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Exploring facial emotion perception in schizophrenia using transcranial magnetic stimulation and spatial filtering

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ABSTRACT

Schizophrenia patients have difficulty extracting emotional information from facial expressions. Perception of facial emotion can be examined by systematically altering the spatial frequency of stimuli and suppressing visual processing with temporal precision using transcranial magnetic stimulation (TMS). In the present study, we compared 25 schizophrenia patients and 27 healthy controls using a facial emotion identification task. Spatial processing was examined by presenting facial photographs that contained either high (HSF), low (LSF), or broadband/unfiltered (BSF) spatial frequencies. Temporal processing was manipulated using a single-pulse TMS delivered to the visual cortex either before (forward masking) or after (backward masking) photograph presentation. Consistent with previous studies, schizophrenia patients performed significantly below controls across all three spatial frequencies. A spatial frequency by forward/backward masking interaction effect demonstrated reduced performance in the forward masking component in the BSF condition and a reversed performance pattern in the HSF condition, with no significant differences between forward and backward masking in the LSF condition. However, the group by spatial frequency interaction was not significant. These findings indicate that manipulating visual suppression of emotional information at the level of the primary visual cortex results in comparable effects on both groups. This suggests that patients' deficits in facial emotion identification are not explained by low-level processes in the retino-geniculo-striate projection, but may rather depend on deficits of affect perception occurring at later integrative processing stages.

1. Introduction

Impairment in social functioning has been extensively documented in schizophrenia and recognized as one of the hallmarks of the disorder (American Psychiatric Association, 1994). Over the last decade, considerable research has focused on social cognition, which is the ability to construct mental representations about others, oneself, and relations between others and oneself. Social cognition is thought to facilitate skillful social interactions and is, therefore, considered a potential determinant of social dysfunction among people with schizophrenia. An important aspect of social cognition is the ability to perceive emotions. Numerous studies have shown that individuals with schizophrenia are less accurate than healthy controls in their ability to perceive emotions (Addington and Addington, 1998; Gold et al., 2012; Penn et al., 2002; Sergi et al., 2006). Although emotion perception deficits in schizophrenia have been reported across various modalities of expression, most research has focused on affect perception, due to its essential role in adaptive functioning (Butler et al., 2008b; Williams et al., 2009).

An experimental paradigm that has been employed to examine the underlying mechanism of affect perception deficits in schizophrenia, involves a systematic alteration of the spatial frequency of facial stimuli (Pourtois et al., 2005). The effectiveness of this

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manipulation is based on the distinct properties of two neuroanatomically defined visual pathways, magnocellular and parvocellular (also called M and P), which convey visual information from the retina to the relevant brain areas (Breitmeyer, 1984; Ogmen, 1993). The M pathway is composed of large, rapidly conducting neurons that are specialized for processing quickly changing stimuli and are strongly activated by stimuli that are relatively large (low spatial frequency; LSF), providing initial detection and segregation of objects from the background (Bar et al., 2006). The P pathway, on the other hand, is composed of smaller, more slowly conducting neurons that are specialized for processing slowly changing, clearly defined patterns and are activated by relatively small (high spatial frequency; HSF) stimuli, coding the details of objects (Butler et al., 2001; Merigan and Maunsell, 1993). Thus, when extracting emotional information from faces, the M-pathway quickly processes coarse emotional LSF information through relatively direct projections to subcortical regions, such as the amygdala and ventral striatum, whereas the P-pathway processes the slower, fine-grained HSF visual information about faces in general, subserved by the fusiform cortex (Vuilleumier et al., 2003).

Spatial frequency of stimuli can be manipulated using various filtering techniques. Typically, normal, unfiltered faces that have the entire broadband spatial frequency (BSF) are compared with filtered HSF faces, which contain mainly HSF information, and filtered LSF faces, which contain mainly LSF information. Studies that examined affect perception deficits in schizophrenia by manipulating the spatial frequency of simple visual and facial stimuli suggested M pathway-driven deficit (Butler et al., 2001; Clark et al., 2013; Lee et al., 2011). For example, several studies found that when spatial frequency of stimuli was manipulated, schizophrenia patients performed differentially worse in the LSF condition (Butler et al., 2001, 2008b). Other studies reported that for schizophrenia patients perceived emotions in HSF faces differ from those in LSF faces (McBain et al., 2010). Patients may even ignore information entirely when the faces obtain only very low spatial frequencies (Clark et al., 2013).

Another related aspect of affect perception, which did not receive much attention, is the temporal processing of facial emotion. An experimental manipulation of temporal processing of emotion perception can be achieved through visual suppression with a single-pulse transcranial magnetic stimulation (TMS; Amassian et al., 1989; Corthout et al., 2002; Pascual-Leone and Walsh, 2001). In TMS, a bank of capacitors is rapidly discharged into an electric coil to produce a magnetic field pulse. When the coil is placed near the head, the magnetic field induces an electric field in the underlying region of the brain, which, when sufficiently intense, depolarizes cortical neurons, generating action potentials (Barker and Jalinous, 1985). Such stimulation is a safe way to temporarily alter cortical function and can be employed to effectively suppress visual perception with temporal precision (Amassian et al., 1989; Antal et al., 2002).

In a recent study, we examined the processes underlying emotion perception in healthy individuals by employing both spatial frequency alteration through spatial filtering and visual suppression through TMS (Rassovsky et al., 2013). The integration of these procedures into a single experimental paradigm enabled us to systematically investigate the interactive effects of spatial and temporal properties on affect perception. Specifically, we employed an emotion identification task with standard spatial frequency filtering techniques (Butler et al., 2001; Pourtois et al., 2005; Vuilleumier et al., 2003), while also systematically manipulating the temporal processing of visual stimuli by administering a single-pulse TMS to the visual cortex.

Results indicated that LSF information might play a greater role than HSF information in emotional processing. However, the quickest perceptual processing of facial emotion information was afforded only when the broadband of spatial frequencies was intact. These findings were interpreted within the basic vision framework of the dual-channel model of retino-cortical dynamics (Breitmeyer, 1984; Ogmen, 1993; Ogmen et al., 2003). A current formulation of this model suggests that conscious visual processing requires not only a fast feedforward sweep of information from the retina to and through the visual cortex, but also an iterative feedforward-feedback reentrant exchanges of neural signals among the different brain levels (Di Lollo et al., 2000; Pascual-Leone and Walsh, 2001). Studies examining visual suppression through single-pulse TMS suggest that forward masking reflects the suppression of the early responses in V1 activating the cortical feedforward sweep, whereas backward masking reflects mostly the later V1 responses due to reentrant activation from post-V1 levels (Breitmeyer et al., 2004; Corthout et al., 1999; Lamme and Roelfsema, 2000). It appears then that in the aforementioned study (Rassovsky et al., 2013), BSF face stimuli were suppressed more with forward than backward TMS masking, suggesting greater reliance on the feedforward process, whereas the filtered HSF faces were most strongly suppressed in the backward masking components, demonstrating the increasing involvement of reentrant activation from post-V1 levels.

In the present study, we examined whether the speed of processing advantage of unfiltered faces seen in healthy individuals would also be found in schizophrenia patients. Additionally, if, as suggested previously, schizophrenia patients have a differential impairment in the M pathway, we would expect significant group by spatial frequency interactions. Finally, we sought to examine whether patients would also demonstrate enhanced susceptibility to TMS masking given their well-documented evidence of visual masking deficits (Braff et al., 1991; Rassovsky et al., 2004; Rund, 1993).

2. Method

2.1. Participants

Participants included schizophrenia patients and healthy controls. Patients were recruited through outpatient clinics at the UCLA and the VA Greater Los Angeles Healthcare System and through presentations in the community. All patients were administered the Structured Clinical Interview for DSM-IV (SCID-P) (First et al., 1997) and met the DSM-IV diagnostic criteria for Schizophrenia (American Psychiatric Association, 1994). All interviewers were trained to administer the SCID by the Diagnostic Core of the Mental Illness Research, Education, and Clinical Center (MIRECC) Treatment Unit, and were required to obtain a Kappa of 0.75 for key psychotic and mood items before proceeding to interview participants independently. Patients were excluded if they had an identifiable neurological condition, IQ < 70 based on medical records, or met criteria for substance dependence in the last six months.

The healthy control group was recruited through online advertisements. They were administered the SCID, as well as selected sections of the Structured Clinical Interview for DSM-IV Axis II Disorders. Exclusion criteria were the same for controls as for patients, with the additional exclusion of histories of any psychotic disorders (including family history in first-degree relatives), any diagnosis in the schizophrenia spectrum, recurrent major depression, bipolar disorder, history of substance dependence, or substance abuse in the past month. The data for the control group were published previously (Rassovsky et al., 2013) and used in the present study as comparison for the new and unpublished data of the schizophrenia patients.