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Abstract

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Virtual faces as a tool to study emotion recognition deficits in schizophrenia

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Abstract Studies investigating emotion recognition in patients with schizophrenia predominantly presented photographs of facial expressions. Better control and higher flexibility of emotion displays could be afforded by virtual reality (VR). VR allows the manipulation of facial expression and can simulate social interactions in a controlled and yet more naturalistic environment. However, to our knowledge there is no study that systematically investigated whether patients with schizophrenia show the same emotion recognition deficits when emotions are expressed by virtual as compared to natural faces. Twenty schizophrenia patients and 20 controls rated pictures of natural and virtual faces with respect to the basic emotion expressed (happiness, sadness, anger, fear, disgust and neutrality). Consistent with our hypothesis, results revealed that emotion recognition impairments also emerge for emotions expressed by virtual characters. Because virtual in contrast to natural expressions only contain major emotional features schizophrenia patients already seem to be impaired in the recognition of basic emotional features. This finding has practical implication as it supports the use of virtual emotional expressions for psychiatric research: the ease of changing facial features, animating avatar faces and creating therapeutic simulations makes validated artificial expressions perfectly suited to study and treat emotion recognition deficits in schizophrenia.

Keywords: face recognition; emotion processing; virtual reality (VR); avatar; therapy

1. Introduction

Social functioning strongly depends upon accurately recognizing emotions communicated by other people (Liberman et al., 1998). Studies indicated that patients with schizophrenia are impaired in the ability to perceive facial expressions of emotions (Gur et al., 2002a; Schneider et al., 2006; Kohler et al., 2003; Brune, 2005; Hooker and Park, 2002). This impairment seems stable across different stages of the disorder (Wölwer et al., 1996), is manifested in unaffected siblings of patients (Kee et al., 2004), is resistant to antipsychotic treatment (Herbener et al., 2005), and forms a major factor leading to social isolation experienced by many patients (Kee et al., 1998). Consequently, there is a necessity to specifically train schizophrenia patients in improving social perception. Existing training methods mainly rely upon role-playing and computerized instructions (Bellack et al., 1997; Wölwer et al., 2005). These techniques are, however, very time-consuming for patients and require high personnel expanse.

Virtual reality (VR) could provide a more efficient therapy of social and emotional impairments because it has the potential to create a realistic, 3-dimensional world, with which the user can interact independently. This technology is able to closely mimic behavior in actual life, which further offers the potential to understand the disorder and treat patients in hospital and home settings. There has been a growing interest in research involving VR and psychiatric disorders. A very recent study presented a thorough overview of the various opportunities VR offers in understanding and treating schizophrenia (Freeman, 2008). For instance, VR provides a very objective means of symptom assessment in schizophrenia. It is reported that social perception ability can be easily assessed during the interaction with virtual characters (avatars) (Kim et al., 2007). Furthermore, distortion of reality perception and memory functions can be measured within a virtual environment (Sorkin et al., 2008; Weniger and Irle, 2008). VR has also been applied in therapy by developing a virtual conversation training program for patients with schizophrenia (Ku et al., 2006; Ku et al., 2007). Patients evaluated the program positively, felt a sense of presence in the virtual environment, and behaved as if the avatar was really interacting with them. Moreover, patients' behavior towards the avatar varied with their symptoms: the time that elapsed until patients gave a response within a conversation with an avatar was positively correlated with their degree of blunted affect as measured beforehand. These diagnostic and therapeutic studies implemented virtual avatars into virtual environments, with which patients were asked to interact. Before artificial faces displaying emotions can be included in virtual training programs it should be tested if virtual facial expressions are perceived in the same way as natural faces. To our knowledge there is no study, however, that systematically investigated whether patients with schizophrenia show the same emotion recognition deficits when emotions are expressed by a virtual as compared to a natural face. Therefore, the aim of the current study was firstly, to test if emotion recognition in schizophrenia is also impaired when emotions are presented by avatars. Secondly, we were interested to see if possible deficits in the recognition of virtual emotional expressions were also related to patients' psychopathology.

For this purpose the present study compared performance of schizophrenia patients and healthy participants in an emotion recognition task that involved natural and virtual faces. Additionally, performance was correlated with psychopathological scores. We hypothesized that schizophrenia patients would also show deficits in the recognition of virtual emotional expressions. Concerning the emotion specificity of schizophrenia patients' recognition deficits in natural faces there is a great heterogeneity of findings. However, most of the studies have found the impairment to be largest for particular negative emotions like fear, sadness or disgust (Kohler et al., 2004; Edwards et al., 2001; Behere et al., 2009). Accordingly, we expected similar differential deficits for virtual emotion recognition.

2. Methods

2.1 Subjects

Twenty patients (9 women, 11 men; 2 inpatients, 18 outpatients) treated for schizophrenia at the Department of Psychiatry and Psychotherapy of the RWTH Aachen University participated in the study. A control sample of 20 control subjects with no prior history of any psychiatric or neurological disorder (9 women, 11 men) was recruited through advertisements in the same clinic and was matched to the patient group by gender and age. Because schizophrenia patients may have suffered a decrement in their cognitive functions that is related to the illness itself (Keefe et al., 2005) we additionally matched patients and control subjects according to years of parental education (± 2 years) rather then according to own educational attainment. There were no significant differences between groups on these demographic variables (see Table 1).

Table 1 to be inserted about here

All patients were diagnosed with a schizophrenic disorder according to the Structured Clinical Interview for DSM-IV, axis-I disorders (SCID-I; Wittchen et al., 1997). Specifically, fifteen patients were diagnosed with paranoid schizophrenia, three with a schizophrenic residuum, one with catatonic schizophrenia and one with schizoaffective psychosis. Patients did not have any other psychiatric or neurological disorders. Severity of positive and negative symptomatology as well as general psychopathology was assessed by version A of the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987). On average, the stably treated patients showed low positive (mean: 13.06 ± 6.5) and negative (mean: 15.89 ± 6.04) symptomatology. The general psychopathology score was also low, with an average score of 30 ± 8.84. At the point of entry to the study, all but one patients attended treatment and received second generation neuroleptic medication. Doses of all different neuroleptics were converted into chlorpromazine equivalents. On average, patients were taking 647.00 mg of chlorpromazine with a standard deviation (SD) of 87.03. Seven of the patients were additionally taking anti-depressive medication at the time of the study. To control for cognitive impairments all subjects filled the MWT-B, a German test measuring verbal crystallized intelligence (Mehrfachwahl Wortschatz Intelligenztest, MWT-B, Merz et al., 1975). All subjects achieved a verbal intelligence quotient (IQ) above 97. Furthermore, subjects’ current affective state was evaluated by the Positive and Negative Affect Scale (PANAS; Watson et al., 1988). To control for possible facilitation effects in the recognition of virtual emotion through extensive experience with virtual characters in game play, computer game experience was evaluated by a questionnaire (Piazza et al., 2008) that assessed type, frequency and consequences of game play. Table 1 shows the relevant demographics of the sample.

The study was approved by the local Ethics commission and performed according to the Declaration of Helsinki. All participants gave written informed consent after having received a full description of the study.

2.2 Facial stimuli

2.2.1 Virtual facial stimuli

Virtual facial expressions of medium intensity were created with the Face Poser of the Software Development Kit implemented in the Half-Life 2® computer game (Valve Software, Bellevue, Washington, USA). The implementation of the five basic emotional expressions (happiness, anger, fear, sadness and disgust) - as defined by Paul Ekman (Ekman, 1992) - as well as neutral emotion was achieved using the description of facial surface changes as presented within the handbook of Facial Action Coding System (FACS, Ekman and Friesen, 1978). The detailed description of stimulus development and data on stimulus validation can be found elsewhere (Dyck et al., 2008).

2.2.2 Natural facial stimuli

Photographs of 7 female actors and 12 male actors expressing the five emotions and neutrality (no emotional expression) were taken from a stimulus set that has been standardized and used reliably as neurobehavioral probes in emotion research (Gur et al., 2002b). Natural faces with medium intensity that were matched in intensity to virtual faces (Dyck et al., 2008) were selected for the current study.

2.3 Procedure

Facial stimuli were presented in 4 different blocks using MATLAB 7.0® (Mathworks Inc., Sherborn, USA). Two blocks presented only natural faces while the other two blocks presented virtual faces. In total we presented 114 faces (19 actors by 6 emotions) for every face type. To minimize effects of fatigue, we randomly presented half of the faces in the first block (57 facial expressions) and the other half in the second block. The order of blocks was counterbalanced. Every face was presented until a response button was pressed, for a maximum of 7 seconds. Participants read short instructions indicating that the goal of the experiment was to test how people perceive emotions within facial expressions and that some images would be computer generated while others would be photographs of real human faces. Participants were asked to judge the emotion depicted by the particular face as spontaneously as possible by choosing one of the following categories: happiness, anger, fear, sadness, disgust, or neutral. The experimental design is depicted in Figure 1.

Figure 1 to be inserted about here

2.4 Statistical analysis

Responses are binominal (true or false) and recognition rates vary between chance level and 100% accuracy and thus may be not well described by a purely linear model. Therefore, we applied a generalized linear model (binominal responses in a probit regression model) to test the recognition rates with respect to the within-subject factors *face type* (natural or virtual) and *emotion* (happiness, anger, fear, sadness, disgust, or neutral) and the between-subject factor *group* (schizophrenia patients or control subjects). Participant's gender, age, own education and computer game experience were considered as covariates in this model. To increase the power of the statistical model non-significant covariates were excluded from the model and the probit regression model was computed separately for natural and virtual faces. For explorative reasons, we additionally calculated probit regression models for every emotion, separately for natural and virtual faces. All *p*-values were Bonferroni-corrected.

Response times (RT) can be expected to be asymptotically normal distributed and, therefore, were analyzed in a linear model (repeated measure analysis of variance; paired t-test) applying the same independent variables. To test for the validity of emotions expressed by virtual faces in comparison to natural faces, we computed Spearman's correlations between overall accuracy scores as well as RTs of natural and virtual faces, for control subjects and patients separately.

Furthermore, confusion matrices for the error responses were calculated for the two experimental groups and distributions were compared using the Kolmogorov-Smirnov test for two samples.

To examine a possible association between PANSS scores and emotion recognition performance in the schizophrenia group a probit regression model with PANSS scores as within-subjects factors was computed for natural and virtual faces separately. Statistical analyses were performed with SPSS® (SPSS inc., Chicago, USA) and MATLAB 7.0® (Mathworks Inc., Sherborn, USA).

3. Results

3.1 Accuracy scores in emotion recognition task

The probit regression model including the four different covariates (age, gender, level of own education and experience with computer games) indicated significant main effects for age ($z = 3.71$, $p < .001$) and gender ($z = 2.87$, $p < 0.01$). Age was shown to have a negative effect on emotion recognition and females were on average performing better than males. The covariates education and experience with computer games did not significantly explain variance (education: $z = 1.08$, $p = 0.28$; game experience: $z = 1.15$, $p = 0.25$). To increase the power of the model we excluded them from further analyses. Furthermore, there was no significant main effect of *face type* ($z = 1.9$, $p > .05$). Averaged across all emotions, the probit model revealed a significant main effect of *group* with schizophrenia patients generally scoring lower than control subjects ($z = 2.84$, $p < .005$) as well as a significant interaction between *group* and *emotion* ($z = 12.24$, $p < .05$). Considering each face type separately we found a significant main effect of *group* for natural faces (z = 3.01, $p < .005$, see Fig. 2A) as well as for virtual faces (z = 3.51, $p < .001$, Fig. 2B). Moreover, significant *emotion* by *group* interactions emerged for both face types (natural: z = 13.26, $p < .05$; virtual: z = 13.39, $p < .05$).

To further explore these *emotion by group* interactions, the different emotions were analyzed separately. For natural faces, patients scored significantly lower only in the recognition of disgusted faces (z = 2.96, $p < .004$; see Fig. 2A). There were trends towards worse performance in happy (z = 2.32, $p = .02$) and fearful faces (z = 1.67, $p = .09$). For virtual faces, in contrast, patients were impaired in the recognition of sadness (z = 3.26, $p < .002$) and fear (z = 2.82, $p < .005$; see Fig. 2B). Further marginally significant differences could be shown for angry (z = 2.02, $p = .02$) and disgusted expressions (z = 1.93, $p = .05$). Both groups recognized disgust (control subjects: z = 10.76, $p < .0001$; schizophrenia subjects: z = 9.83, $p < .0001$) and neutrality (control subjects: z = 5.56, $p < .0001$; schizophrenia subjects: z = 4.17, $p < .0001$) better when expressed by a natural compared to a virtual face. In contrast, sadness was identified more accurately in virtual faces by both groups (control subjects: z = 7.23, $p < .0001$; schizophrenia subjects: z = 5.31, $p < .0001$). Control subjects also showed better performance in recognizing fear in virtual as compared to natural faces (z = 2.58, $p < .01$).

Figure 2 to be inserted about here

Because the recognition rate for virtual disgust was only slightly above 20% we may consider it as chance performance. To check if this finding affects our group results we recalculated the allover analysis excluding the emotion *disgust*. Results did not significantly change. The significant main effect of *group* remained (z = 3.71, $p < .001$) as well as the interaction between *group* and *emotion* (z = 11.53, $p < .05$).

3.2 RT scores in emotion recognition task

For RTs, the ANOVA indicated no significant effect of the covariates age, gender, level of own education, or computer game experience. Patients showed a trend towards generally slower RTs as indicated by a marginally significant main effect of *group* ($F(1, 38) = 3.83$, $p = .06$). This effect was, however, independent of emotion and face type as indicated by non-significant interactions of *emotion by group* ($F(1, 38) = 2.04$, $p > .05$) and *face type by group* ($F(2.88, 109.47) = 0.01$, $p > .05$). For explorative reasons, paired t-tests were computed comparing RTs in control subjects and patients for the different emotions. Only for happy natural faces, response times were significantly slower in patients as compared to healthy controls ($t(26.55) = - 3.524$, $p = .002$, see Fig. 3). Furthermore, a correlation analysis discarded the possibility of a speed-accuracy trade-off for any emotion.

Figure 3 to be inserted about here

3.3 Validity

For both experimental groups we found very high correlations between recognition accuracy in natural and virtual faces (control subjects: $r = .75$, $p < .001$; schizophrenia subjects: $r = .61$, $p = .005$). Response times for both face types were also significantly correlated (control subjects: $r = .82$, $p < .001$; schizophrenia subjects: $r = .86$, $p < .001$).

3.4 Error pattern in emotion recognition task

Confusion matrices compared the error patterns for virtual and natural faces between both experimental groups. No significant differences in error patterns were indicated between patients and control subjects after correcting for multiple comparisons. A trend emerged in the recognition of fear ($K = 0.19$, $p = 0.035$). Control subjects mainly confused fear with sadness whereas patients with schizophrenia tended to rate fearful faces as neutral.

3.5 Correlations with psychopathology/medication

Accuracy scores for the recognition of natural faces were negatively correlated with positive symptomatology according to the PANSS (z = - 2.64, p = .008, uncorrected) while accuracy scores for virtual faces were not (z = -.38, p = .71). Considering the different emotions, positive PANSS scores were negatively associated with the recognition of neutrality (z = -4.35, p < .0001) and sadness (z = -2.58, p = .009, uncorrected) in natural faces. An inspection of the types of confusions revealed that patients with high positive symptomatology mainly confused neutrality with sadness (4.8%), happiness (4.3%), or anger (3.8%) while sadness was mistaken for disgust (22.5%), neutrality (21.3%), or anger (19.7%).

Pertaining to possible associations between medication and task performance, chlorpromazine doses did neither correlate with accuracy nor with RTs in the emotion recognition tasks.

4. Discussion

Considering the increasing interest in virtual reality as a method for diagnosis and treatment of schizophrenia, the goal of the present study was to investigate whether patients with schizophrenia are also impaired in emotion recognition when virtual as compared to natural facial expressions are presented. Consistent with our hypothesis, findings indicated that emotion recognition impairments also emerge for emotions expressed by virtual characters, extending a previous finding of Kim et al. (2007) showing a reduction in social perception ability in schizophrenia when angry, sad, and happy situations had to be recognized in VR. As further expected, deficits were differential for the negative emotions of fear and sadness. Regarding the recognition of natural faces, we could replicate former findings of an emotion recognition deficit that was differential for the emotion disgust (Kohler et al., 2003; Behere et al., 2009). For the other negative emotions of fear and sadness we could show trends towards decreased performance in schizophrenia patients.

4.1 Virtual emotions in schizophrenia

The present study is the first to systematically document deficits in recognizing basic emotions expressed by virtual faces in schizophrenia. This finding supports the use of virtual facial expressions for psychiatric research. Now that we know that schizophrenia patients show similar deficits in the recognition of virtual and natural faces we can use the advantages of virtual faces such as the ease of control, animation and change of parameters to develop further diagnostic and therapeutic interventions. The fact that patients show deficits in the recognition of virtual emotions further indicates that they are already impaired in the recognition of basic emotional features because virtual expressions only contain major and frequent features; natural faces, in contrast, also contain infrequent and minor features that vary inter-individually (Kohler et al., 2004). This variability could make them more difficult to recognize. Our results support this pattern: recognition rates for the negative emotions excluding disgust were higher for virtual than natural faces, in both experimental groups. This finding has practical implications because VR allows the direct manipulation of different facial features. For treatment purposes facial expressions with a gradation of difficulty could be created in a controlled manner. This approach would pave a systematic way to rehabilitation programs, in which patients are first trained to recognize emotions with only major emotional features. Once they would improve in the recognition of these major emotional features more subtle and rare emotional features could be incorporated in the virtual expressions.

4.2 Psychopathology

Our results reveal an association between positive symptomatology and the recognition of natural faces. Patients with more pronounced positive symptoms committed more errors in the recognition of natural faces, especially in the recognition of neutral and sad expressions. It is known that positive symptoms of schizophrenia such as hallucinations and delusions often reflect feelings of threat, persecution and suspiciousness in patients. Regarding neutral expressions, patients may over-interpret them and impute emotional value (anger, sadness, and happiness) to them. This is consistent with previous research showing that during acute psychotic states which are dominated through positive symptomatology patients tend to misattribute emotional valence to neutral stimuli (Kapur, 2003; Surguladze et al., 2006). Natural expressions of sadness were most difficult to recognize in the current study. Patients with more pronounced positive symptoms may have misattributed more negative emotions (anger, disgust) into them as patients without this paranoid ideation. Notably, this association could only be seen in the recognition pattern of natural and not of virtual facial expressions. This pattern could indicate a different apperception of virtual faces. Virtual characters may be inherently less intimidating than real faces due to their game-like qualities and the intrinsic unreality of the virtual worlds they inhabit (Marsella et al., 2003; Robins et al., 2005). The fact that virtual faces may be perceived as less intimidating by patients may entail an advantage for therapy programs: it facilitates learning of social skills under relatively lower stimulus-induced anxiety.

4.3 Methodological considerations and outlook

In comparison to previous studies the indicated deficits in the recognition of natural emotions seem to be less pronounced in the current study. There are several possible explanations for this discrepancy. First, the state of the illness in our patient sample was mainly non-acute. Previous studies already indicated that acute patients show stronger deficits in emotional face recognition. Penn et al. (2000) compared two samples of schizophrenia patients, one receiving acute care and one receiving extended care, to control subjects. The acutely ill sample revealed a specific emotion recognition deficit while the deficit in the extended care sample was more generalized and not emotion-specific. Second, facial expressions presented in our study were of medium intensity while previous studies mainly used high intensive stimuli. The intensity of the stimuli could have influenced recognition rates in the present study. Kohler et al. (2003) directly compared the recognition of mild versus extreme intensities of emotion in patients with schizophrenia and showed that patients were not able to profit from greater emotional intensity. In contrast, schizophrenia patients made more misattributions to other emotions when expressions were more extreme.

Another limitation of our results is that accuracy rates for virtual disgust were only at chance level (slightly above 20%). This finding mimics results from earlier studies suggesting that disgust is not recognized consistently within virtual faces (Moser et al., 2006; Spencer-Smith et al., 2001). This effect can be explained by the difficulty to generate a specific action unit - the nose wrinkle- that is distinguishing for disgust. Due to low polygon counts at this specific region it was not possible to achieve consistent wrinkling. For virtual applications involving the emotion of disgust, an improvement of naso-labial rendering should be realized in future programs.

At last, our experimental groups marginally differed with respect to own level of education and experience with computer games. Regarding the level of own education it is well-known that that individuals with schizophrenia do not perform on cognitive tests at the level predicted by their parental education. While schizophrenia patients may score within the normal range on cognitive tests, it is likely that these patients have suffered a decrement in their cognitive functions (Keefe et al., 2005). These findings have led to the assertion that matching schizophrenic patients and normal control subjects on education or IQ may cause systematic mismatching of theoretically expected ability (the ‘matching fallacy’; Meehl, 1970) as the educational failure and reduced IQ seem to be related to the illness itself. We therefore decided to match schizophrenia patients primary on parental education and secondary only on own education. Though, we included own education level as a covariate into our analyses. Consistent with findings from a recent meta-analysis by Kohler et al. (2009) it did not seem to be associated with the ability to recognize emotions. Concluding, we do not believe that this difference in own education between our two experimental groups influenced our results. Similarly, schizophrenia patients had less previous experience with computer games than control subjects. Our previous study (Dyck et al., 2008) already indicated that game experience is not critically related to emotion recognition and we could confirm this finding in the present study.

In conclusion, the present study has demonstrated that schizophrenia patients also show deficits in emotion recognition when emotions are expressed by virtual faces. Virtual characters represent a valuable tool that extends research options in the field of schizophrenia because control, animation and change of parameters can be directly achieved. Avatars applied in the present study also have the advantage of being implemented in a video game engine. Accordingly, they can be easily integrated into interactive and realistic social environmental scenes. These would supply an optimal setting for exercising emotion recognition in a social context and could provide a tool for investigating the neural processes underlying impairments in social behavior of patients with schizophrenia in a more realistic way.

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Tables

Table 1 Demographic information of the two experimental groups

	control subjects		SZ patients		t-test
	mean	SD	mean	SD	*p*
age (years)	36.9	± 2.23	36.75	± 1.99	0.97
own education (years)	14.6	± 0.79	12.55	± 0.55	0.06
parental education (years)	11.2	± 3.29	11.82	± 0.94	0.62
PANAS positive	30.5	± 6.05	26.40	± 5.30	0.06
PANAS negative	12.1	± 5.30	14.50	± 5.50	0.17
Video game experience (n/total n per group)	7/20	-	2/20	-	-
IQ (MWT-B)	117.5	± 2.93	111.95	± 3.28	0.26
PANSS positive	-	-	13.06	± 6.50	-
PANSS negative	-	-	15.89	± 6.04	-
PANSS psychopathology	-	-	30.00	± 8.84	-
PANSS total	-	-	59.00	± 16.34	-
CPZ- equivalent antipsychotic dose (mg/day)	-	-	647.00	± 87.03	-

SD, standard deviation; SZ, schizophrenia; MWT-B, Mehrfachwahl Wortschatz Intelligenztest (vocabulary intelligence test) ; CPZ, chlorpromazine

Figure 1: Experimental design with an example of a disgusted and sad facial expression for natural and virtual faces each.

Figure 2: Emotion recognition rate with standard error of mean for A. natural and B. virtual facial expressions for control subjects and schizophrenia patients (chance performance was 16.67%).

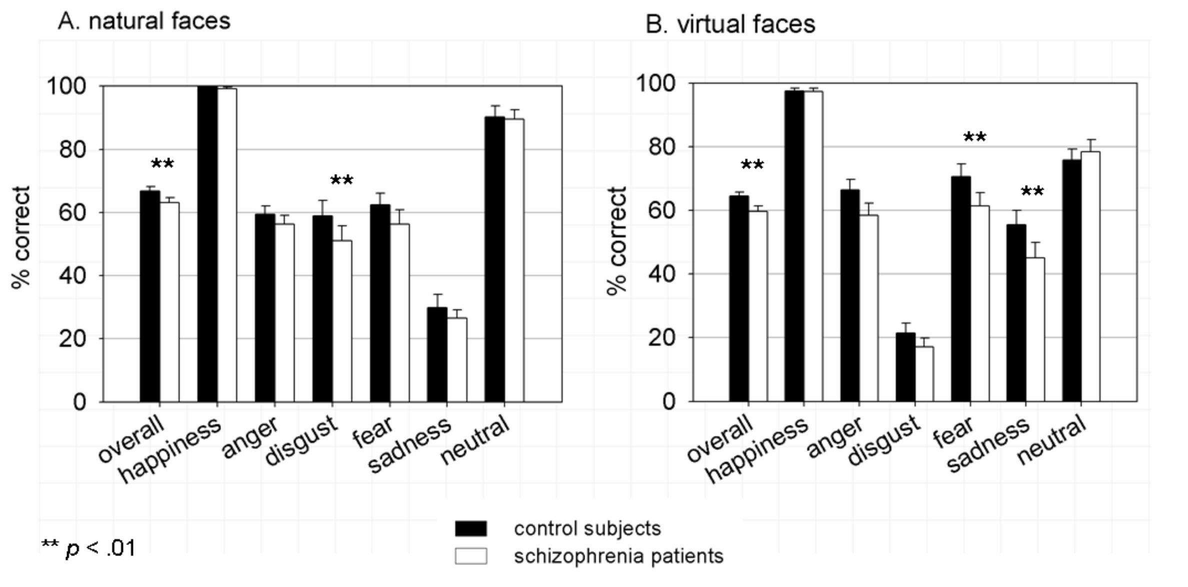

Figure 3: Response times with standard error of mean for A. natural and B. virtual facial expressions for control subjects and schizophrenia patients.