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Neural basis of implicit memory for socio-emotional information in schizophrenia

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Abstract

Individuals with schizophrenia are impaired in processing social signals such as facial expressions of emotion. Perceiving facial expressions is a complex process that depends on a distributed neural network of regions involved in affective, cognitive, and visual processing. We examined repetition priming, a non-conscious form of perceptual learning, to explore the visual-perceptual processes associated with perceiving facial expression in people with schizophrenia. Functional magnetic resonance imaging (fMRI) was also employed to probe the sensitivity of face-responsive regions in the ventral pathway to the repetition of stimuli. Subjects viewed blocks of novel and repeated faces displaying fear expressions and neutral expressions and identified each face as male or female. Gender decisions were faster for repeated encoding relative to initial encoding of faces, indicating significant priming for facial expressions. Priming was normal in schizophrenia patients, but, as expected, recognition memory for the expressions was impaired. Neuroimaging findings showed that priming-related activation for patients was reduced in the left fusiform gyrus, relative to controls, regardless of facial expression. The findings suggest that schizophrenia patients have altered neural sensitivity in regions of the ventral visual processing stream that underlie early perceptual learning of objects and faces.

Keywords

Repetition priming; Face perception; Facial expression; Fusiform gyrus; Ventral visual cortex

1. Introduction

Schizophrenia is associated with deficits in social cognition that diminish the ability to perceive, interpret, and benefit from social experiences (Penn et al., 2008). Perception of facial expression is one such deficit that persists throughout the course of the illness and has a significant impact on social functioning (Mandal et al., 1998; Edwards et al., 2002; Kohler et al., 2010). Research has established that visual-perceptual processes play a significant role

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in the disturbances of emotion perception in this disorder (e.g. Butler et al., 2009; Chen et al., 2009; Norton et al., 2009; Lee et al., 2010; McBain et al., 2010). However, few studies have examined the sensitivity of visual-perceptual mechanisms to repetition and learning. Here we examined repetition priming to study how the repetition of facial expressions modulates performance in a visual-perceptual task of face processing and neural activity in the ventral visual pathway. We specifically were interested in whether schizophrenia patients exhibited normal experience-dependent changes in occipito-temporal regions that are critical for processing faces.

Repetition priming refers to the facilitation in processing a stimulus as a result of a prior encounter with the same stimulus. Behaviorally, it is expressed as improved accuracy or faster reaction time to identify repeated items. Repetition priming is an implicit or non-conscious form of learning that is distinguished from explicit memory measured in tests of recall and recognition (Graf and Schacter, 1985; Tulving and Schacter, 1990; Schacter et al., 2004). The characteristic neural response associated with repetition priming is a reduction in neural activity, referred to as repetition suppression or neural priming (Buckner et al., 1995; Schacter and Buckner, 1998; Henson, 2003; Grill-Spector et al., 2006). Theoretically, a collection of processes drive the repetition effect, such as response preparation, facilitated motor response, stimulus-response learning, and enhanced processing of specific stimulus attributes (Wiggs and Martin, 1998; Schacter et al., 2004; Schnyer et al., 2007).

Studies of repetition priming have been particularly useful in identifying components of object and face processing and the neural pathways that underlie these components (Henson et al. 2003, for review). Repetition of facial stimuli is associated with reduced activity in regions of the occipito-temporal cortex that respond preferentially to faces and facial features relative to non-face objects. For example, there is reduced activity in the right inferior occipital gyrus (occipital face area) and bilateral regions of the fusiform gyrus extending anteriorly into the fusiform face area (FFA) for repeated faces with neutral expressions (Henson et al., 2002; Henson, 2003; Eger et al., 2005; Rotshstein et al., 2005; Pitcher et al., 2011). Repetition of faces displaying emotional expressions (e.g., fear, anger) is also associated with attenuated activity in the right inferior occipital gyrus and bilateral fusiform gyri (Suzuki et al., 2011; Xu and Biederman, 2010), as well as in the right superior temporal sulcus (STS) (Winston et al., 2004). The occipital face area (OFA), fusiform face area (FFA), and superior temporal sulcus (STS) form the core of a distributed neural network in the occipito-temporal cortex for face perception. The OFA is involved in early visual processing of faces and face parts (Gauthier et al., 2000; Rotshstein et al., 2005; Pitcher et al., 2007, 2011), the FFA mediates the processing of internal and external features (Andrews et al., 2010) and facial identity (Kanwisher et al., 1997; Haxby et al., 2000) and the STS responds to eye-gaze direction and facial expressions (Haxby et al., 2000). The findings of repetition effects in these face-sensitive regions in the occipito-temporal cortex suggest that repetition facilitates the processing of stimulus attributes such as facial features or identity.

The question addressed here is whether or not repetition modulates the processing of facial expressions and the neural regions associated with face perception in individuals with schizophrenia. We utilized a perceptual priming paradigm in which the identical visual stimulus was repeated following initial encoding to provide a window into the early visual stages of face processing that might support implicit memory for facial expressions. At the behavioral level, several studies in schizophrenia have shown that repetition priming in a variety of implicit memory tasks is not impaired (Clare et al., 1993, Schwartz et al., 1993; Gras-Vincendon et al., 1994; Doniger et al., 2001; Soler et al., 2011). But these studies have examined priming for words and common objects and not facial expressions. Therefore we do not know whether repetition priming in tasks with facial expressions is preserved in

schizophrenia. At the neural level, data suggest that schizophrenia patients have bilateral structural and functional abnormalities in the fusiform gyrus (Onitsuka et al., 2003, 2006; Quintana et al., 2003; Johnston et al., 2005; although see Yoon et al., 2006), a key neural substrate of face perception. In particular, functional neuroimaging studies showed that schizophrenia patients, relative to controls, had reduced activity in the lateral fusiform gyrus in response to facial expressions, irrespective of whether or not subjects identified the emotional expression (Gur et al., 2002a; Quintana et al., 2003; Johnston et al., 2005). However, the neural activity associated with repetition priming of faces displaying emotion has not been studied in schizophrenia.

Deficits in social perception are widely recognized to play a significant role in the functional outcomes of adults with schizophrenia (e.g., Couture et al., 2006). Although many studies have been conducted to better understand the affective and cognitive processes responsible for the impairment in facial affect perception, no studies have examined early perceptual learning or priming of facial expressions. This approach may help isolate the visual processes and neural systems that are impaired, and those that are preserved, in the processing of facial expressions. Such findings could have implications for remediation strategies designed to target impairments of social cognition in people with schizophrenia.

The aims of this study were first, to test whether repetition facilitated performance in a gender decision task with facial expressions in patients with schizophrenia, and second, to test whether patients showed the expected reduction in activity in the occipito-temporal cortex with repetition. To closely compare the behavioral and neural effects of repetition in this patient group, we used the same paradigm to study behavioral priming and neural priming. This design, comparing initial encoding to repeated encoding of stimuli within a short timespan, was modeled after functional magnetic resonance imaging (fMRI) studies of repetition priming used to study the neural basis of implicit memory (Demb et al., 1995; Gabrieli et al., 1996). As repetition effects are known to diminish rapidly with intervening items (Henson et al., 2003), this paradigm maximizes repetition facilitation by repeating sets of stimuli immediately, albeit in a different order, following initial encoding. Thus, activation visualized with fMRI reflects repetition facilitation at its maximum. The same design was used for the behavioral and fMRI studies in order to gauge whether the magnitude of priming from the smaller sample of the fMRI study was comparable to that obtained from a larger group of subjects in a laboratory setting. In the first experiment, blocks of faces with fear expressions and neutral expressions were presented twice, initially and immediately repeated, and subjects identified the gender of the face on each presentation. Repetition priming is evidenced by faster responses to identify the gender upon repeated relative to initial encoding of faces. We also assessed recognition memory for the same facial expressions to compare performance between implicit (gender decision) and explicit (recognition) memory tasks. In the second study, we used fMRI to test whether repetition priming in schizophrenia patients was associated with reduced neural activity in object-sensitive areas of occipito-temporal cortex.

2. Materials and methods

2.1. Behavioral study

2.1.1. Subjects—Patients (21M, 1F) were recruited from outpatient mental health services at the Washington DC Veterans Affairs Medical Center. All met criteria for a diagnosis of schizophrenia ($N = 15$) or schizoaffective disorder ($N = 7$) using the Structured Clinical Interview for DSM-IV (First et al., 1997) and chart review. Structured interviews were conducted by psychologists and doctoral-level students in psychology. All patients were treated with atypical antipsychotic medications ($N = 21$) with the exception of one patient who received a conventional antipsychotic medication. Control subjects (14M, 4F) were

recruited from advertisements posted at the Medical Center. Exclusion criteria were past or current psychiatric disorder, alcohol and substance use disorder, neurological disorder, or current serious medical illness. The groups did not differ in terms of age (Patient: M = 47.68, S.D. = 9.33; Control: M = 48.9, S.D. = 6.62), and pre-morbid IQ as measured by the revised National Adult Reading Test (NART; Blair and Spreen, 1989) (Patient: M = 104.3, S.D. = 7.53; Control: M = 105.5, S.D. = 9.54, all P values > 0.05). However, controls had completed on average one more year of education relative to the patients (Patient: M = 13.0, S.D. = 1.35; Control = M = 14.2, S.D. = 2.10, P < 0.05).

2.1.2. Materials and procedure—The stimuli consisted of 120 faces: 60 unique faces each shown with a neutral expression and a fear expression. Faces were selected from the NimStim Set of Facial Expressions (Tottenham et al., 2009) and the University of Pennsylvania database of facial expressions (Gur et al., 2002b, 2010). Although the NimStim face stimuli are a relatively new set of facial expressions, our prior work using these materials in participants with schizophrenia has shown that performance in an implicit task varied as a function of the facial expression (Schwartz et al., 2010). The stimuli were divided into two lists of 60 unique faces. Each list comprised 30 neutral expressions and 30 fear expressions. A face with a fear expression on List 1 appeared with a neutral expression on List 2, and vice versa. Half of the subjects received List 1 and the remaining half received List 2.

Stimuli were presented using E-Prime (Version 1.0 Psychology Software Tools Inc.). Subjects viewed a continuous sequence of 10 blocks of trials that alternated between fear and neutral expressions. The blocked design was used to keep the design in the behavioral study parallel to the imaging study. In each block, six unique faces with the same facial expression were presented for initial encoding and then immediately repeated in a different random order (see Fig. 1). The sequence for each trial was a fixation trial, consisting of a crosshair to alert subjects of the imminent stimulus presentation (1000 ms), face stimulus (1000 ms), and blank screen (1000 ms). Subjects were instructed to identify the face as male or female (gender decision) using the mouse key pad. The left key was labeled “M” for male and the right key was labeled “F” for female. Accuracy and response latency to novel and repeated faces were recorded.

A test of recognition memory was administered immediately after the gender decision task to compare implicit versus explicit memory for facial expressions. Subjects viewed 60 pairs of faces of the same person: one face displayed a neutral expression and the other face displayed a fear expression (Fig. 1). Subjects were instructed to choose the face with the expression they had previously seen. Each pair was presented for 5 s. Responses were said aloud and the experimenter recorded accuracy.

2.2. Imaging study

2.2.1. Subjects—Another group of eight patients (seven male, one female) and eight controls (seven male, one female) participated in the imaging study and met the same inclusion and exclusion criteria as those described above. Participants in the patient and control groups did not differ in terms of age (Patient: M = 52.13, S.D. = 6.0; Control: M = 50.5, S.D. = 6.82), education (Patient: M = 13.75, S.D. = 2.05; Control: M = 13.38; S.D. = 0.92), or pre-morbid IQ (Patient: M = 102.8, S.D. = 12.30; Control: M = 100.98, S.D. = 13.09), all P values > 0.05.

2.2.2. Task procedure—The gender decision task described above was used during the scanning session. The task was split into two runs of five blocks. Each block was followed by a fixation trial of 9 s. The timing and structure (initial and repeated encoding of sets of

stimuli comprising one block and emotional expression alternating across blocks) of the trial sequence remained the same as described above. Subjects pressed a right hand-held button when the face was male and a left hand-held button when the face was female.

2.2.3. fMRI acquisition—Images were acquired on a 3T Siemens magnet (Siemens Magnetom Trio, Erlangen, Germany). Head movement was minimized with foam padding placed in the head coil. Stimuli were generated in E-prime (Version 2.0 Psychology Software Tools Inc) and back-projected onto a screen (209 × 279 cm^2) that was viewed via a coil-mounted mirror. Functional images (77/run) were acquired using a T2-sensitive gradient EPI sequence. The first two scans in each run were acquired for signal stabilization, before the task began, and thus were discarded from analysis, resulting in 75 images in each run. Fifty axial slices (3.2 × 3.2 × 3.2 mm^3) were acquired covering the whole brain using the following parameters: TR = 3000 ms, TE = 30 ms, 205 × 205 mm^2 FOV, and 90° flip angle. Immediately following functional imaging, a high resolution sagittal T_1-weighted structural scan was obtained for the purpose of anatomical localization. The scan was acquired using a 3D MPRAGE sequence with TR = 1600 ms, TE = 4.4 ms, 256 × 256 mm^2 FOV, 160-mm slab with 1-mm-thick slices, 256 × 256 × 160 matrix (effective resolution of 1.0 mm^3), 1 excitation and a 15° flip angle.

2.2.4. fMRI data analysis—Data were analyzed using SPM5 (http://www.fil.ion.ucl.ac.uk/spm) implemented in MATLAB (Version 7.0, Mathworks, Inc., Sherborn, MA). Images for individual subjects were realigned to the first image of each run. No subject displayed more than 3 mm of motion in the *x*, *y*, and *z* directions. Functional images were normalized into MNI anatomical space and aligned to the high-resolution T1structural image for the individual subject. Normalized images were smoothed with an isotropic 8 mm full width half-maximum Gaussian kernel and temporally filtered (high-pass filter: SPM default calculated based upon trial frequency). fMRI responses were modeled by canonical hemodynamic response function with a boxcar function lasting for the duration of each set of stimuli with the block. For each subject, a linear contrast identified activation during repetition priming (Initial > Repeated encoding) separately for faces with neutral and fearful expressions

For second-level analysis, we first examined whether significant priming-related activation was observed in occipito-temporal cortex, irrespective of facial expression, in each group using one-sample *t*-tests. Next, we conducted a Group (Patients, Controls) × Emotion (Neutral, Fear) analysis of variance (ANOVA) on the repetition priming contrast to identify: (1) regions showing a main effect of Group assessing differences in priming-related activation between patients and controls irrespective of facial expression; and (2) regions showing a Group × Emotion interaction assessing group differences in priming-related activation by facial expression. Each of these analyses was restricted to our apriori area of interest, occipito-temporal cortex, by using an anatomical mask of regions created from the AAL atlas (Tzourio-Mazoyer et al., 2002) including inferior temporal gyrus, fusiform gyrus, lingual gyrus, and visual cortex. For each analysis, maps were thresholded at $P < 0.005$, $k = 35$ which is an overall significance level of $P < 0.05$ corrected for multiple comparisons based on Monte Carlo simulation of random noise distribution [using 3dClustSim module of AFNI (Forman et al., 1995)].

3. Results

3.1. Behavioral study

Performance for the gender decision and recognition memory tasks is shown in Fig. 2. In the gender decision task, a trial was scored as correct if the subject correctly identified the face as male or female. The total number of errors and the mean response time (RT) to make the

decision were calculated for each expression condition at each presentation for each participant. Errors were excluded from the RT analysis. A separate 2 (Group) × 2 (Expression) × 2 (Presentation) analysis of variance (ANOVA) was performed for RT and accuracy, with Group as a between-subject factor and Expression and Presentation as within-subject factors. Because novel items presented for initial encoding occurred in multiple blocks, we were able to perform trend analyses to assess practice effects by determining whether gender decisions improved across blocks. For the recognition task, the total number of errors in each expression condition was calculated and analyzed in a 2 (Group) × 2 (Expression) ANOVA.

Repetition priming was observed as evidenced by shorter RTs for faces upon repeated relative to initial encoding, $F(1, 38) = 36.81$, $P < 0.0001$. Priming did not differ between the groups, $F < 1$, and did not vary as a function of Expression, $F < 1$. There were no significant two-way or three-way interactions, all $Fs < 1$. Priming was not confounded by practice effects, as novel items were not identified faster over blocks (linear trend for Neutral faces: $F(1,38) = 0.12$, $P > 0.05$; linear trend for Fear faces: $F(1, 38) = 1.61$, $P > 0.05$). Analysis of the error data indicated more errors in the Fear condition ($M = 1.31$, S.D. = 1.47) than in the Neutral condition ($M = 0.89$, S.D. = 1.14), $F(1, 38) = 5.03$, $P < 0.05$. However, there was no difference in the error rate between the groups, $F(1, 38) = 2.00$, $P > 0.05$, or between initial and repeated encoding of faces, $F < 1$.

As expected, error rate in recognition memory was higher in the patient group, $F(1, 38) = 12.70$, $P < 0.001$, but errors did not vary as a function of Expression, $F(1, 38) = 1.56$, $P > 0.05$, and there was no interaction of Group × Expression, $F < 1$. To rule out the possibility that the groups differed for recognition performance due to differences in education level, we performed an analysis of covariance on recognition errors. The results did not change: errors remained higher in the patient group, $F(1, 37) = 8.96$, $P < 0.01$, and there was no effect of Expression, $P > 0.05$ or an interaction of Group × Expression, $P > 0.05$.

The findings above demonstrate repetition priming as gender decisions were faster for repeated than initial presentation of faces. We were also interested in assessing whether repeated faces were identified faster than novel images of different faces. This comparison is more similar to standard paradigms of repetition priming in which studied items are compared to items not previously encountered. The block design allowed us to compare performance for repeated faces from one block (e.g., repeated faces in block 1) with performance for faces in the next block that were subsequently presented (e.g., novel faces in block 2). Repeated faces were identified faster than novel images of different faces indicating significant priming in both the Neutral, $t(39) = 3.89$, $P < 0.0001$ and Fear conditions, $t(39) = 3.28$, $P < 0.01$. To compare these two measures of priming, we conducted a 2 × 2 × 2 ANOVA, with Expression and Type of Priming as within-subjects factors, and Group as a between-subjects factor. The results indicated that priming measured in the gender decision task did not vary as a function of Group, Expression, or Type of Priming, all P values > 0.05

To sum up, repetition priming was observed for faces with fear expressions and neutral expressions irrespective of whether repeated items were compared with novel images of the same face (i.e., initial encoding) or a different face. Priming of gender decisions for facial expressions was not impaired in schizophrenia. In contrast, explicit recognition memory for the facial expressions was impaired. However, in the absence of a significant Group × Expression interaction, we are unable to ascertain whether the deficit in recognition memory for schizophrenia patients is due to deficits in identifying and remembering emotional stimuli or simply due to general problems in explicit memory.

3.2. Imaging study

3.2.1. Behavioral results—The results for the gender decision task performed during the scanning session yielded similar results to those reported above. There was a significant reduction in mean RT for faces upon repeated than initial encoding indicating repetition priming (initial: $M = 649.40$ ms, S.D. = 98.71; repeated: $M = 626.37$; S.D. = 87 ms), $F(1, 16) = 12.05$, $P < 0.01$. There was no statistical difference in overall performance between the groups, (Patient: $M = 651.46$ ms, S.D. = 121.8; Control: $M = 624.25$ ms, S.D. = 52.7), $F < 1$, no difference between Expression conditions (Fear: $M = 636.72$ ms, S.D. = 95.69; Neutral: $M = 639.1$ ms, S.D. = 89.5), $F < 1$, and no interaction of Group × Expression, $F < 1$. Furthermore, there were no significant main effects or interactions for accuracy, P values > 0.05.

3.2.2. Imaging results—All reported coordinates are converted from MNI to Talairach space using the algorithm mni2tal (http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach).

One-sample t-tests indicated that priming-related activation was evident in occipito-temporal cortex in each group (see Table 1, Fig. 3A). For participants with schizophrenia, priming was associated with a reduction in the posterior fusiform gyrus in the right hemisphere. For control participants, significant reductions were found bilaterally in the right fusiform gyrus, right inferior occipital gyrus, and left fusiform gyrus.

Results of the Group × Expression ANOVA revealed a significant main effect of Group in one large cluster in left fusiform gyrus ($x = -36$, $y = -44$, $z = -14$, 123 voxels, $Z = 3.07$) such that priming-related activation was greater in control subjects relative to patients, irrespective of facial expression (see Fig. 3B). No regions showed a Group × Expression interaction indicating that priming-related activation in occipito-temporal cortex did not vary by facial expression for either control or patient group.

It appears that the type of expression (fear vs. neutral) affected neither behavioral priming nor priming-related brain activity (cf. Suzuki et al., 2011). One possibility is that naming the gender of the face, rather than identifying the facial expression, reduced encoding of the emotional aspects of the faces. The priming paradigm was used to assess occipito-temporal regions associated with face perception (e.g., fusiform gyrus) rather than regions associated with emotional processing (e.g., amygdala). The finding that priming-related activity was observed in the ventral visual cortex suggests that visual perceptual properties of faces rather than emotional aspects were encoded. Thus priming-related differences between the groups in lateral fusiform gyrus reflect differences in neural activity that are not specific to the emotional expression but can nonetheless affect the processing of facial expressions.

4. Discussion

The aim of the study was to examine behavioral priming and priming-related neural activity for faces with emotional expressions in patients with schizophrenia. There were three main findings: (1) repetition priming was unimpaired in schizophrenia patients; (2) there was a reduction in neural activity for repeated facial expressions in occipito-temporal regions, and (3) group differences in priming-related activation were observed in the left lateral fusiform gyrus.

The behavioral findings showed repetition priming in the gender decision task for facial expressions, as decisions were faster for repeated compared to initial presentations of faces. These findings replicate prior reports of repetition priming for (unfamiliar) faces (Goshen-Gottstein and Ganel, 2000; Martin et al., 2010). In contrast, recognition memory for facial

expressions was impaired in participants with schizophrenia. Consistent with previous reports, we observed that implicit memory is preserved in the context of impaired explicit memory in individuals with schizophrenia (Clare et al., 1993; Schwartz et al., 1993; Marie et al., 2001; Soler et al., 2011). Thus, the present results extend the findings of intact implicit memory for words and common objects in schizophrenia to include priming for faces with emotional expressions.

The neuroimaging data revealed the predictable reduction in neural activity associated with stimulus repetition (e.g. Schacter and Buckner, 1998; Henson, 2003; Grill-Spector et al., 2006). Specifically, there was a reduction in the neural response for repeated faces in the right inferior occipital cortex and in bilateral posterior regions of the fusiform gyrus (see also Eger et al., 2005; Pitcher et al., 2007). There was overlap between the two groups in priming-related neural activity in right ventral cortex. However, group differences were observed in the spatial extent and laterality of neural activity. Participants with schizophrenia did not show priming-related reduction in left fusiform gyrus. These findings suggest a disturbance in experience-related neural modulation in schizophrenia (see also, Jeong and Kubicki, 2010).

Research suggests that there is a hierarchical organization of priming-related neural activity that shows lateralized specialization (e.g., Koutstaal et al., 2001; Eger et al., 2005; see also Marsolek et al., 1992; Marsolek, 1995; Vaidya et al., 1998). Priming-related activation that is sensitive to changes in the perceptual features of an item tends to be right lateralized, whereas activity that is less sensitive to such changes is left lateralized. Furthermore, as one proceeds from posterior to anterior regions in the ventral visual processing stream, priming-related activation is less dependent on the repetition of the identical image of a face, suggesting that anterior regions code for more abstract information (Eger et al., 2005). The finding in the patient group that priming-related activity was observed in right occipito-temporal regions associated with early visual face and object processing suggests that repetition modified a more feature-dependent representation of faces. By comparison, bilateral activation extending into more anterior regions of the fusiform gyrus in the control group signals broader activation of abstract, possibly categorical (male/female) representations. As abstract representations support explicit memory, it is possible that deficits in explicit memory in schizophrenia were associated to the lack of sensitivity in anterior left fusiform gyrus to repetition.

One limitation of the study is that we did not include stimuli other than faces to localize regions that respond specifically to faces. This limits our ability to conclude with greater certainty that repetition of stimuli reduced regions that are selective for faces relative to other objects. Another limitation is that the larger number of males than females in the sample could have potentially biased performance in the priming task, especially since the task required subjects to identify the gender of each face. In addition, the small sample size in the neuroimaging study limited statistical power to identify priming-related neural activation in other cortical regions (Wig et al., 2009). Future studies with a larger sample of patients will also allow us to examine the relation between repetition facilitation and clinical symptoms of schizophrenia.

Repetition priming served as a valuable tool to explore visual-perceptual processes associated with face processing in people with schizophrenia. The findings suggest that the repetition paradigm can help isolate mechanisms of implicit memory in the ventral visual cortex. In this study, initial encoding was compared to repeated encoding of the identical visual stimulus to assess a form of perceptual implicit memory. Thus normal priming effects in patients with schizophrenia suggest that enhanced gender decisions for facial expressions can be made on the basis of perceptual features of the stimulus (e.g., face parts, hairstyle). It

is also possible to vary stimulus attributes (e.g., unfamiliar vs. familiar faces) or the type of response (e.g., stimulus-response mapping) to test whether abstract or conceptual forms of implicit memory are intact in people with schizophrenia. These studies are important to identifying areas of preserved versus impaired processing of facial expressions in this disorder.

Although we did not observe a deficit in priming of gender decisions for facial expressions for the patients, the data suggest abnormal repetition-related activity, particularly in the left fusiform gyrus. It is likely that altered sensitivity to stimulus repetition disrupts memory and affective processes that depend on specialized information processing mediated by the ventral processing stream. Future studies will need to determine the scope and impact of this deficit and ways to enhance the neural response to socio-emotional stimuli in schizophrenia.

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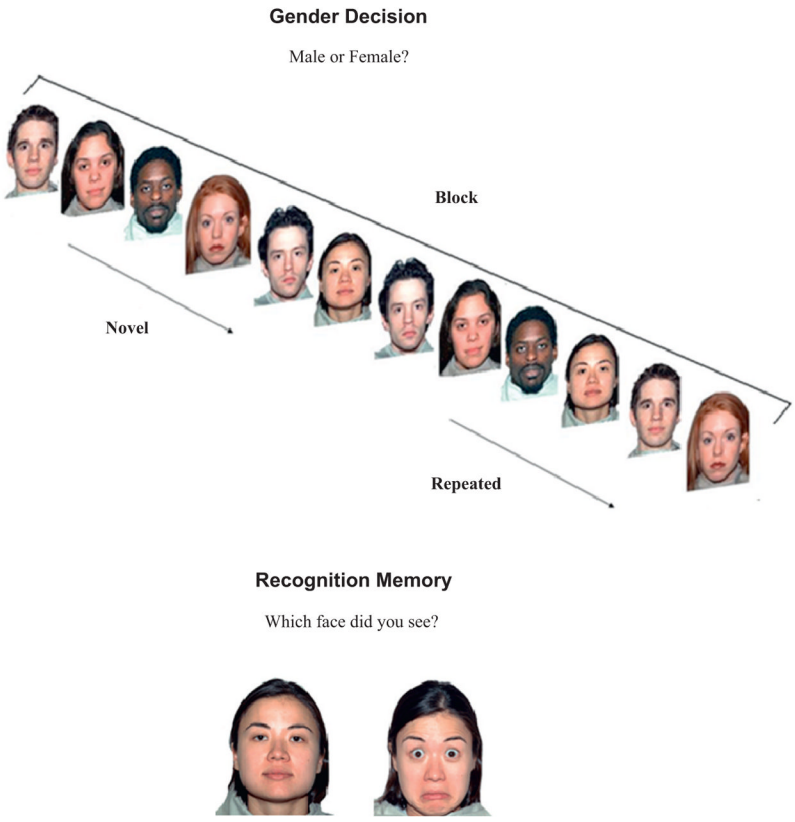

Fig. 1.

Examples of a block of neutral faces in the gender decision task and a pair of faces in the recognition memory task. In the gender decision task, subjects responded male or female for each face. After initial presentation of the six faces in the block (novel faces), the set of six faces was repeated in a different random order (repeated faces). In the recognition memory task, subjects identified which one of the two faces they saw in the previous sequence of trials. Subjects were told that they had seen the model in the photograph with only one of the facial expressions.

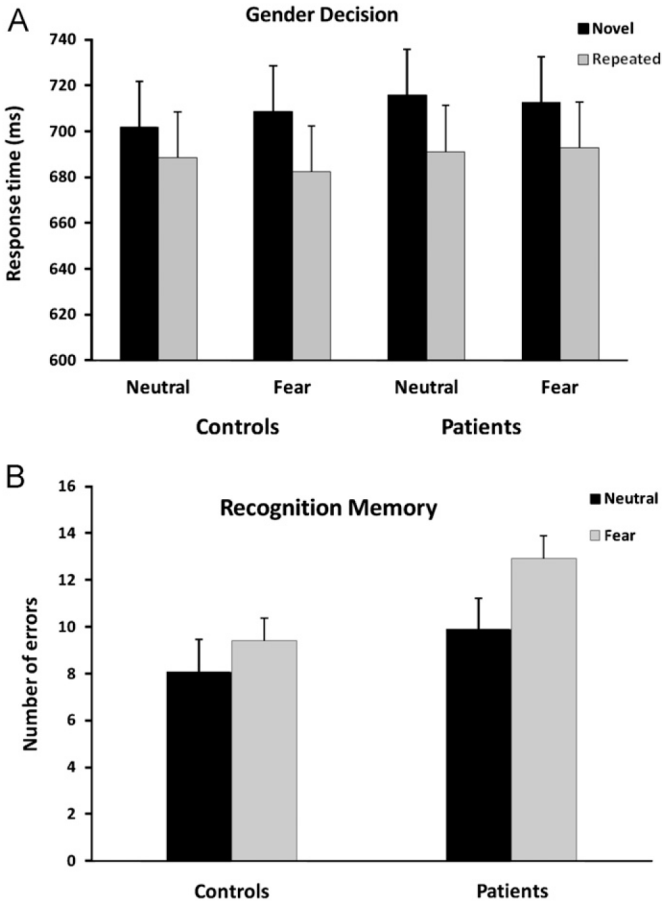

Fig. 2.

(A) Mean RT to identify the face as male or female as a function of Presentation condition (novel, repeated), Expression condition (neutral, fear), and Group (control, patient). (B) Mean number of errors in the recognition memory test as a function of Expression condition and Group. Error bars for each task are presented as the standard error of the mean.

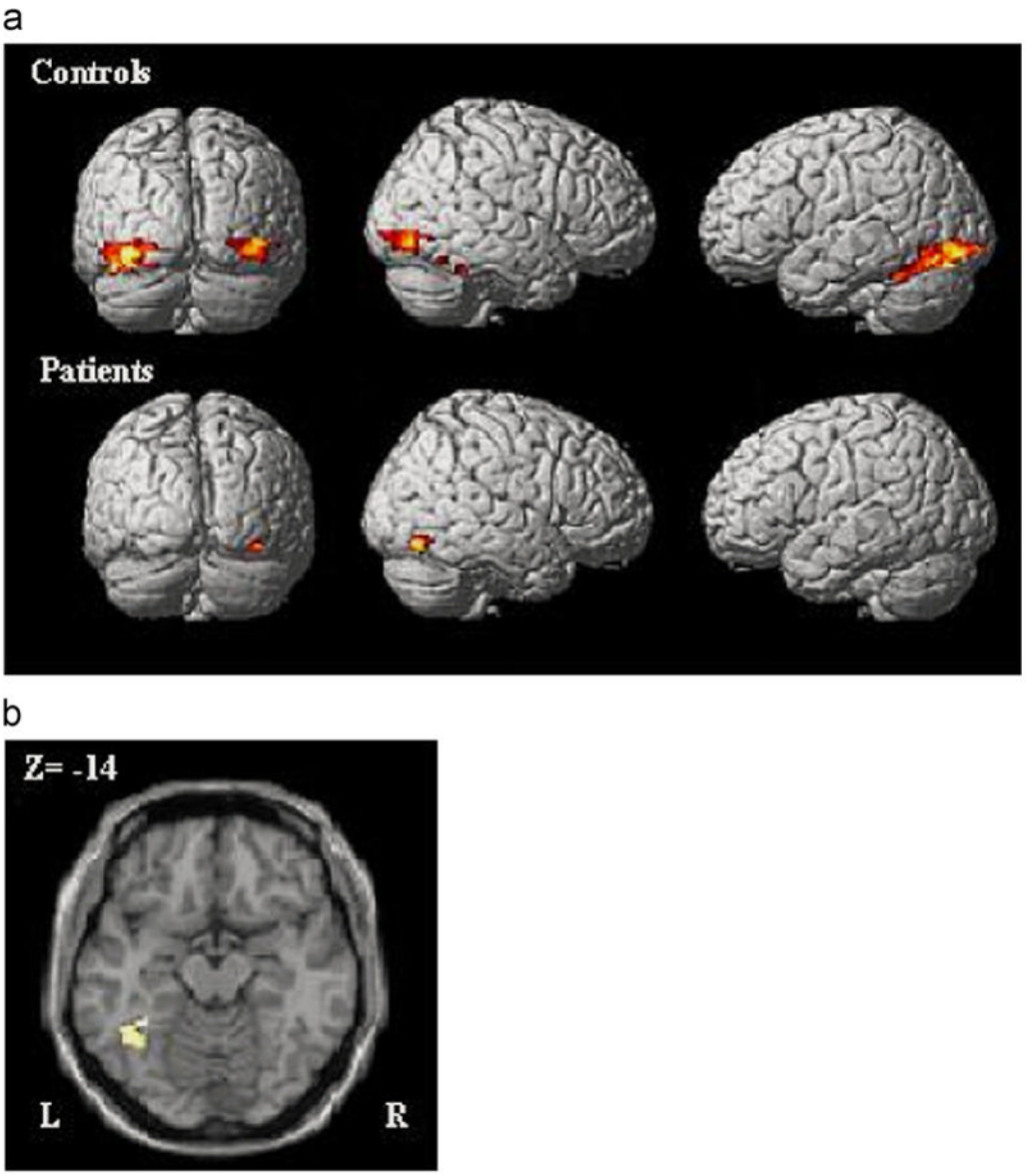

Fig. 3.

(A) Regions showing significant priming-related activation (initial encoding > repeated encoding) irrespective of Expression in a one-sample t-test for controls (top row) and patients (bottom row), $p < 0.05$ corrected. Activation in the fusiform gyrus was right lateralized for patients and bilateral for controls. (B) Region in the left fusiform gyrus that showed a significant difference in priming-related activation between patients and controls (main effect of Group), $p < 0.05$ corrected.

Table 1

Summary of regions showing a significant reduction in activity with the repetition of faces for patients and controls.

Structure	Brodmann area	Cluster size (voxel)	Z-value	Peak coordinates		
				x	*y*	*z*
Controls						
Left fusiform gyrus	18	926	4.03	−38	−88	−10
Right inferior occipital gyrus	19	279	3.65	42	−82	−10
Right fusiform gyrus	37	110	4.24	44	−44	−28
Patients						
Right fusiform gyrus	19	102	3.72	34	−72	−14