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Exploring Virtual Reality Avatars: Assessing Basic Emotion Representations for Mental Health Applications

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Abstract: The importance of digitalization is increasing fast and has also found its way into medicine and therapeutic applications. Serious Games represent a category of interactive digital or analog games that can be used for this purpose. The use of new technologies such as virtual reality (VR) or virtual characters like avatars can have a supportive effect especially for people who perceive social interactions as challenging, which often occurs for people with autism spectrum disorders (ASD). Therefore, a study was conducted to evaluate three different types of avatars as well as their representation of the six basic emotions and a neutral category. Overall, 14 men and 9 women (M = 34.09 years old) participated in the study. The results show that the representation of the basic emotions was assessed significantly different for the different avatar types. Furthermore, differences regarding how well the target emotions were met were shown. Overall, the study results can help to identify suitable types of avatars to include it into future emotion-related scenarios of social interaction.

Keywords: Avatars, Basic emotions, Evaluation, Mental health, Autism Spectrum Disorders (ASD).

1. INTRODUCTION

The importance of digitalization has increased constantly during the last decades (Kravchenko et al., 2019) and was additionally driven further by the COVID19-pandemic (Humphreys, 2020; Mumm et al., 2020). The digitalization has also found its way into medicine and therapeutic applications. Within this field, mHealth (mobile Health, Matusiewicz, 2018) apps were, for example, used to improve the quality of life of patients, the communication between them and their doctors/therapists, and help to improve the acceptance and handling of medical devices like hearing aids (Wagner-Hartl et al., 2022). Another example is the use of virtual reality (VR). Nowadays, the development of VR technologies is progressing very fast which is leading to more and more realistic and therefore, experienceable simulations (Dörner et al., 2019). VR is also increasingly used within emotion research (Somarathna et al., 2021; Schmid and Wagner-Hartl, 2023) There is a wide variety of possibilities to use VR within the context of mental health, e.g., from the therapy of anxiety disorders (Dörner et al., 2019) up to the training of emotional and social skills for people with autism spectrum disorders (ASD; Yuan and Ip, 2018).

1.1 Autism Spectrum Disorders (ASD)

Autism spectrum disorders (ASD) can be described as referring "to a group of complex neurodevelopment disorders (…)" (National Institute of Mental Health, NIMH, 2023). ASD is "(…) one of the most prevalence neurodevelopmental disorders" (Rylaarsdamm and Guemez-Gamboa, 2019) with estimated prevalence of 1 child in 100 children (Zeidan et al., 2022) to 1 in 59 children aged 8 years in the United States (Baio et al., 2018).

People with ASD often experience difficulties in social interaction and communication, especially everyday situations with social interactions can be perceived as challenging and to cope with them can require a lot of effort (Freeth and Morgan, 2023; NIMH, 2023; Lord et al., 2018; American Psychiatric Association, 2013).

Following Tebartz van Elst and colleagues (2021) practicing challenging everyday situations with role-playing can be helpful for people with ASD. The use of new technologies such as virtual reality (VR), computer-based trainings or virtual characters like avatars can have a supportive effect (Hopkins et al., 2011; Kellems et al., 2020; Parsons and Mitchell, 2002; Yuan and Ip, 2018).

1.2 Serious Games

Serious games represent a category of interactive digital or analog games that extend beyond mere entertainment, designed with the primary objective of serving educational, training, simulation, or awareness purposes (Dörner et al., 2016; Solinski-Nowak et al., 2018). These games leverage elements of gameplay to immerse users in purposeful experiences, making them effective tools for learning, skill development, and addressing real-world challenges (Strahringer and Leyh, 2017).

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By blending entertainment with education and training, serious games offer a unique and effective approach to tackling complex issues and fostering learning in a variety of domains (Lamaarti et al., 2014; Solinska-Nowak et al., 2018). In the realm of education, serious games are used to enhance the learning process by incorporating educational content into game scenarios (Jacob and Teuteberg, 2017). This approach can make complex contents more engaging and facilitates a more active and participatory learning experience. The gamification of educational content also aims to improve retention and comprehension (Chittaro and Buttussi, 2015; Winter et al., 2020).

In the field of healthcare, serious games find applications in medical training, patient rehabilitation, and raising awareness about health issues (Dörner et al., 2016; Lamaarti et al., 2014). These games can simulate medical procedures, provide virtual environments for therapeutic interventions, and deliver health-related information in an interactive and memorable manner. Business and corporate training benefit from serious games as well (Jacob and Teuteberg, 2017). Simulations and scenarios integrated into games can be used to train employees in decision-making, leadership, and teamwork, offering a risk-free environment to practice and refine skills.

1.3 Use of Avatars

Former research reported a positive impact on the user's habits, especially regarding a healthier lifestyle, for the use of avatars as digital representations (Lin et al., 2006). Hence, an improvement in motivation, knowledge as well as self-care of patients with chronic diseases (e.g., diabetes, depression) was shown for several avatar-based health apps (Johnson et al., 2014; Pinto et al., 2013). Furthermore, it was shown that a humanoid appearance of the used avatar seems to be the preferred one (e.g., Nowak and Rauh, 2006; Gunser et al., 2020) and that a users' personal adjustment of the appearance of the used avatar increases the emotional bond between them (Kim, 2014). Nojavanasghari et al. (2017) emphasize the importance of using avatar-based trainings for children with ASD to give them the possibility to practice social interaction in a safe environment.

1.4 Aim of the Study

To develop an avatar-based therapeutic application, it is first necessary to identify suitable types of avatars to include them into emotion-related scenarios of social interaction in the future. This should serve as an initial exploratory approach as a basis for the development of the future application. Therefore, an exploratory study was conducted to evaluate three different types of avatars as well as their representation of the six basic emotions and a neutral category.

The following research questions should be answered:

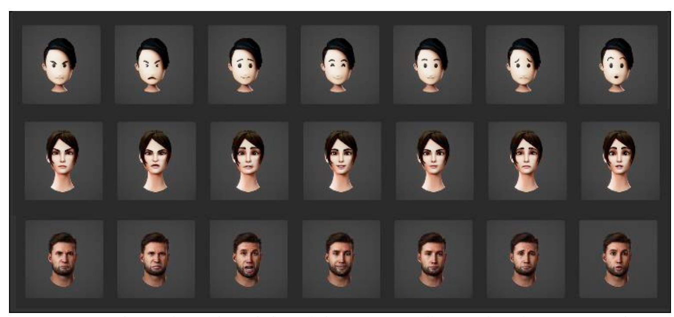
1. Do different avatar types differ regarding the participants' assessments of how well they represent the basic emotions overall?
2. Is there a difference in the achievement of the respective target emotion for the basic emotions and the neutral category for different avatar types?
3. Does the evaluation of different avatar types differ per environment (gaming, private, professional environment) as well as regarding their preferred presentation (head only, up to chest, full body) for themselves as well as for their counterpart/other person involved?

2. METHOD

2.1 Development of the Avatars

The goal in developing the avatars was not only to depict various emotions but also to offer different levels of difficulty. Therefore, it was decided to create various versions of an avatar. These include a cartoonish and simple avatar, followed by a stylized, moderately detailed avatar, and finally, a realistic avatar for the greatest challenge (see Figure 1).

From a technical perspective, a basic 3D model was first created for the avatars. It was crucial to ensure that the model's topology was anatomically correct and included sufficient details at all times. The topology in humans is based on the muscle fibers beneath the skin and is essential as it determines the facial characteristics. Close-up shots intended to reflect complex facial expressions such as anger or sadness require different levels of deformation in the face. If the topology is flawed, these expressions can quickly appear unnatural.



Note. Presented Emotions (from left to right): angry, disgust, fear, happy, neutral, sad, surprise

Figure 1. Avatars used within the study - line 1: cartoonish, simple avatar, line 2: stylized, moderately detailed avatar, and line 3: realistic avatar.

Subsequently, blend shapes were created. These are alternative versions of the model with the desired facial changes. For instance, a copy of the mesh was created and sculpted into a smiling position, which was then added as a blend shape. Using a slider, one can then switch between different blend shapes.

As a foundation and reference for the expressions, the Facial Action Coding System (FACS) was utilized, among other sources (Ekman, and Friesen, 1978; Farnsworth, 2022). The FACS refers to a set of facial muscle movements that correspond to a displayed emotion. Since FACS also illustrates various movements of individual facial muscles during corresponding emotions, different blend shapes could be derived from it. In addition to FACS, real footage of human faces displaying various emotions was used as a reference in the creation process. This ensured that the emotions were depicted naturally.

2.2 Study Participants

Overall, 14 men and 9 women participated in the study. The participants were aged between 18 and 61 years ($M = 34.09$, $SD = 14.41$). Following the results of a *t*-test, men and women did not differ significantly regarding age, $t(21) = .14$, $p = .891$. 30.44% of the participants were employees, 17.39% public officials and 52.17% students. Gender was statistically equally distributed within these three groups, $\chi^2(2, N=23) = .41$, $p = .815$. 39.13% of the participants reported that they seldomly play games on a computer, a smartphone, or a video game console. 8.70% play such games rather seldom, 13.04% occasionally, 21.74% rather often and 17.39% often. The values of the Affinity for Technology Interaction (ATI) Scale (Franke et al., 2019; 9 items using a 5point scale ranging from completely disagree = 1 to completely agree = 6) of the sample were: $M = 4.34$, $SD = .17$, *Cronbachs* $\alpha = .89$. No significant gender differences can be shown regarding the gaming frequency of the participants, $z = -.89$, $p = .376$, nor regarding their affinity for technology interaction, $t(21) = 1.50$, $p = .148$.

Following the results of the Ritvo Autism and Asperger Diagnostic Scale (RAADS-14 Screen, Eriksson et al., 2013), the results show a range from 0 to 24 (out of 42) for the total score ($M = 9.74$, $SD = 1.59$, *Cronbachs* $\alpha = .76$). Following Eriksson et al. (2013) "This self-rating questionnaire […] identifies most patients with ASD while excluding approximately 50% of non-ASD patients, using the suggested cut-off point of 14." (ibid., p. 10). Overall, six participants showed a score above the cut-off point of 14 (one men, five women). All participants provided their informed consent at the begin of the study and participated in the study voluntary.

2.3 Study Procedure and Materials

The study (within-subjects design) consists of three different parts. The whole study was presented via tablet (Samsung Galaxy Tab A) to the participants. First the participants were informed about the study and provided their informed consent, followed by their sociodemographic data. Afterwards they processed the Affinity for Technology Interaction (ATI) Scale (Franke et al., 2019) and the Ritvo Autism and Asperger Diagnostic Scale (RAADS-14 Screen, Eriksson et al., 2013). Within the second part of the study the emotional expressions representing six basic emotions (angry, disgust, fear, happiness, sadness, and surprise) and a neutral category were assessed for each of the three used avatar types: (1) cartoonish, simple avatar, (2) stylized, moderately detailed avatar, and (3) realistic avatar (see also Figure 1). Therefore, semantic differentials (6-point scale: 1-not at all – 6-very) were used representing each emotion and the neutral category. Furthermore, the participants had the possibility to describe and evaluate other perceived emotions if a participant needed it for an adequate emotional assessment of the facial expression of the presented avatar. Regarding research question 2 whether a difference in the achievement of the respective target emotion for the basic emotions and the neutral category for different avatar types can be shown, the difference of the respective target emotion and the assessed emotion of each facial expression were calculated (0 = target emotion exactly met; 5 = target emotion not at all met). In addition, the participants were asked to evaluate each facial expression using a slider from 0-100% regarding how positive and how negative the emotional facial expression was perceived. Overall, each participant evaluated seven facial expressions of three different avatars, which results in a total of 21 assessed facial expressions within this second part of the study. The avatar types were randomly assigned to the participants. Furthermore, regarding each avatar, the seven used facial expressions were presented in a randomized order too. In the last part of the study, all used facial emotional expressions of each avatar were presented with an overview of all presented emotions. The used figures can be seen in Figure 1 (each presented line; avatars presented in a randomized order). The participants were asked to assess how well the emotional facial expressions of each of the three avatar types represented the basic emotions overall, using a 5-point scale from "not good at all" (1) to "very good" (5). Afterward, the participants were asked to order them regarding their willingness to use the different avatar types within different environments (gaming, private, professional) as well as assess their preferred type of presentation (head only, up to chest, full body) for themselves as well as for their counterpart/other person involved for each environment. At the end of the study, the participants were thanked for their participation and the study was completed. Overall, the participants needed about 35 minutes to complete the study.

2.4 Statistical analyses

IBM SPSS statistics was used to calculate the results. The statistical analyses were based on a significance level of 5%. ANOVAs with repeated measures and Friedman Tests were used for the statistical analyses.

3. RESULTS

3.1 Overall Representation of the Basic Emotions

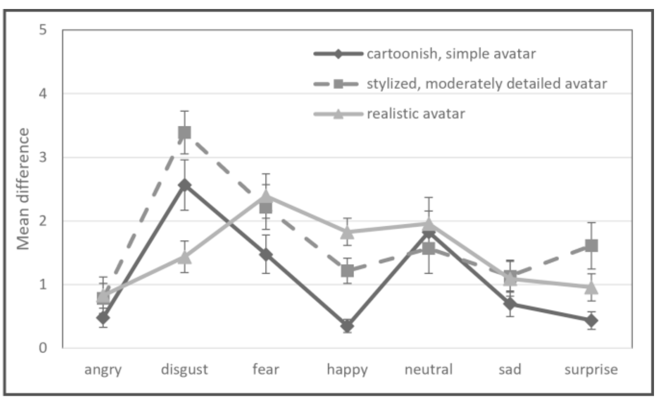
To answer the first research question if different avatar types differ regarding the participants' assessment of how well they represent the basic emotions overall, an analysis of variance (ANOVA) with repeated measures was conducted. The results show a significant effect type of avatar, $F(2, 21) = 3.66$, $p = .043$, $\eta^2_{part.} = .258$. Following post-hoc analyses, the representation of the basic emotions was assessed as significantly better for the cartoonish, simple avatar ($M = 4.04$, $SD = .71$) than for the stylized, moderately detailed avatar ($M = 3.39$, $SD = .94$), and the realistic avatar ($M = 3.43$, $SD = 1.24$; both $p < .05$).

3.2 Achievement of the Target Emotions

Regarding research question 2 whether a difference in the achievement of the respective target emotion for the basic emotions and the neutral category for different avatar types can be shown, the results of a two-factorial analysis of variance with repeated measures on both factors, revealed a significant interaction type of emotional expression x type of avatar, $F_{HF}(10.44, 229.77) = 3.73$, $p < .001$, $\eta^2_{part.} = .145$, and a significant repeated measurement effect type of emotional expression, $F_{HF}(4.21, 92.60) = 15.21$, $p < .001$, $\eta^2_{part.} = .409$, and type of avatar, $F(2, 21) = 8.28$, $p = .002$, $\eta^2_{part.} = .441$ (see Figure 2).

Following the results of post-hoc analyses (all $p < .05$), the emotional expression of disgust was significantly better met for the realistic avatar than for the stylized avatar. Furthermore, the facial expression of being happy was significantly better met for the cartoonish, simple avatar than regarding the stylized avatar and the realistic avatar. Also, the stylized avatar met this emotion significantly better than the realistic one. Additionally, the expression of surprise was significantly better met with the cartoonish, simple avatar than with the stylized avatar.

Furthermore, regarding the cartoonish, simple avatar, the facial expressions of angriness was significantly better met than disgust as well as the neutral category. Also, both happiness and surprise were significantly better met than disgust, fear, and the neutral category. Additionally, sadness was significantly better met than the facial expression for disgust and the neutral category.



Note. 0 = target emotion exactly met; 5 = target emotion not at all met; I … standard error of mean

Figure 2. Mean difference in the achievement of the respective target emotion for the basic emotions and the neutral category for the different avatar types.

For the realistic avatar post-hoc analyses revealed that the facial emotional expression of fear was significantly worse met than those of the two emotional expressions angry and surprise. In addition, regarding the third avatar type, the stylized, moderately detailed avatar, the results show that facial emotional expression of disgust was, from the participants point of view, worse met than those of the emotional expressions angry, sad, surprise and happiness.

3.2 Environmental Differences and Preferred Representation

First, to answer the first part of research question 3, if the evaluation of different avatar types differs per environment (gaming, private, professional environment), Friedman tests were performed to analyze differences regarding the rankings of the preference of the three different types of avatars for each environment. Following the results, a tendency towards significance regarding the different ranks can be shown for the gaming environment, $\chi^2(2, N = 23) = 5.30$, $p = .070$, and the professional environment, $\chi^2(2, N = 23) = 5.57$, $p = .062$, but not regarding the private environment, $\chi^2(2, N = 23) = 2.44$, $p = .296$. The mean ranks for the different avatars are shown in table 1.

Table 1. Preference to use the avatar types within the different environments - mean ranks.

type of avatar / environment	cartoonish, simple avatar	stylized, moderately detailed avatar	realistic avatar
gaming environment	2.17	1.61	2.22
professional environment	2.00	1.65	2.35
private environment	2.17	1.74	2.09

To answer the second part of research question 3, the participants had to assess their preferred type of presentation (head only, up to chest, full body) for themselves as well as for their counterpart/other person involved within the different environments/situations. Table 2 presents the descriptive results.

Table 2. Frequencies of the preferred type of presentation (self and other) within the different environments.

presentation type / environment	head only		up to chest		full body	
	self	other	self	other	self	other
gaming environment	3	3	1	0	19	20
professional environment	16	15	5	6	2	2
private environment	8	7	6	8	9	8

4. DISCUSSION

The study was conducted to evaluate three different types of avatars (cartoonish, simple avatar, stylized, moderately detailed avatar, and a realistic avatar) as well as their facial representation of the six basic emotions (anger, disgust, fear, happiness, sadness, surprise) and a neutral category to identify suitable representations for the development of a therapeutic application resp. serios game for persons with autism spectrum disorders (ASD). Furthermore, different environments (gaming, private, professional environment) and representation types (head only, up to chest, full body) were evaluated to enlarge the research field regarding other potential future areas of application.

Regarding the first research question, the results show that all three evaluated avatar types were assessed as expressing the basic emotions as rather good to good. Nonetheless, the overall representation of the basic emotions was assessed significantly better for the cartoonish, simple avatar than for the stylized, moderately detailed avatar and the realistic avatar. Moreover, based on the results, differences in the achievement of the respective target emotions can be shown for the different types of avatars (research question 2).

Tendencies towards significance were shown regarding the preference to use the avatar types within the different environments, for the gaming and the professional environment. For both, the mean ranks show the following order of the avatar types: stylized, moderately detailed avatar followed by the cartoonish, simple avatar and the realistic avatar.

Regarding the participants' preferred type of presentation for themselves as well as for their counterpart/other person involved within the different environments, the descriptive analyses give a first indication towards the importance to distinguish between the different environments. So, in the gaming environment the most frequent preferred type of representation was "full body" for both representations (self and others). Whereas, in the professional environment the variant "head only" was the most frequent mentioned. For the private environment all types of representation were chosen by the participants with a likewise frequency. Following this first descriptive analyses it is recommended to investigate this aspect of research further in the future.

Nonetheless, the study had some limitations: First, the evaluation takes place solely via tablet and not in a virtual environment. Therefore, the used avatars were presented in 2D and not in 3D in the presented study. Future research will be needed to expand this regarding virtual reality (VR). This seems to be especially important because former studies had shown that users can benefit from using VR for social skills training (Parsons and Mitchell, 2002), for example regarding the possibility to repeat training sessions or scenarios for several times within a safe training environment. In this first exploratory approach, the three avatar-types used were not balanced regarding gender. This may have an effect on the results. Whereas, the cartoonish, simple avatar was chosen to be more gender-neutral, the stylized, moderately detailed avatar is likely more female and the realistic one more male. A possible effect of the gender of the avatars still needs to be investigated in future studies. In addition, an enlargement of the range of the used avatars regarding their styles and level of realism could be considered. Furthermore, based on a first exploratory approach, the sample size was not that big and should be enlarged in future studies, to involve more potential future users, and especially persons with ASD. In addition, an investigation of group differences such as gender or age differences or previous gaming and/or VR-experience etc. would also be interesting for future studies.

To sum it up, the representations of the basic emotions were assessed significantly different for the different avatar types. Additionally, differences regarding how well the target emotions were displayed were shown. Furthermore, following the results, environmental aspects as well as preferences regarding the presented part of the avatar should be considered for the development of an avatar that represents the user as well as his/her counterpart within an interaction resp. (social) scenario. Overall, the study results can help to identify suitable types of avatars that can be included in future emotion-related scenarios of social interaction.

AUTHOR'S STATEMENT

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