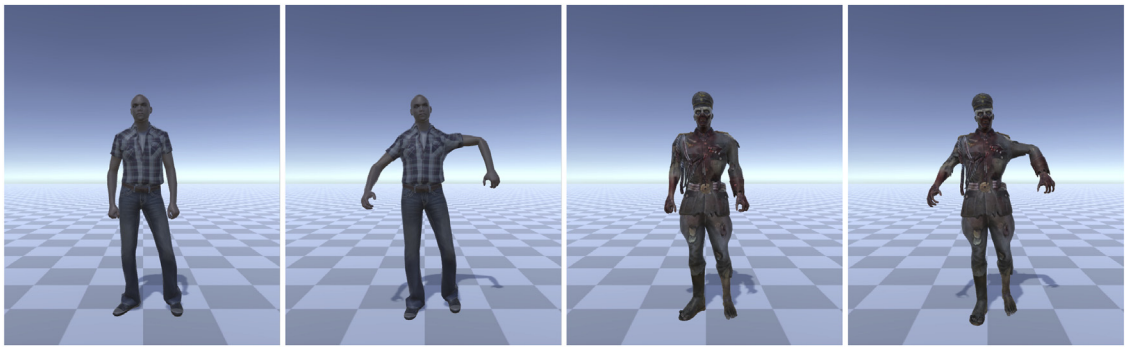

Fig. 1. The two different virtual characters used in our application in conjunction with their low- and high-amplitude motion. From left to right: regular-male character with low-amplitude motion, regular-male character with high-amplitude motion, zombie-male character with low-amplitude motion, and zombie-male character with high-amplitude motion.

asked to complete the demographic section, and then were asked to wear the Oculus Rift HMD (see Fig. 2). Before commencing the experiment, the participants were informed briefly about what they would see and what they would be asked to do, and they were given the option to stop the experiment at any time if they felt any kind of discomfort. After this briefing, an experimenter (third author) began the experiment application, beginning with an empty scene (see the left panel on Fig. 3).

The participants were asked questions Q1 and Q2 only on this initial load of the experiment while the scene was still empty. The moment the participants were done answering Q2, the experimenter made a low-amplitude or high-amplitude regular-male character appear in a distance from the participants (see middle panel on Fig. 3). The participants were asked Q3, and then the experimenter changed the position of the virtual character in order to bring him gradually closer, until the virtual character stood in front of the participant. With the character closer to them, the participants were asked questions Q4-Q8. Fig. 3 illustrates the three distinct stages that participants saw for the regular-male character and the zombie-male character (both assigned to low-amplitude motion). The images show the participants' exact view when looking forward. Similar scenes were observed in the other two conditions (regular-male and zombie-male assigned to high-amplitude motion). It should be noted that participants were able to freely rotate their heads and walk around the virtual environment in order to observe the virtual characters from different perspective and distance.

After participants completed the first iteration of questions with the low-amplitude or high-amplitude regular-male character, the procedure was repeated, with one empty scene between each transition. There was partial counterbalancing among the four conditions: (1) low-amplitude regular male, (2) high-amplitude regular male, (3) low-amplitude zombie male, and (4) high-amplitude zombie male. The regular-male character appeared first to avoid participants' sudden exposure to an unusual character and inconvenience, but a possible carry-over effect was dealt with by using randomization of the motion condition. Thus, the regular character appeared first with either low- or high-amplitude motion, followed by the zombie male with either low- or high-amplitude motion. The order of the conditions was randomized across four groups of 18 subjects as follows: 1234, 1243, 2134, 2143. For each condition, the experimenter was asking the participants to answer Q3-Q8 and changing the position as aforementioned after asking Q2. Following the questions assessing emotional intensity, participants rated their likability of the characters (subjective valence), and in particular, four characteristics (i.e., face, body, size, motion) for each of the four virtual characters. The order of the conditions was randomized across the four characters.

4. Results

4.1. Data analysis

Data on the emotional reactivity to the high-amplitude zombie male were reflected and inverse transformed because of severe negative skewness. After carrying out the mathematical transformations, we screened variables for univariate and multivariate normality, linearity among variables, univariate and multivariate outliers, multicollinearity, equality of error variances for each of the dependent variables, and equality of variance-covariance matrices. All these assumptions were met (Tabachnick, Fidell, & Osterlind, 2001). Table 1 shows the descriptive statistics (means and standard deviations) and Pearson correlations among the emotional reactivity variables. In addition, Fig. 4 indicates emotional reactivity (intensity) for each experimental condition without mathematical transformations; the correlational value for emotional reactivity to the high-amplitude zombie male in Table 1 is based on the transformed values. Table 2 shows descriptive statistics on the original values of emotional reactivity (intensity) as a function of gender and virtual experience. Table 3 shows the descriptive statistics (means and standard deviations) and Pearson correlations among the emotional valence variables; the correlational value for the valence to the high-amplitude zombie male in Table 3 is based on the transformed values.

4.2. Emotional reactivity to virtual characters

We conducted a repeated-measures analysis of variance

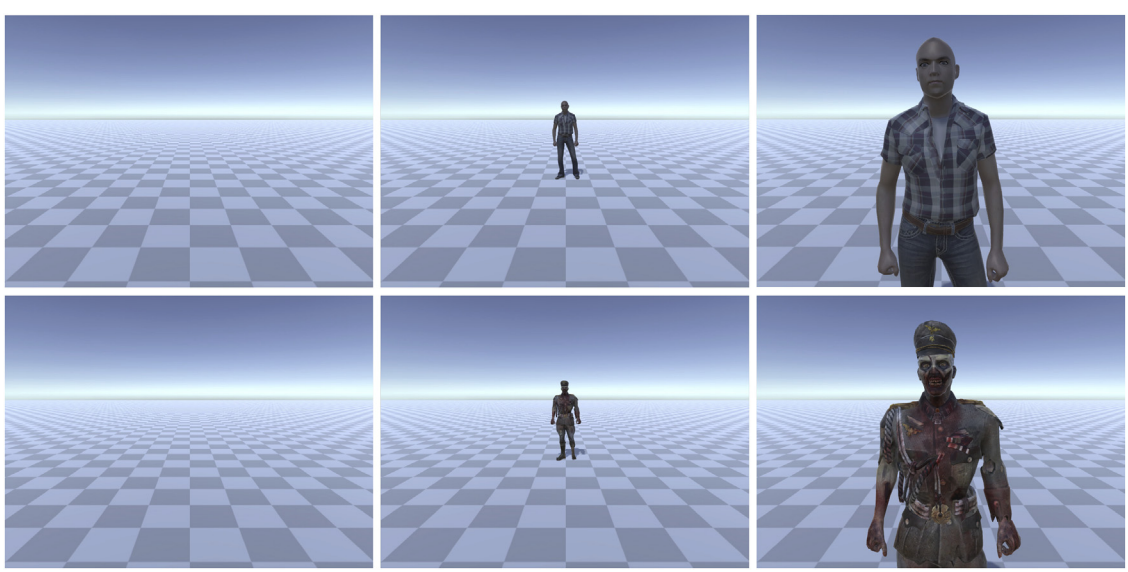

Fig. 3. The regular-male character (upper row) and the zombie-male character (lower row), both assigned to low-amplitude motion. The experiment starts with an empty scene (left panel) and the experimenter asks Q1 and Q2, then the character appears far from the participant (middle panel) and the experimenter asks Q3, and then the virtual character is coming in front of the participant (right panel) and the experimenter asks Q4-Q8.

Table 1
Descriptive statistics for emotional reactivity (intensity) and Pearson correlations among variables.

Variable	Mean	SD	2	3	4
1. Emotional reactivity to low-amplitude regular male	2.10	1.18	.60*	.55*	.50*
2. Emotional reactivity to high-amplitude regular male	3.38	1.59		.63*	.74*
3. Emotional reactivity to low-amplitude zombie male	4.31	1.37			.72*
4. Emotional reactivity to high-amplitude zombie male	5.42	1.55			

*$p < .01$; Ratings for all variables ranged from 1 (min) to 7 (max).

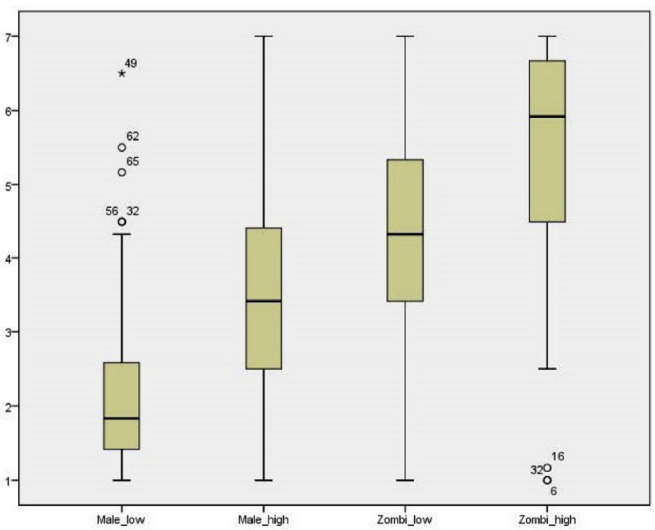

Fig. 4. Emotional reactivity to each virtual character without mathematical transformations. Boxes enclose the middle 50% of the data. The median is denoted by a thick horizontal line. See Table 1 for means and standard deviations.

(ANOVA) with two between-subjects factors: (a) gender (male vs. female) and (b) VR experience (have vs. have not), as well as four repeated measures of emotional reactivity (ER): low-amplitude regular male, high-amplitude regular male, low-amplitude zombie male, and high-amplitude zombie male. The means and standard deviations for the emotional reactivity scores are presented in Table 2. The repeated measures of ANOVA with Greenhouse-Geisser-corrected estimates of sphericity ($\varepsilon = .90$) revealed a significant difference: $F(2.72, 184.64) = 197.21$, $p < .001$, $\eta_p^2 = .74$. Pairwise comparisons, using a Bonferroni correction ($a = 0.0125$), indicated that the ER to the high-amplitude zombie male was significantly more negative than the ER to the low-amplitude zombie male ($p < .001$), high-amplitude regular male ($p < .001$), and low-amplitude regular male ($p < .001$). The ER to the low-amplitude zombie male was significantly more negative than the ER to the high-amplitude regular male ($p < .001$) and low-amplitude regular male ($p < .001$). Finally, the ER to the high-amplitude regular male was significantly more negative than the ER to the low-amplitude regular male ($p < .001$).

4.3. Gender differences in emotional intensity

A 2×2 between-subjects multivariate analysis of variance (MANOVA) was performed on the four conditions of emotional intensity as dependent variables. Independent variables were gender and VR experience (have vs. have not). Using Wilks's statistic, the omnibus MANOVA indicated that gender had a significant effect on the combined dependent variables: $\Lambda = .69$, $F(4, 65) = 7.28$, $p < .001$, $\eta_p^2 = .31$. Females showed significantly higher negative emotional intensity than males. There was not a significant effect of VR experience on the combined dependent variables: $\Lambda = .96$, $F(4, 65) = .63$, $p > .05$, $\eta_p^2 = .04$. Neither the multivariate interaction of independent variables (gender $\times$ VR experience) on the combined dependent variables was significant, $\Lambda = .94$, $F(4, 65) = 1.12$, $p > .05$, $\eta_p^2 = .07$.

Table 2
Descriptive statistics for emotional reactivity (intensity) as a function of gender and virtual experience.

ER Variable	Gender	VR Experience	Mean	SD	N
Low-amplitude regular male	Male	Never	1.80	.86	31
		Once or more	1.75	.76	25
		Total	1.78	.81	56
	Female	Never	3.04	1.58	11
		Once or more	3.63	1.68	5
		Total	3.23	1.58	16
	Total	Never	2.13	1.20	42
		Once or more	2.07	1.17	30
		Total	2.10	1.18	72
High-amplitude regular male	Male	Never	2.86	1.32	31
		Once or more	3.28	1.48	25
		Total	3.05	1.40	56
	Female	Never	4.60	1.81	11
		Once or more	4.37	1.68	5
		Total	4.53	1.71	16
	Total	Never	3.32	1.64	42
		Once or more	3.46	1.54	30
		Total	3.37	1.59	72
Low-amplitude zombie male	Male	Never	3.76	1.17	31
		Once or more	4.26	1.41	25
		Total	3.98	1.29	56
	Female	Never	5.31	.98	11
		Once or more	5.77	.92	5
		Total	5.46	0.96	16
	Total	Never	4.11	1.31	42
		Once or more	4.51	1.55	30
		Total	4.31	1.37	72
High-amplitude zombie male	Male	Never	4.74	180	31
		Once or more	5.55	1.22	25
		Total	5.10	1.60	56
	Female	Never	6.61	0.37	11
		Once or more	6.27	.86	5
		Total	6.50	.56	16
	Total	Never	5.23	1.75	42
		Once or more	5.67	1.19	30
		Total	5.41	1.55	72

In addition, MANOVA follow-up between-subjects analyses showed that females experienced significantly higher negative emotional reactivity than males for the low-amplitude regular male [$F(1, 68) = 25.25$, $p < .001$, $\eta_p^2 = .27$], high-amplitude regular male [$F(1, 68) = 10.09$, $p < .01$, $\eta_p^2 = .13$], low-amplitude zombie male [$F(1, 68) = 17.30$, $p = .001$, $\eta_p^2 = .20$], and high-amplitude zombie male [$F(1, 68) = 11.02$, $p = .001$, $\eta_p^2 = .14$]. Similarly, MANOVA post-hoc pairwise comparisons with gender as an independent variable, after a Bonferroni adjustment ($a = .0125$) showed the same results. Thus, we can see that the effect of gender on emotional reactivity (intensity) is significant for each virtual character.

Table 3
Descriptive Statistics (Means and SDs, Minimum and Maximum values) for Emotional Valence to Virtual Characters and Pearson Correlations among Variables.

Variable	Mean	SD	Min	Max	2	3	4
Emotional valence to low-amplitude regular male	5.24	1.03	2.75	7.00	.64**	.49**	.28*
Emotional valence to high-amplitude regular male	4.35	1.34	1.00	7.00		.56**	.48**
Emotional valence to low-amplitude zombie male	3.54	1.18	1.00	7.00			.84**
Emotional valence to high-amplitude zombie male	2.85	1.26	1.00	6.50			

*$p < .05$, **$p < .01$; Ratings for all characteristics of the virtual characters ranged from 1 (min) to 7 (max). As is shown in Table 3, the actual average overall rating for each virtual character varied.

4.4. Emotional valence to virtual characters

We evaluated the extent to which virtual characters were perceived by participants in a way that they were designed to be perceived. Emotional valence was measured in terms of likeability on a 1-7-point scale (1 for dislike - 7 for like). Lower values showed negative emotional valence (or lower likeability of characters).

We conducted a repeated-measures analysis of variance (ANOVA) with four repeated measures of emotional valence (EV) for the four virtual characters. The repeated measures ANOVA with Greenhouse-Geisser-corrected estimates of sphericity ($\varepsilon = .89$) revealed a significant difference: $F(2.68, 189.95) = 287.84$, $p < .001$, $\eta_p^2 = .80$. Pairwise comparisons, using a Bonferroni correction (a = 0.0125), indicated that the EV to the high-amplitude zombie male was significantly more negative (lower likability) than the EV to the low-amplitude zombie male ($p < .001$), high-amplitude regular male ($p < .001$), and low-amplitude regular male ($p < .001$). The EV to the low-amplitude zombie male was significantly more negative (lower likability) than the EV to the high-amplitude regular male ($p < .001$) and low-amplitude regular male ($p < .001$). Finally, the EV to the high-amplitude regular male was significantly more negative than the EV to the low-amplitude regular male ($p < .001$) (see Table 3).

4.5. Features of virtual characters and emotional valence

If features of appearance and motion of virtual characters have a dynamic impact on emotional valence (see RH 4), the differential influence of the four characteristics will change across the virtual characters. For this reason, we examined the patterns of correlations among the four characteristics with the emotional valence (likeability) of each character. The likeability of the low-amplitude regular male tended to be more highly associated with *(low) motion* (Pearson's $r = .81$, $p < .001$) compared with his face evaluation ($r = .69$, $p < .001$), body appearance ($r = .66$, $p < .001$), and body size ($r = .67$, $p < .001$). The likeability of the high-amplitude regular male tended to be more highly associated with his *body appearance* ($r = .82$, $p < .001$) and *face evaluation* ($r = .79$, $p < .001$) compared with his body size ($r = .72$, $p < .001$), and motion ($r = .71$, $p < .001$). The likeability of the low-amplitude zombie male tended to be more highly associated with his *body size* ($r = .77$, $p < .001$), *body appearance* ($r = .68$, $p < .001$) and *(low) motion* ($r = .68$, $p < .001$) compared with his relatively lower face evaluation ($r = .59$, $p < .001$). The likeability of the high-amplitude zombie male tended to be more highly associated with his *body appearance* ($r = .76$, $p < .001$), *body size* ($r = .76$, $p < .001$) and *(high) motion* ($r = .71$, $p < .001$) compared with his relatively lower face evaluation ($r = .65$, $p < .001$). Overall, this suggests that the face evaluation has a greater impact on the low likeability (negative emotional valence) of aversive characters, but the pattern is complex and dynamic.

4.6. Gender differences in emotional valence

A between-subjects multivariate analysis of variance (MANOVA) was performed on the four conditions of emotional valence as dependent variables, and gender as the independent variable. Using Wilks's statistic, the omnibus MANOVA indicated that gender had a marginally non-significant effect on the combined dependent variables: $\Lambda = .88$, $F(4, 67) = 2.21$, $p = .077$, $\eta_p^2 = .12$. Overall, there were no gender differences in emotional valence. MANOVA follow-up between-subjects analyses showed no gender differences in the evaluation of regular virtual characters. Males ($M = 5.32$, $SD = 1.17$) did not rate (like) the low-amplitude regular male [$F(1, 70) = 1.63$, $p > .05$, $\eta_p^2 = .02$] significantly higher than females ($M = 4.95$, $SD = .98$). Similarly, males ($M = 4.45$, $SD = 1.36$) did not like the high-amplitude regular male [$F(1, 70) = 1.43$, $p > .05$, $\eta_p^2 = .02$] significantly more than females ($M = 4.00$, $SD = 1.26$).

Instead, gender differences were observed in the evaluation of zombie (aversive) virtual characters. Males ($M = 3.73$, $SD = 1.18$) rated (liked) the low-amplitude zombie male [$F(1, 70) = 7.11$, $p = .01$, $\eta_p^2 = .09$] significantly higher than females ($M = 2.87$, $SD = .90$). Finally, males ($M = 3.06$, $SD = 1.28$) rated (liked) the high-amplitude zombie male [$F(1, 70) = 8.38$, $p < .01$, $\eta_p^2 = .11$] significantly higher than females ($M = 2.10$, $SD = .88$). After a Bonferroni adjustment (a = .0125), post-hoc pairwise comparisons with gender as an independent variable showed the same results. Thus, the effect of gender on emotional valence was only significant for the zombie (aversive) characters but not for the regular (neutral) characters.

5. Discussion

We conducted a virtual reality experiment on emotional reactivity. Seventy-two students took part in the study. The evaluation of the emotional valence dimension ensured that the virtual characters were perceived by participants in the way that they were designed to be perceived. The aversive and/or active stimuli elicited more negative emotional valence than neutral and/or passive stimuli. This adds to the internal validity of the experiment as the perceived likeability of the virtual characters in the eyes of the participants had the intended impact.

Both the appearance and motion of the virtual characters significantly affected participants' emotional reaction system (valence and reactivity). Specifically, there was differential impact of the four characteristics (face, body, size, motion) for the virtual characters on emotional valence across the virtual characters. The face evaluation tended to have a greater impact on the negative emotional valence of aversive characters, but the overall pattern was complex and dynamic across the combinations of features of virtual characters in each condition. This suggests that there is a comparative advantage of virtual experiments over more conventional ways of eliciting emotional reactions (e.g., pictorial material, videos watching) when studying the emotional reaction system. Motion of 3D models that characterize virtual environments may better contribute to the complex, dynamic and multidimensional nature of virtual perception and emotional valence compared to the static pictorial material and 2D video watching (Coté, 2015; Konar

and Chakraborty, 2009; Mainzer, 2007). In other words, motion in combination with physical appearance has greater ecological validity than static or remoted images, because they tend to be combined in authentic social interactions.

Most importantly, the pattern of emotional reactivity (intensity) to virtual characters was clear: there were more positive reactions to the low-amplitude regular-male character, and more negative/defensive reactions to the high-amplitude zombie-male character. The negativity of emotional reactions to the four virtual characters escalated linearly from least negative to most negative among the four experimental conditions: (1) low-amplitude regular-male, (2) high-amplitude regular-male, (3) low-amplitude zombie-male, and (4) high-amplitude zombie-male. This pattern of emotional reactivity (intensity) suggests that the aversive stimuli (zombie characters) generated more negative emotional reactions than the regular/neutral characters, and that the high-amplitude characters generated more negative emotional reactions than the low-amplitude characters.

Overall, immersive virtual environments can generate vivid spontaneous emotional experiences. The intensity of emotional arousal and readiness to interact with a virtual character is influenced by the characteristics of artificial virtual characters. Our results are consistent with results from several studies that used pictorial stimuli and measured emotional responses either using physiological measures (e.g., heart rate) or evaluative judgments (Bradley et al., 2001; Hillman et al., 2004). Contradictory results were found with other studies (Codispoti et al., 2008; Deng et al., 2016; Fischer et al., 2004; Gohier et al., 2013); this includes inconsistencies in emotional reactivity between males and females regarding emotional reactivity may be caused by the specific content of the stimuli (e.g., disgust, fear, embarrassment) and its other characteristics (e.g., degrees of perceived aversity), and by the degrees of immersion into an artificial environment. For example, pictorial material is less immersive than video clips, and video clips are less immersive than virtual environments with a feeling of presence, such as those in our experiment. Though it would be unwise to suggest a linear logic (from static to more dynamic experimental conditions) to interpret inconsistencies in emotional reactivity across studies. Several parameters of the type of stimuli (e.g., auditory-visual virtual reality) and corresponding combinations of emotional valence and reactivity (e.g., physiological response) remain unknown. However, given the complex and dynamic nature of emotional reactivity in relation to the other dimension of emotional valence, we think that variations in virtual reality scenarios can be a useful tool for evaluating both dimensions in future research.

The instantaneous emotional reactions (emotional reactivity) of students contacting with distinct variations of a visual stimulus (neutral vs. aversive) can vary depending on the physical characteristics (appearance and motion) of the stimulus. This differentiated response to types of virtual stimuli suggest that students are able to produce distinct spontaneous representations of the virtual world, while they are immersed into it. Different "virtual beings" are not all the same in the eye of the beholder. A sense of instinctive reality is still strong within virtual world. Based on the results of this study, we cannot make general inferences about the clarity or blurriness of boundaries between virtuality and reality, which some theoreticians have doubted (Ropolyi, 2016). Nevertheless, we can make inferences about the capability of users to distinguish between various levels of virtual reality, which suggests a clear sense of reality within virtuality. Human beings can be immersed into a virtual world, but they are not lost in it.

This study also revealed gender differences in emotional valence. Females showed more negative emotional valence (lower likeability) to aversive characters than males. The pattern for emotional reactivity (intensity) was even stronger. Females showed significantly higher levels of negative emotional intensity for each virtual character and the four conditions combined compared to males. This is not a totally surprising result: studies using traditional cues (e.g., pictures) have found that women have a disposition to respond with greater defensive reactivity to aversive facial pictures regardless of specific content (Bradley et al., 2001; Huang & Hu, 2009; Stevens & Hamann, 2012). Biological and sociocultural factors (e.g., physical strength, comparison of the size of virtual character to the participant's physical size, man-like appearance of the stimuli, contact proximity, social norms) may shape gender differences in emotional reactivity to artificial entities with anthropomorphic interfaces (Astrid et al., 2010; Deng et al., 2016; Fox et al., 2015; Huang & Hu, 2009; Rosenthal-von der Pütten, Krämer, HoffmannSobieraj, & Eimler, 2013; Stevens & Hamann, 2012), and can be possible mediators of gender differences in emotional response (valence and intensity) to aversive stimuli (Bradley et al., 2001; Clark et al., 1994; Deng et al., 2016; Huang & Hu, 2009).

What may be an unprecedented finding in this study is that females had greater defensive emotional reactivity, even for a neutral virtual stimulus (the regular passive character), mostly likely because this stimulus was presented in an immersive VR environment. Sociocultural factors may be related to these gender differences in negative emotional reactivity (Deng et al., 2016; Fischer et al., 2004). In the current study, three female participants from MENA countries had consistently higher levels of negative emotional reactivity even for the two regular virtual characters (see also outliers in Fig. 4) that could be considered neutral in a Western cultural context. This observation could be further explored. However, multivariate and univariate analyses that excluded the above three participants yielded exactly the same results with a smaller effect size (η_p^2), showing that cultural differences may add to gender differences in emotional reactivity, but they do not change their statistical significance or direction. Finally, a possible theoretical explanation for the gender differences is the influence of gender stereotypes that exist in the surrounding social environment and the conforming power they exert. For example, social stereotypes require males to be calmer in the face of fear and embarrassment/disgust and to report lower emotional reactions. In other words, social expectations and social desirability may shape emotional expressivity (Deng et al., 2016; Fisher & Dubé, 2005).

5.1. Limitations and future research

No statistical differences in emotional reactivity (intensity) as a function of the virtual experience were found. However, in this study, it was not feasible to examine the full continuum of VR experience. The sample size was small and only nine participants had more than three experiences with VR, so we had to collapse a possible third level of the measure, using a VR experience variable with two levels (have vs. have not). This binary measure of VR experience is not sensitive to the continuum of VR experience. Thus, the finding about the non-significant role of VR experience in emotional reactivity is far from being conclusive.

In addition, the use of a male virtual character might influence gender differences. However, if we had an additional female character, this would significantly increase the duration of experiment and might cause fatigue and loss of motivation among participants. Thus, this is an area that should be explored in future research.

Finally, the inclusion of participants with specific characteristics (e.g., students with phobias, autism spectrum disorders) in future research would help cultivate a better understanding of human behavior based on the variation of the virtual stimuli, emotional

valence, emotional content, emotional intensity and varying degrees of presence.

6. Conclusion

Appearance and motion of the virtual characters affected both dimensions of the emotional reaction system: valence and reactivity. The emotional valence pattern was complex, and dynamic, influenced by changes in the features of the virtual characters in each condition. Emotional reactivity (intensity) to aversive and/or active stimuli was more negative than reactivity to neutral and/or passive stimuli, with an escalated linearly in their intensity from a neutral to the most negative stimuli combining aversive appearance and high-amplitude. The results suggest that young adults kept a clear sense of reality within immersive virtuality. To the best of our knowledge, our study makes this point clear, and this a significant contribution to our understanding of emotional reactivity towards aversive stimuli. This evidence for reality within immersive virtuality for typical populations can constitute a base for virtual reality experiments with atypical populations. Virtuality can be a useful diagnostic and a therapeutic tool for treating phobias (Suied et al., 2013), and a motivating platform to safely practice and rehearse social skills for people with autism spectrum disorders (Didehbani, Allen, Kandalaft, Krawczyk, & Chapman, 2016).

Females indicated significantly higher levels of negative emotional valence to aversive virtual characters and higher negative emotional reactivity to all virtual characters. These findings on gender differences may relate to emotional expressivity influenced by gender/cultural roles and/or underlying physiological reactions (Deng et al., 2016).

Appendix 1. Emotional reactivity questionnaire

Label	Statement/Question	Anchors of the Scale
Preliminary Questions		
Q1	I feel uncomfortable being in this virtual environment.	1 = not uncomfortable at all, 7 = totally uncomfortable.
Q2	I would feel nervous standing in front of a virtual character.	1 = not nervous at all, 7 = totally nervous.
Emotional Reactivity in Virtual Reality Context		
Q3	Would you feel uneasy if this virtual character communicated with you?	1 = not uneasy at all, 7 = totally uneasy.
Q4	Would you feel uneasy if this virtual character tried to touch you?	1 = not uneasy at all, 7 = totally uneasy.
Q5	Does the motion of the character make you feel uncomfortable?	1 = not uncomfortable at all, 7 = totally uncomfortable.
Q6	Do you feel that the motion of the character makes you unready to interact with him?	1 = not unready at all, 7 = totally unready.
Q7	Does the appearance of the character make you feel uncomfortable?	1 = not uncomfortable at all, 7 = totally uncomfortable.
Q8	Do you feel that the appearance of the character make you unready to interact with him?	1 = not unready at all, 7 = totally unready.

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