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Preliminary Study of the Perception of Emotions Expressed by Virtual Agents in the context of Parkinson's disease

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ABSTRACT

In the context of Parkinson's disease, this preliminary work aims to study the recognition profiles of emotional faces, dynamically expressed by virtual agents in a Healthy Control (HC) population. In this online experiment, users had to watch 56 trials of two-second animations, showing an emotion progressively expressed by an avatar and then indicate the recognized emotion by clicking a button. 211 participants completed this experiment online as HC. Of the demographics variables, only age influenced negatively recognition accuracy in HC. The intensity of the expression influenced accuracy as well. Interaction effects between gender, emotion, intensity, and avatar gender are also discussed. The results of four patients with Parkinson's Disease are presented as well. Patients tended to have lower recognition accuracy than age-matched HC (59% for age-matched HC; 45.1% for patients). Joy, sadness and fear seemed less recognized by patients.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; • **Applied computing** → **Health informatics**.

KEYWORDS

Emotion Recognition, Virtual Agents, Non-verbal communication, Parkinson's Disease

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1 PARKINSON'S DISEASE AND EMOTIONS

Parkinson's disease (PD) is generally characterized as a motor disorder. However, PD patients are also affected by cognitive and emotional impairments from prodromal to late stages of the disease progression. Some emotional impairments can stem from motor symptoms, such as hypomimia (MDS-UPDRS-III-19 sub score). Also known as "poker face", hypomimia is characterized by a reduction in emotional facial expressions and spontaneous facial movement. Cognition and emotion are different but tightly connected to different degree to trigger appearance of several non-motor symptoms including apathy, impulse compulsive disorders, and mood disorders such as anxiety, dysthymia and depression. Apathy, depression and anxiety have been linked with altered emotion recognition patterns and should be controlled for (Apathy: [19]; depression and anxiety: [7]). Dopamine agonists used as medication for patients

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can also alter their social behavior, notably by triggering impulse compulsive disorders [22].

Deficits in identifying emotion through the facial expressions of others, as well as their own subjective feeling of emotion (alexithymia) are often reported [3]. According to the simulation theory, recognizing emotions in others requires mimicking the expression. When the expression is imitated, the sensory feedback allows for the emotion to be identified. Correlations between difficulties expressing an emotion and recognizing it in others were reported in PD patients [18]. Facial Emotion Recognition (FER) impairment and alexithymia in PD patients might stem from hypomimia.

These impairments can severely impact the social life of the patients. Novice practitioners can be influenced by the masking of their patients, wrongly judging them as less extraverted and more neurotic [21]. Masking is correlated with social rejection and worse partner interaction [17].

We believe that multimodal technology and virtual agents can be used in social skills training for social-affective interactions. Our end goal is the reeducation of the emotional expression of PD patients, improving the amplitude of the emotional facial motricity. To do so, we aim to use virtual agents to represent the facial expression objectives and give online feedback on the facial expressions produced by PD patients. Virtual agents have the advantage of modularity and reproducibility over filmed actors. An infinite combination of parameter settings such as age, gender, race of the avatar, emotion and emotion intensity and duration can be controlled precisely via scripting, instead of requiring actors. Other modalities, such as vocal emotion recognition training could be easily added to the script. However, using avatars requires a construct validity verification. Are they recognized as well as natural expressions? Do avatars worsen the FER deficit in PD patients? Is age or video-game use correlated with recognition rate? If the emotions expressed by those avatars weren't recognized, it could bias the reeducation phase later. Thus, this preliminary study aimed at qualifying the perception of emotions expressed with two avatars before conducting a large comparative study between HC and PD groups.

2 VIRTUAL AGENTS AND EMOTIONS

There is extensive research about the recognition rates of emotions expressed by avatars. However, the methodology varies greatly between studies (animation duration, population targeted and construction of the facial expressions) and the technology is evolving fast, making it very difficult to compare results between studies. Most studies featured static, rather than dynamic, material. The effect of dynamic material on the recognition rates seems to depend on age. Dyck et al [9] reported that age moderated the recognition accuracy of pictures of natural and virtual faces (i.e. static material). Beyond the age of 40, precision decreased for virtual but not natural faces, suggesting media exposure may influence recognition. Beer et al. [5] reported that age-related differences in emotion recognition transcended human faces to virtual agent faces. De Borst et al. [6] concluded that emotion recognition depended on how well the emotions are expressed more than whether they are expressed by a human face. They reported that perception of emotional expression

in human-like characters can be processed similarly to human stimuli. However, Kegel et al. [15] showed differences in the perception of fearful dynamic avatars and dynamic human faces. Gender [23], culture [8] and race [11] have been reported to influence FER.

Few studies have been carried out to see if Parkinson's disease emotion recognition deficit translates with dynamic virtual characters. Argaud et al. [2] has shown that PD patients had significantly lower accuracy scores compared to controls for joy and neutral expressions but not anger. The dynamic nature of the material matters. Presenting PD patients with static faces could worsen their recognition accuracy compared to dynamic faces, artificially inflating their FER deficit [14]. Ho et al. [12] has recently shown deficits in anger and disgust recognition with dynamic human faces. They reported that age, slow mentation and poor cognition were associated with FER deficit in PD patients, and not in age-matched controls. It could be hypothesized that the recognition deficits of Parkinson's disease patients will subsist for dynamic virtual agents. This study aims to qualify how facial expressions and emotions expressed by virtual agents are perceived by people. PD patients have been suggested to trust avatar faces more than human faces [13].

As we aim to target daily social interactions, we chose to investigate dynamic material, to maximize the ecological aspect of the manipulation. Our hypothesis is that using avatars could be an effective tool for the reeducation of emotional facial expression perception and production for patients.

3 ONLINE EXPERIMENTATION AND PRELIMINARY RESULTS

3.1 Methods

We chose to study the six basic emotions: joy, sadness, fear, anger, disgust and surprise [10], allowing our results to be compared to the literature. The contempt facial expression was added as a control. In this 5-minute-long experiment, we presented the subjects with an avatar progressively expressing an emotional facial expression (EFE) for 2 seconds (as in [23, 14]). After the end of the animation, the avatar disappears and an interface consisting of 8 buttons (the order was not randomized) appears. The subjects could select one of the six basic emotions and had the option to select "Other" or "I don't know". Subjects were instructed to be as precise as possible.

The experiment featured 56 trials, 28 with a Caucasian female avatar and 28 with a Caucasian male avatar. The presentation order of the emotions was pseudo-randomized: each combination of the parameters was presented twice to the subject. Two thresholds representing 50% and 100% of the maximum intensity were introduced (see Figure 1). It should be noted that those thresholds are mathematical constructs, based on the blendshape model of facial animation (see [1]). A half-threshold expression does necessarily mean the real-life emotion is of half intensity.

Each trial featured a combination of 3 parameters: avatar gender, intensity and emotion. In total, the experiment featured 2 repetitions \times 2 genders \times 2 thresholds \times 7 emotions = 56 trials. Both avatars had the same technology and scripts for expressions. We used the native Genesis 8 avatar implementations of joy, surprise, fear and anger. Sadness, disgust and control were scripted using the blendshapes. Blendshapes represent a linear weighted sum of the target faces, allowing to represent an emotional expression by

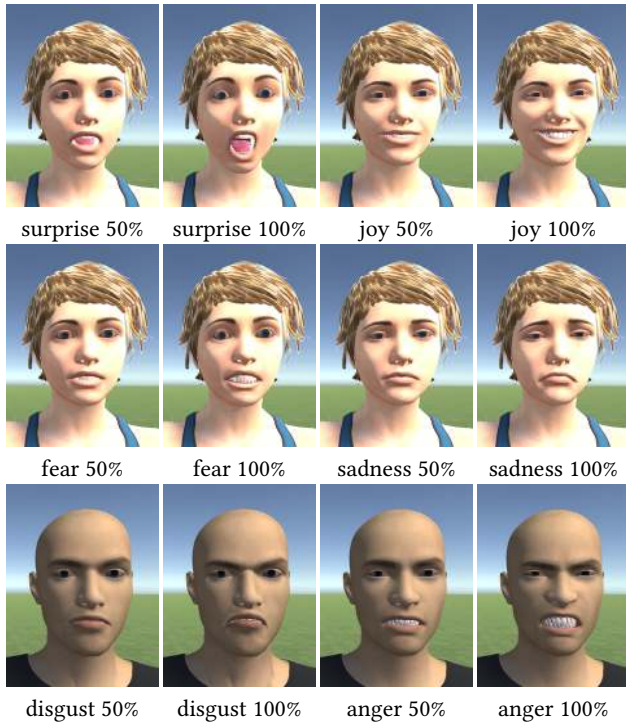


Figure 1: Facial emotion recognition stimulus material with two thresholds.

approximating facial muscle actions [1]. We scripted their incrementation frequency accordingly to keep constant the duration of the animation across thresholds. Gender, age, frequency of use of a computer or cellphone and frequency of videogame playing were collected as well. The software was created with Unity3D. A WebGL version was hosted on a French server from July 10th, 2020 to August 15th, 2020.

3.2 Participants

242 French-speaking subjects were recruited as Healthy Controls (HC) through mailing lists. 211 of them finished the study. 100 women and 111 men completed the study. The mean age was 36.6 years old (SD = 14.6). Men participants were older than women (Mann-Whitney-Wilcoxon (MWW) test $W = 4442$, $p = 0.012$; 38.1 for men; 35 for women). Videogame-use was coded as such: 4: every day; 3: every week; 2: every month; 1: less often or never. Mean videogame use was 2.05 (SD = 1.16). It differed significantly between genders (2.32 for men; 1.75 for women; MWW test, $W = 3530$, $p = 0.0005$). Four patients with Parkinson’s disease (PD) were recruited (3 men, 1 woman). The mean age was 61 years old (SD = 11.1), higher than HC controls (Welch’s t-test, $t = 4.31$, $p = 0.02$). Mean videogame use was 1.5 (SD = 1), it did not differ from HC. All participants consented to have their results and demographic data used anonymously in this study.

3.3 Overall results and demographic variables

Mean global recognition accuracy (RA, percentage of the trials where the correct emotion was selected) for HC was 63.5%. Gender and video game use did not moderate mean RA. Only age was a significant moderator of mean RA, with an average reduction effect on mean RA of -0.2% per year of age (age 18 to 84; Pearson correlation, $t = 5.03$, $p < 0.001$, $r = -0.33$). Mean response selection time was 2.3s (2.4s for age-matched HC).

3.4 Avatar gender effect

For HC, gender congruence of the avatar did not affect the mean RA. In this experiment, the gender of the avatar was not randomized. After analysis, this effect of order was not significant. A significant interaction effect between threshold and avatar gender was found in HC ($F(1,1) = 8.90$, $p = 0.0003$ for HC). It was only significant in half-threshold trials: subtle emotions expressed by the male avatar were better recognized than those of the female avatar (MWW test, $W = 3620700$, $p = 0.004$). We found an interaction effect between emotion and avatar gender ($F(1,1) = 9.41$, $p = 0.0002$). Joy and anger were better recognized with the male avatar (as reported for joy in [20]). Sadness was better recognized with the female avatar.

3.5 Threshold effect

Emotion threshold influenced RA ($F(1,1) = 139.29$, $p < 0.0001$). For HC, maximum-threshold trials had a mean RA of 68.2% versus 58.9% for half-intensity trials (Welch’s t-test, $t = 10.42$, $p < 0.001$). As shown by Figure 2, there was a significant interaction effect between emotion and threshold ($F(1,1) = 17.97$, $p < 0.0001$ for HC). For HC, RA increased with the maximum threshold for 3 out of 7 emotions (anger, sadness, fear) and worsened for 2 emotions (disgust, surprise). There was a significant interaction effect between age and threshold ($F(1,1) = 6.30$, $p = 0.012$). Maximum threshold increased RA by 12.7% for participants over 48 years old, and 8.3% for younger participants (MWW test, $W = 3333900$, $p = 0.022$).

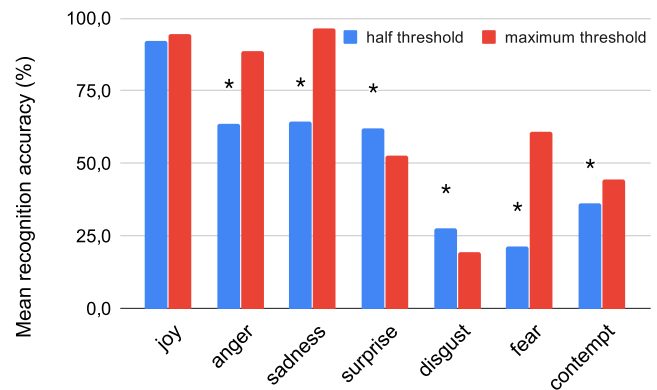


Figure 2: Effect of emotion and threshold on mean recognition accuracy in HC. Chance performance: 14.3%. (*: $p < 0.01$)

3.6 Emotion effect

Emotion had a significant effect on the recognition accuracy of the trial ($F(1,1) = 2697.5$, $p < 0.0001$). Mean RA differed highly between

emotions. For HC, accurately recognized emotions were joy (95.5%), sadness (88.9%), anger (79.8%) and surprise (70.3%), as reported in Figure 2. Poorly recognized emotions were fear (48.9%), contempt – the control option which should have been recognized as “Other” – (44.3%) and disgust (16.9%, just above chance performance). Disgust and fear were the two emotions that were the least recognized overall. Disgust was mistaken for anger (79.7% of the errors). This error has been reported before [5, 10] and disgust is reportedly difficult to convey with avatar faces [5, 16]. Fear was mistaken for surprise (44.4% of the errors). For HC, contempt was mistaken for joy (83.3% of the errors). We found a significant interaction effect between gender and emotion ($F(1,1) = 13.76, p = 0.0002$). Men recognized joy and surprise better than women. Women recognized fear and contempt (other) better than men.

3.7 Patients' results

Mean global RA for patients was 45.1%, as compared to 59% in age-matched HC. Age-matched HC seemed to perform better than patients for joy (replicating [2]), sadness and fear. Patient's fear RA was way below age-matched group's fear RA. Patients seemed to recognize anger surprise, disgust and contempt as well as age-matched HC did.

The mean response selection time was 5.8s for patients. Patients included in this study had good motor condition. Their higher response time could not be attributed to a higher reaction time overall.

As reported in Figure 3, accurately recognized emotions were sadness (65.6%), joy (62.5%), surprise (56.3%) and anger (53.1%). Poorly recognized emotions were contempt (50%), disgust (21.9%) and fear (6.3%). Disgust was mistaken for anger (48% of the errors). Fear was mistaken for surprise (26.7% of the errors). Contempt was mistaken for surprise (37.5%) and joy (25%).

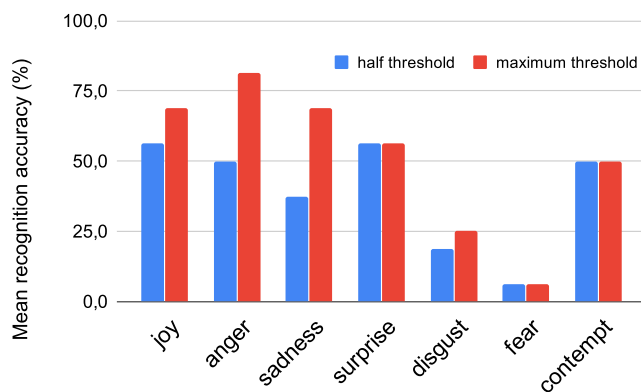


Figure 3: Effect of emotion and threshold on mean recognition accuracy in patients.

Maximum-threshold trials had a mean overall RA of 50.1% versus 39.3% for half-intensity trials. RA increased with the maximum threshold for 4 emotions (joy, anger, sadness, disgust) and remained unaffected for the remaining 3 others (contempt, fear, surprise).

4 CONCLUSION

In this article, we present the results of an online experiment. Those results validate our approach's feasibility: our Proof of Concept was usable by a reasonably large number of participants, patients and healthy controls.

A few limits of our study should be noted. As stated by Ricciardi et al. [18], the very high RA of the joy expression might stem from a design bias: being the only positive emotion of the 6 described by Ekman might have inflated its recognition rate. Including more positive emotions (pride, euphoria) would allow to mitigate this effect but those emotions are complex constructions, with less prototypical facial expressions. The closed-choice paradigm that was used was also a help to participants but was mitigated by the availability of “other” and “I don't know” options.

As three of the seven emotions tested were constructed, it would be necessary to assess their construct validity. All emotions except fear in the patient's group were recognized above chance threshold. Those avatars could be suitable candidates for future studies as EFE training objectives and feedback. Future experiments could include academically validated avatar expressions, such as those presented by Broekens et al. [25] and Yu et al. [24]. Our recognition accuracy results are comparable to those reported with dynamic avatars in [2, 16].

As shown by Aviezer et al. [4], emotion perception is largely dependent on context, including situation, body language and prosody. Studying the recognition patterns of EFE depending on the congruence of the context in PD patients would allow to characterize more precisely the FER deficit. The removal of body language and context from experiments might artificially inflate the FER deficits of patients.

As avatars were used, the recognition rates reported reflect the adequacy between the participant's mental representation of an emotional expression and the avatar's actual expression. Including more context might allow more ecological observations to conclude on the nature of the FER deficit observed in patients. Future experiments will include more patients and could feature EEG, EMG and eye-tracking measures to investigate the nature of the differences in emotion recognition profiles between groups.

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