Training of Affect Recognition impacts electrophysiological correlates of facial affect recognition in schizophrenia: Analyses of fixation-locked potentials

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Abstract

Objectives. Training of Affect Recognition (TAR) is a useful approach to restoring cognitive function in schizophrenic patients. Along with improving visual exploration of faces and altering central information processing in relevant brain areas, TAR attenuates impairments in facial affect recognition. In the present study, we investigate the effects of TAR on early electrophysiological correlates of facial affect recognition in schizophrenia. Methods. The study population comprised 12 schizophrenic patients and 14 healthy controls. In each individual, we carried out EEG, concomitant measurements of scanning eye movements and fixation-based low resolution electromagnetic tomography (sLORETA) analyses of brain electric activity. All analyses were performed at baseline and after participation in TAR. Results. In patients, brain activation patterns significantly changed after completing the TAR. Functional improvements were particularly pronounced in the superior parietal and inferior parietal lobes, where trained patients showed a larger increase in activation than untrained healthy controls. Conclusions. The TAR activates compensatory brain processes involved in the perception, attention and evaluation of emotional stimuli. This may underlie the established behavioral effects of the TAR in schizophrenic patients, which include improvements in facial affect recognition and alterations of visual exploration strategies.

Key words: schizophrenia, affect recognition, eye movement, EEG, sLORETA

Introduction

Impaired cognitive functioning is a well-established symptom of schizophrenia. In addition to impaired basic cognition (i.e. attention, memory, executive functions) (Trémeau 2006), impaired social cognition has been widely described (Pinkham 2014) and this includes difficulties in recognizing and discriminating facial affect (Kohler et al. 2009). Poor facial affect recognition is observed throughout the course of schizophrenia and is less amenable to pharmacotherapy than other symptoms of the disorder (Wölwer et al. 1996; Hempel et al. 2010; Green et al. 2012). The ability to adequately interpret and respond to facial expressions is essential for successful interaction with others and for active participation in social and community life (Morris et al. 2009). Consequently, schizophrenic patients have a poorer social outcome, i.e. they are less likely to have friends or hold a job (Couture et al. 2006; Pinkham et al. 2008). Because schizophrenia patients often report these disabilities to be most disturbing, there is an urgent need for treatment strategies to enhance their functional abilities. Although social cognitive remediation is still at an early stage of development, the initial efficacy results are encouraging (Wölwer et al. 2010). The Training of Affect Recognition (TAR) developed in our group (Frommann et al. 2003) has been shown to effectively attenuate facial affect recognition deficits (Wölwer et al. 2005; Wölwer and Frommann 2011; Sachs et al. 2012; Luckhaus et al. 2013). Accumulating evidence suggests that difficulties in recognizing and discriminating facial affect...
relate to abnormal functioning in the underlying neural network. Studies of cerebral networks for emotional behaviour in animals and humans have implicated cortical regions including the orbitofrontal, dorsolateral prefrontal and temporal cortex, parts of the parietal cortex and the limbic system, primarily the amygdala, hypothalamus and the mesocorticolimbic dopaminergic systems (LeDoux 1995; Adolphs et al. 1996). Previous research indicates that the TAR modifies activity in neural processes by increasing activation in the left middle and superior occipital lobe, the right inferior and superior parietal cortex, and the inferior frontal cortex bilaterally accompanied by improved affect recognition (Habel et al. 2010). The authors conclude that patients may have learned more efficient attentional, perceptual or cognitive strategies during training (Habel et al. 2010). These results are promising, showing the potential of therapeutic interventions to manipulate information processing in patients on a cerebral basis. However, to date accordant findings are sparse. Event related potentials (ERP) represent an ideal means for analyses of information processing stages as they provide important (spatio)-temporal information on the neurophysiological basis of emotion recognition (Vuilleumier and Pourtois 2007) since “reading” emotions from faces takes place very rapidly within the first 100 ms (Liu and Ioannides 2010). There seems to be an advantage for negatively valenced facial expressions (anger, fear) (Pourtois et al. 2005; Rellecke et al. 2012). However, to date there have been no study-based analyses of neurophysiological data of affect recognition on deliberate fixations on a face during affect recognition.

Eimer and Holmes (2007) have shown in several ERP studies that selective brain responses to emotional faces occur within certain time frames, showing a characteristic waveform in the EEG. They describe brain responses that occur very shortly after stimulus onset and strongly depend on attention, i.e. only a face that is fixated elicits the typical brain response (Eimer and Holmes 2007). The authors propose that after initial automatic detection of the emotional content of a face by particular brain structures (such as the amygdala for fearful faces, etc.) a second higher level, attention-dependent processing takes place starting very early in parallel with other processes.

To date it remains unclear, whether schizophrenia patients suffer from a deficit at the early perceptual stage or the later conceptual recognition state – or both.

Taking into account the strong dependence on attention, it seems crucial for the investigation of facial affect recognition that subjects pay attention to the presented stimuli. Paying attention is presumably reflected by a deliberate fixation. Explorative eye movements are furthermore assumed to directly reflect the temporal course of information processing during execution of a cognitive task (Toh et al. 2011). Accordingly, scan path analysis may enable the differentiation of particular cognitive dysfunctions in schizophrenia and provide, in combination with EEG, a powerful approach to understanding (i) the time point(s) within the stream of information processing at which disturbances occur and (ii) the location(s) in the brain at which these disturbances manifest.

In the present study, we analysed brain electric activity based on deliberate fixations on a facial stimulus (thought to indicate effortful processing of the presented face) and behavioural performance and gaze parameters as described previously (Drusch et al. 2014). By means of this novel methodological approach, we aimed to investigate dysfunctions of brain networks associated with the impairments in facial affect recognition in schizophrenic patients. To obtain this goal, schizophrenia patients participated in the TAR with concomitant assessment of gaze behaviour and EEG collected at baseline and retest. The temporal onset of the first fixation was imported into the EEG measures that were then analysed with regard to this new marker. Offline analyses of fixation-locked EEG data were extended to low-resolution brain electromagnetic tomography in order to locate sources of potentially abnormal activity during affect recognition. By integrating behavioural and neurophysiological data we sought to capture the “reflective mode of processing” more closely. Thus, aims of the present study were (i) to identify dysfunctional brain areas associated with the impairment of facial affect recognition and (ii) evaluate the effect of TAR on dysfunctional information processing in schizophrenia.

Methods

Study design

The presented data derive from a clinical study investigating the Training of Affect Recognition (TAR) on gaze behaviour and affect recognition in schizophrenia (Drusch et al. 2014). Within a controlled interventional follow-up design, a group of 16 schizophrenia patients was assessed at baseline and after participating in the TAR for 6 weeks. A group of healthy participants was assessed at baseline and after an interval of approximately 6–8 weeks of no intervention.

The study protocol was approved by the local ethics committee of the University of Düsseldorf and written informed consent was obtained from each participant.
Training of Affect Recognition in schizophrenia

Sample
Sixteen post-acute in and out patients diagnosed with schizophrenia (Structured Clinical Interview for DSM-IV (First et al. 1995) and 16 healthy controls with no history of psychiatric disorder participated in the study. The clinical sample was recruited at the Department of Psychiatry and Psychotherapy of the University of Duesseldorf, Germany. Healthy controls were recruited by word of mouth and matched by age and gender. All patients were matched for DSM-IV (First et al. 1995) and 16 healthy controls with no history of psychiatric disorder participated in the study. The clinical sample was recruited at the Department of Psychiatry and Psychotherapy of the University of Duesseldorf, Germany. Healthy controls were recruited by word of mouth and matched by age and gender. All patients were matched by age and gender. All patients were medicated with atypical antipsychotics (amisulpride N = 2, clozapine N = 4, melperon N = 1, olanzapine N = 4, quetiapine N = 1, risperidone N = 4 and xepion N = 1. Mean dosage was 607 mg chlorpromazine equivalents (CPZE) ± 421 mg, ranging from 275 to 1550 mg CPZE. Nine patients received only one antipsychotic medicament, one patient received two antipsychotics and two patients received three antipsychotics. Medication was kept stable throughout the training period. Mean duration of illness was 10.67 years (SD 8.6) and mean number of acute psychotic episodes was 3.88 (SD 1.89).

At baseline, all participants were examined for inclusion criteria (i.e. age 18–60 years; intelligence quotient (IQ) > 80; good German language skills; no neurological diseases).

While groups did not differ regarding age and gender, the patients’ premorbid IQ, assessed with the multiple choice vocabulary test (MWT-B) (Lehrl 2005), and years of education differed significantly from those of the controls. However, neither variable was significantly related to the dependent variables and therefore not incorporated into further analyses.

Participants were excluded from scan path and EEG analyses if their eye-tracking ratio was ≤ 90% or if the calibration did not reach a pre-defined accuracy criterion (x= / y-deviations ± 1.0°). Four patients and two healthy participants were therefore excluded.

Patients significantly improved performance during training period. At retest, patients had improved affect recognition performance up to the level seen in healthy controls. Along with the improvement, a change in scan path characteristics was observed: patients significantly increased number of fixation in salient facial feature areas – namely the mouth – and decreased number of fixation in non-feature areas (“white space”). For a detailed description of behavioural and gaze data see Drusch et al. (2014).

Training of affect recognition (TAR)
The TAR trains patients to decode facial emotions. It is conducted in 12 group sessions of 45–60 min twice a week with two patients per group. Based on an errorless learning approach, the TAR employs both repeated practice as well as establishing alternative strategies of emotion processing (e.g., verbalization, self-instruction, using situational anchors).

Psychometric assessment
Verbal and working memory, motor skills, semantic and letter fluency, and executive functions were assessed by means of the Brief Assessment of Cognition in Schizophrenia (BACS) (Keefe et al. 2004). As expected, the healthy controls outperformed patients before and after the training period. To exclude prosopagnosia, non-affective face recognition was assessed by the Benton Face Recognition Test (BFRT) (Benton et al. 1978).

Psychopathological assessment
Within the present trial, patients showed a rather mild pathology, which remained stable throughout the trial. Symptom severity was rated at baseline and after completion of the TAR by means of the Positive and Negative Syndrome Scale (PANSS) (Kay et al. 1987) (see Table I for demographic characteristics and Table II for clinical characteristics).

Affect recognition
For affect recognition assessment, 70 coloured portraits from the Karolinska Directed Emotional Faces picture set (KDEF) (Lundqvist et al. 1998) were presented. Five male and five female models expressed the six basic emotions – happiness, fear, sadness, anger, surprise and disgust – and a neutral face. In the present study only 30 stimuli displaying three emotions (fear, sadness and surprise) were taken into further analyses of source localization. There are three main reasons fortifying the chosen

Table I. Demographic variables for schizophrenia patients (SZ) and healthy controls (HC). There are no differences between groups regarding age but schizophrenia patients show significantly fewer years of education and a lower intelligence quotient (IQ) as indicated by T values (T) and level of significance (P).

|               | SZ mean (SD) | HC mean (SD) | T (P)   |
|---------------|--------------|--------------|---------|
| Age           | 36.69 (11.37)| 33.69 (8.82) | -0.82 (0.42) |
| Gender        | 4 females    | 3 females    |         |
| Education     | 11.69 (1.58) | 13.25 (.78)  | 3.55 (<0.01) |
| (years)       |              |              |         |
| IQ            | 103.88 (11.97)| 119.33 (11.93)| 3.6 (<0.01) |
Table II. PANSS data for schizophrenia patients. Mean number of positive, negative and global symptoms at baseline (T0) and retest (T1) are shown respectively. No significant change of symptoms occurred throughout the training period.

|                  | T0 mean (SD) | T1 mean (SD) |
|------------------|--------------|--------------|
| PANSS positive   | 12.5 (4.23)  | 12.0 (4.71)  |
| PANSS negative   | 11.9 (4.49)  | 12.2 (6.89)  |
| PANSS global     | 25.9 (6.17)  | 26.5 (6.49)  |

SZ, schizophrenia patients; HC, healthy controls; PANSS, positive and negative syndrome scale.

approach: (i) there is evidence of disproportionate impairment in the identification of negative emotions (including fear, sadness), whereas recognition of positively valenced emotions and neutral faces seems less impaired in schizophrenia patients (Gaebel and Wolwer 1992; Schneider et al. 1995; Edwards et al. 2001; Kohler et al. 2003; Silver et al. 2009), (ii) positively and negatively valenced emotions are processed by different brain networks (Holt et al. 2006; Rauch et al. 2010; Suslow et al. 2013) and (iii) an item analysis of performance data at baseline only for the chosen emotions provided discrimination between groups (Drusch et al. 2014), thus TAR effects can only be expected for these emotions.

Pictures were 27.2 × 20.1 cm in size, with a resolution of 562 × 762 pixels embedded in a background of ten different black-and-white patterns. Pictures were displayed on a monitor in a pseudo-randomized order, precluding that the same emotion, gender, displayed person, position of the fixation cross, and type of background occurred consecutively. Before each stimulus, a black fixation cross was randomly presented in one corner of the screen (upper left, upper right, lower left or lower right). In order to avoid a fixation bias to the nose, no centrally placed fixation cross was used. As soon as participants had fixated the cross for at least 500 ms, the subsequent stimulus appeared. If the participants did not fixate the cross, it remained on the screen for 2000 ms before the stimulus appeared. Each stimulus was presented for 3000 ms. Subsequently a list of emotions (happy, anxious, sad, angry, surprised, disgusted and neutral) was presented next to a miniature picture of the facial stimulus. The list remained on the screen for 6000 ms. Participants were asked to verbally communicate their judgment which was recorded by the investigator. The facial affect recognition task lasted 20 min on average.

Eye-tracking and gaze parameters

Eye movements were recorded via a video-based pupil eye tracking system at 250 Hz (iView RED250, SMI, Berlin, Germany). The remote (contact free) eye tracker is integrated in a 22-inch computer screen (1290 × 800 px resolution). The iViewX system records the eye position in a 40 × 20 cm field at a distance of 70 cm with a sampling rate of 250 Hz and a spatial resolution of 0.03°. Eye movement data were collected binocularly with high accuracy (0.4°). To allow for this high accuracy, calibration of eye position was conducted using a target display of nine dots covering the whole screen. Analyses of the recorded eye movement data was conducted with the software BeGaze (SMI, Berlin, Germany).

During recording, participants were seated at 60–70 cm distance from the computer screen in a chair adjustable for height to ensure optimal position towards the tracking system.

Location, start time, and duration of all fixations were analysed. Four different areas of interest (AOI) were defined: eyes, nose, mouth (i.e. salient feature areas) and any other parts of the picture (i.e. “white space” – non-salient feature area). Fixations were defined as a gaze that remained stable for at least 100 ms (for further details, see Drusch et al. 2014).

EEG and ERP recordings

ERP data were recorded at 39 electrodes according to the extended 10/20 system. Cz was used as reference. Vertical and horizontal electrooculogram (EOG) was recorded from the supraorbit of the right eye and the outer canthus, respectively. EEG was recorded via a Syn-Amp Amplifier controlled through the SCAN software package (Neuroscan, Herndon, VA) and digitized at 1000 Hz. The impedance at each electrode was kept below 5 kΩ.

Data were analysed via the software package Vision Analyzer 2.1 (Brain Products, Munich, Germany). Recordings were off-line downsampled to 250 Hz, filtered (low cutoff: 0.53 Hz, time constant 0.3, 12 dB/oct, high cutoff: 50 Hz, 12 dB/oct), baseline corrected to 100 ms prestimulus, and corrected for artifacts (±70 μV, gradient 20 μV/ms). An independent component analysis was conducted to remove ocular activity (blinks) from the signal (Brown et al. 2001). Segments with artefacts were discarded. EPR amplitudes were measured as peak to baseline values.

After artefact rejection a total mean of 29.0 and 29.1 artifact-free segments for fixation-locked potentials in schizophrenia patients (SZ) (28.6 pre- and 29.6 post-training) and healthy controls (HC) (29.4 pre- and 28.6 post-training), respectively, entered statistical analyses. The number of artefact-free segments did not differ between groups (P > 0.26 for all comparisons).
Fixation-locked potentials

In order to capture brain electric activity representing effortful processing of the presented stimulus, data were analysed with regard to the first fixation into the face. For evaluation of the fixation-locked potentials, first fixations on the fixation cross were excluded from analyses taking only those first fixations located in the face area into account. Two time windows were identified by visual inspection of the global field power (GFP) waveform (a positive peak at approximately 60 ms after onset of the first fixation and a negative peak at 150 ms) and analysed at the four midline electrodes (Fz, Cz, Pz and Oz). Due to the novel character of the methodological approach, no previous work was found to validate the selected time windows.

sLORETA analyses

In order to locate generators of brain electrical activity during emotional picture perception, a current source density (CSD) analysis was performed using the standardized low-resolution electromagnetic tomography (sLORETA) software package (Pascual-Marqui et al. 1994, 2002). sLORETA is a minimum norm approach relying on the observation of coherent firing of neighboring neurons, assuming the smoothest of all activity distributions to be the most probable (Pascual-Marqui et al. 1994, 2002). From a multichannel EEG, the electrical activity at each voxel is computed as the amplitude of the CSD (μV/cm²) and mapped in the sLORETA image. LORETA images for each subject in the fixed time frames between 56–64 and 144–152 ms post-stimulus, respectively, were calculated to obtain the sLORETA value for each voxel. The version of LORETA used in the present study is based on the digitized MNI brain, converted to corrected Talairach coordinates, estimating the global field power distribution for the brain electric activity for 6239 cortical gray matter voxel at 5 mm spatial resolution.

Statistics

Performance of affect recognition and scan path parameters (number and duration of fixations) were evaluated by 2 (groups) × 2 (retest) ANOVA for repeated measures. In case of significant interactions Fisher’s LSD post hoc tests were conducted.

Statistical analyses of peak amplitude of fixation-locked potentials were conducted by repeated measures ANOVA on each component of interest with electrode position (Fz, Cz, Pz, Oz) as within subject factor and baseline (T0) and retest (T1) measures as between subject factor. Due to a lack of previous (temporo-spatial) information on fixation-locked potentials all central electrodes (Fz, Cz, Pz, Oz) were evaluated within time windows based on visual inspection of the GFP waveforms. Supplementary Figure 1 (available online at http://informahealthcare.com/doi/abs/10.3109/15622975.2015.1051110) depicts GFP for both groups at baseline and retest.

For baseline and retest measures, topographical current density maps were created and averaged per person on log transformed data via sLORETA software. sLORETA images were compared employing (a) t-statistics for independent groups with respect to corresponding voxels for comparing groups at baseline and retest, (b) t-statistics for paired groups contrasting baseline and retest current density within groups and (c) a contrast of difference maps for comparing baseline to retest changes (per group) between groups. To correct for multiple comparisons, a non-parametric single-threshold test was applied on the basis of the theory for randomization and permutation as implemented in the sLORETA software. Voxel in Talairach space with t-values above the critical 5% error probability threshold, determined by 5000 randomizations, are considered as the region of activation (Pascual-Marqui et al. 2002).

Results

ERP (fixation-locked potentials)

P60. At central sites (Fz, Cz, Pz, Oz), schizophrenia patients (SZ) showed significantly smaller amplitudes compared to healthy controls (HC) (F = 5.2, P = 0.04). The main effect of retest was insignificant (F = 2.2, P = 0.14). A tendency of interaction between group and retest showed an increase in amplitude only in SZ (F = 4.1, P = 0.06). A significant three-fold interaction of group, retest and electrode showed an increase of P60 amplitude in SZ in Pz and Oz at retest that was absent in HC (F = 3.2, P = 0.03).

Post hoc comparisons revealed increased amplitudes at parietal and occipital electrodes (Pz, and Oz, P < 0.001) only in SZ, whereas no amplitude change in HC was noted (P > 0.49 for all comparisons).

N150. There was no effect of group (F = 0.04, P = 0.80), or retest (F = 0.64, P = 0.42) nor an interaction of group and retest (F = 0.35, P = 0.51). A significant effect of site showed massive differences between amplitudes at the four electrodes with largest amplitudes at Oz (F = 35.8, P < 0.001). A significant interaction of group and electrode revealed group differences only at Oz with SZ showing smaller amplitudes than HC (F = 2.3, P = 0.03) and the greatest change of amplitude at Oz, indicated by a
significant threefold interaction of group, retest and electrode \( (F = 3.9, P = 0.01) \).

Looking closer at single electrodes, post hoc tests revealed differences between groups only occi-
tally (Oz) at baseline \( (P = 0.01) \), but no change in amplitude throughout the training period in SZ
\( (P > 0.39 \text{ for all comparisons}) \) and no differences
between groups at retest \( (P > 0.39 \text{ for all com-
parisons}) \). Figure 1 depicts fixation-locked poten-
tials at midline electrodes.

Source localization (LORETA)

Double contrast schizophrenia patients (retest-baseline)
vs. healthy controls (retest-baseline). Analyses of the
cerebral current density at 60 ms after onset of the
first fixation revealed a change of activation from
baseline to retest in inferior parietal lobule, precuneus
and superior parietal lobule that was significantly
larger in SZ than in HC (see Figure 2).

No significant group differences occurred for the
pre-post comparisons of the cerebral current density
at 150 ms.

Schizophrenia patients vs. healthy controls at baseline
(T0). At baseline the two groups showed differences
in cerebral current density at both time windows of
60 and 150 ms after fixation onset, respectively, in
several brain areas.

In detail, at 60 ms SZ showed diminished activa-
tion in angular gyrus, cingulate gyrus, cuneus, infe-
rior frontal gyrus, inferior occipital gyrus, inferior
parietal lobule, lingual gyrus, medial frontal gyrus,
middle occipital gyrus, middle temporal gyrus, para-
central lobule, postcentral gyrus, posterior cingulate,
precuneus and superior parietal lobule compared to HC (see Figure 3a).

Within the time window of 150 ms after fixation
onset SZ showed diminished activation in cuneus,
inferior parietal lobule, lingual gyrus, medial frontal
gyrus, middle temporal gyrus, postcentral gyrus,
posterior cingulate, precuneus, superior frontal gyrus
and superior temporal gyrus compared to HC (see
Figure 3b).

Schizophrenia patients vs. healthy controls at retest (T1).
At retest, there were no significant differences
between groups observed.

Within group contrasts (T1–T0). A significant increase
of activation in postcentral gyrus, superior frontal
gyrus, superior parietal lobule, inferior parietal lob-
ule was observed in SZ after participating in the
TAR. No significant changes in activation occurred
between T0 and T1 in HC (Figure 4).

Discussion

Brain activation patterns induced by affect recogni-
tion tasks have been described extensively based on
conventional functional imaging data (for a review
see Vuilleumier and Pourtois, 2007). To date, no
EEG source localization analyses triggered by a
behavioural index of cognitive control (such as a
fixation on a face) has been conducted within an
affect recognition task.

![Figure 1. The fixation-locked potentials in Schizophrenia patients (SZ) and healthy controls (HC) at baseline (T0) and retest (T1) at
midline electrodes Fz, Cz, Pz and Oz. Differences between groups are most obvious at parietal and occipital electrodes.](image-url)
On the behavioural level, a first report from the present study showed again, that the TAR effectively improves affect recognition performance in schizophrenia patients almost up to the level of healthy controls (Drusch et al. 2014). The current report adds analyses on the electrophysiological level: by analysing brain electric potentials locked to the first fixation, a significant effect of the TAR on amplitudes of a potential with a positive peak at approximately 60 ms after fixation onset, maximal at parietal sites, was observed. Peak amplitude of this “fixation-locked P60” was normalized in schizophrenia patients after participating in the TAR. A later peak at approximately 150 ms after fixation onset, observed at occipital sites, also clearly differed between groups but was only slightly affected by the TAR in schizophrenia patients. Applying sLORETA analyses, the activation pattern at baseline 60 ms after first fixation onset reflected hypoactivation within parts of a formerly described network typically associated with the perception and recognition of emotional faces (e.g. fusiform gyrus, posterior cingulated cortex, media prefrontal cortex) (Fusar-Poli et al. 2009). Interestingly, at retest (after schizophrenia patients had successfully participated in the TAR) there was no significant difference between groups. Thus, for a time interval very close to attention allocation to the stimulus, schizophrenia patients exhibit a “normalized” brain response subsequent to the TAR. Further on in the information processing stream, at 150 ms after fixation onset, group differences observed at baseline were still present after the TAR but yet only marginal and did not reach significance.

Beyond cross-sectional comparisons, the longitudinal analyses of modified activation patterns from baseline to retest revealed specific activation changes in schizophrenia patients at 60 ms after fixation onset. Specifically, activation substantially increased in superior parietal lobule and inferior parietal lobule in schizophrenia patients throughout the TAR. The lateral part of the posterior parietal cortex – particularly the superior parietal lobule (SPL) and inferior parietal lobule (IPL) – has traditionally been considered a higher-order area, known to be involved in controlling somatosensory and visuomotor integration (Iacoboni 2006) spatial aspects of motor behaviour (Tunik et al. 2008; Vingerhoets 2014), visual attention and shift of attention (Rushworth et al. 2001; Wager et al. 2004) and the manipulation of information in working memory (Wager and Smith 2003; Koenigs et al. 2009). Furthermore, the superior parietal lobule is part of the parietal mirror neuron system, activated by the observation of detailed aspects of a motor action (Molenberghs et al. 2010). It has been argued that this mirror neuron system forms the basis for the “experiential understanding of the emotions of others” (Gallese et al. 2004). Thus, behavioural effects of the TAR seem to relate to specific activation increases in areas related to the perception, association and evaluation of emotion.

Our finding of training-induced activity increase in the parietal cortex may be interpreted as a general attention-related compensatory mechanism in schizophrenia patients: Compared to healthy subjects, schizophrenia patients show hypoactivation within parts of the “social brain” (cingulate cortex, fusiform gyrus, and posterior cingulated cortex).
Figure 3. A between-groups contrast: brain areas of significantly diminished cerebral current density at baseline (T0) during emotion recognition in schizophrenia patients (SZ) compared to healthy controls (HC) at (a) 60 ms and (b) 150 ms after first fixation onset. BA, Brodmann area.

| X    | Y    | Z    | t-Value | BA | Lobe          | Structure                  |
|------|------|------|---------|----|---------------|----------------------------|
| 30   | -27  | 47   | -4.51   | 4  | Frontal Lobe  | Precentral Gyrus           |
| 5    | -26  | 66   | -4.09   | 6  | Frontal Lobe  | Medial Frontal Gyrus       |
| -59  | 11   | 27   | -4.09   | 9  | Frontal Lobe  | Inferior Frontal Gyrus     |
| -25  | -68  | 8    | -4.02   | 30 | Limbic Lobe   | Posterior Cingulate        |
| 20   | -32  | 43   | -4.56   | 31 | Limbic Lobe   | Cingulate Gyrus            |
| -20  | -93  | -8   | -3.91   | 17 | Occipital Lobe| Inferior Occipital Gyrus   |
| -30  | -87  | 4    | -5.13   | 18 | Occipital Lobe| Middle Occipital Gyrus     |
| 35   | -36  | 66   | -5.75   | 3, 1 & 2 | Parietal Lobe | Postcentral Gyrus          |
| 20   | -41  | 57   | -5.09   | 5 / 7 | Parietal Lobe | Superior Parietal Lobule  |
| -30  | -81  | 36   | -4.71   | 19 | Parietal Lobe | Precuneus                  |
| 35   | -41  | 53   | -5.40   | 40 | Parietal Lobe | Inferior Parietal Lobule  |
| -35  | -76  | 31   | -4.41   | 39 | Temporal Lobe | Angular Gyrus              |
| -35  | -72  | 27   | -3.96   | 39 | Temporal Lobe | Middle Temporal Gyrus      |

| X    | Y    | Z    | t-Value | BA | Lobe          | Structure                  |
|------|------|------|---------|----|---------------|----------------------------|
| -5   | 31   | 35   | -4.31   | 6 / 8 | Frontal Lobe  | Medial Frontal Gyrus       |
| 5    | 60   | 25   | -4.51   | 9 / 10 | Frontal Lobe  | Superior Frontal Gyrus     |
| 5    | -57  | 17   | -4.71   | 23 | Limbic Lobe   | Posterior Cingulate        |
| 15   | -63  | 3    | -4.52   | 18 / 19 | Occipital Lobe | Lingual Gyrus             |
| -59  | -37  | 30   | -4.17   | 40 | Parietal Lobe | Inferior Parietal Lobule  |
| 20   | -62  | 31   | -4.99   | 5 / 7 | Parietal Lobe | Superior Parietal Lobule  |
| 45   | -68  | 8    | -4.32   | 37 | Temporal Lobe | Gyrus Fusiformis           |
| 45   | -57  | 17   | -4.03   | 22 | Temporal Lobe | Superior Temporal Gyrus    |

Figure 4. A within-group contrast: brain areas of significantly increased cerebral current density during emotion recognition in schizophrenia patients (SZ) at retest (T1) compared to baseline (T0) at 60 ms after first fixation onset.

| X    | Y    | Z    | t-Value | BA | Lobe          | Structure                  |
|------|------|------|---------|----|---------------|----------------------------|
| -10  | 8    | 64   | 5.02    | 6  | Frontal Lobe  | Superior Frontal Gyrus     |
| 5    | -45  | 67   | 5.10    | 5  | Parietal Lobe | Superior Parietal Lobule  |
| 25   | -55  | 63   | 5.02    | 7  | Parietal Lobe | Superior Parietal Lobule  |
| 30   | -56  | 44   | 5.23    | 40 | Parietal Lobe | Inferior Parietal Lobule  |
medial prefrontal cortex, middle temporal gyrus, inferior occipital cortex; regions implicated in self-relevant information processing) possibly underlying the impaired identification of the emotion. During the TAR patients learn to focus on salient facial features such as eyes and mouth, possibly resulting in an analytic, serial detection strategy relying on local facial features to identify the emotion. It is hypothesized that schizophrenia patients, in terms of a deliberate shift of attention toward the stimulus characteristics, compensate for a faulty automatic, holistic capture of the facial emotion. Evaluating the TAR compared to treatment as usual (TAU), Habel et al. (2010) found a similar pattern of change in cortical activity using fMRI associated with improvement in facial affect recognition. The authors conclude that the observed findings “reflect improved information processing as well as cognitive and perceptual strategies practiced and learned during the training”. These assumptions are also confirmed by the findings of Drusch et al. (2014), who showed an adjusted gaze behavior subsequent to the TAR accompanied by improved affect recognition performance.

Beyond schizophrenia, for autistic and alexithymic patients, both sharing deficits in facial emotion recognition, the superior parietal lobule has been discussed as part of such a compensatory network (Bölte et al. 2006; Jongen et al. 2014). Furthermore, previous interventional studies focusing on the training of affect recognition have shown little effect on, e.g., the fusiform face area but rather produced an increase in the network reflecting attentional and visuospatial processing (Bölte et al. 2006; Habel et al. 2010).

Limitations of the promising results from the presented study are due to the rather small study population and the lack of an active control condition. The TAR has previously shown to be clearly superior in improving social cognition compared to a cognitive training of basic cognitive skills (Wölwer et al. 2005), but only behaviour effects were tested. As a first step of exploring neurophysiological effects we investigated whether the TAR normalizes EEG abnormalities (compared to healthy controls) rather than to investigate whether such effects are specific to TAR treatment. Future research needs to compare the TAR to other treatments in order to track brain changes related specifically to the training.

We conclude that, on the basis of abnormal information processing in schizophrenia, in terms of more local, feature-based strategies opposed by more global, holistic processing strategies in healthy controls, the TAR has the power to (a) support the development of more normal visual exploration strategies and (b) to activate compensatory, attention-related processes, leading to (c) an improvement in the recognition of emotional faces. Thus, by altering parietal brain regions involved in perception, attention and evaluation of emotional stimuli, the TAR seems to enable patients to use specific cognitive and attentional information processing strategies more effectively.

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Statement of Interest

None to declare.

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Supplemental material available online

Supplementary Figure 1