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Aberrant Patterns of Visual Facial Information Usage in Schizophrenia

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Deficits in facial emotion perception have been linked to poorer functional outcome in schizophrenia. However, the relationship between abnormal emotion perception and functional outcome remains poorly understood. To better understand the nature of facial emotion perception deficits in schizophrenia, we used the Bubbles Facial Emotion Perception Task to identify differences in usage of visual facial information in schizophrenia patients ($n = 20$) and controls ($n = 20$), when differentiating between angry and neutral facial expressions. As hypothesized, schizophrenia patients required more facial information than controls to accurately differentiate between angry and neutral facial expressions, and they relied on different facial features and spatial frequencies to differentiate these facial expressions. Specifically, schizophrenia patients underutilized the eye regions, overutilized the nose and mouth regions, and virtually ignored information presented at the lowest levels of spatial frequency. In addition, a post hoc one-tailed t test revealed a positive relationship of moderate strength between the degree of divergence from "normal" visual facial information usage in the eye region and lower overall social functioning. These findings provide direct support for aberrant patterns of visual facial information usage in schizophrenia in differentiating between socially salient emotional states.

Keywords: schizophrenia, social cognition, emotion perception

In addition to the symptoms required for a diagnosis, schizophrenia is associated with reliable deficits in social cognition (Green et al., 2008). Recent investigations have supported the notion that social–cognitive factors (such as the ability to perceive emotion, ascertain social cues from behavior, and understand the mental states of others) are better predictors of overall functional outcome in schizophrenia patients than neurocognitive factors (such as overall intellectual ability, psychomotor speed, and memory) or psychiatric symptoms (Pijnenborg et al., 2009). Furthermore, in a recent comprehensive meta-analytic review, Fett and colleagues (2011) found that 16% of the variance in functional outcome could be accounted for by social–cognitive factors, compared with only 6% for neurocognitive factors, highlighting the importance of investigating social cognition in schizophrenia.

One particularly important subdomain of social cognition is *emotion perception*, or the ability to infer emotional information from faces and vocal inflections. The ability to infer emotion from facial expressions in particular has been strongly linked to poorer functional outcome in schizophrenia, including more difficulty completing daily activities, diminished social problem-solving abilities, and poor psychosocial skill acquisition. Recent meta-analytic reviews point to large and robust deficits in facial emotion perception in schizophrenia, with Cohen's d effect sizes in the -0.85 to -1.05 range (Chan, Li, Cheung, & Gong, 2010; Kohler, Walker, Martin, Healy, & Moberg, 2010). Combined, these studies summarize a considerable body of literature that strongly suggests that deficient facial emotion perception in schizophrenia is a highly robust finding, regardless of task type, suggesting an important role for facial emotion perception as a potential determinant of poor functional outcome. This model is consistent with an earlier model of social cognition and functional outcome proposed by Couture, Penn, and Roberts (2006), in which deficits in facial emotion perception in social situations (e.g., mistaking a stressed, upset, or even neutral face for an angry one) in combination with other social–cognitive deficits lead to misattributions regarding the thoughts and intentions of others. Through repeated iterations of poor social interaction, these misattributions are thought to ultimately precipitate increased social and occupational discomfort, decreased life satisfaction, and the perpetuation of a vicious cycle through continued anticipation of negative interactions with others.

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In addition to these well-documented deficits in facial emotion perception, schizophrenia patients also demonstrate visual impairments in the early stages of visual processing, including deficits in processing spatial frequency (see Butler & Javitt, 2005, for a review) that may mediate or otherwise account for poor performance in facial emotion perception tasks (Butler et al., 2009). *Spatial frequency* refers to the number of pairs or cycles of light and dark in a single degree of visual angle and is among the earliest features processed by the visual system. Lower spatial frequencies are generally thought to be processed more quickly than higher spatial frequencies when an image is viewed. Lower spatial frequencies serve as a kind of primary sketch of the image, information from which higher spatial frequencies can then build on shortly thereafter (Morrison & Synchs, 2001).

Several studies employing nonfacial stimuli have reported that schizophrenia patients demonstrate specific deficits in contrast sensitivity (i.e., the lowest contrast at which one is able to detect the difference between light and dark) at low levels of spatial frequency, despite relatively intact contrast sensitivity at higher levels of spatial frequency (Butler et al., 2009; but see Kéri, Antal, Szekeres, Benedek, & Janka, 2002; Slaghuis, 1998). Similarly, results from two studies employing facial stimuli found significant correlations between specific deficits in contrast sensitivity and performance on a facial affect recognition task, supporting the notion that deficient emotion recognition does not rely solely on affective processing, but is also linked to basic, early stage visual processing deficits (Butler et al., 2009; Norton, McBain, Holt, Ongur, & Chen, 2009). However, these studies do not give any indication of how these basic visual deficits impact more natural image recognition or classification, or which bands of spatial frequency are integrated in schizophrenia patients to form a coherent percept. Lee, Gosselin, Wynn, and Green (2011) investigated this issue by using the Bubbles Facial Emotion Perception Task (see below) to conduct a detailed analysis of facial information use in schizophrenia patients in relation to controls while differentiating between comparatively easily distinguishable facial expressions: happy and fearful. For these emotions, they found that patients not only required more visual information than controls to make correct discriminations, but they also used atypical strategies for collecting visual information from faces. For example, for fearful stimuli, patients were found to utilize information primarily from the mouth region, whereas controls utilized visual information from both the mouth and eye regions. These recent results suggest that people with schizophrenia do in fact utilize facial information differently from controls. However, further questions remain regarding whether or not these results hold for less easily distinguishable emotional states and the overall relationship between emotion perception deficits and overall social functioning.

To address these questions, we employed the Bubbles Facial Emotion Perception Task and used angry and neutral facial stimuli. We also measured overall social functioning, allowing for a novel exploration of the relationship between emotion perception and functional outcome. We had three primary hypotheses: (1) Patients will require more facial information, and more time, to correctly discriminate between different affective states relative to controls; (2) patients with schizophrenia will use different locations of the face in making affective discriminations (i.e., mouth/nose region vs. eye region) relative to controls; and (3) patients' divergence of utilization of facial location and spatial frequency from controls for angry and neutral expressions will be significantly associated with lower levels of functional outcome.

Method

Participants

Twenty participants with schizophrenia ($n = 16$) or schizoaffective disorder ($n = 4$) (hereafter referred to as *schizophrenia patients*) were recruited from outpatient psychosis clinics and the community. All schizophrenia patients were taking antipsychotic medication at time of testing. Twenty healthy control participants were recruited from the community via postings. Exclusion criteria for all participants included (a) age under 18 years or over 60 years, (b) mental retardation as defined by an estimated IQ less than 70, (c) history of a neurological illness or loss of consciousness longer than 20 min, (d) uncorrected ophthalmologic illness, (e) current substance abuse or dependence, (f) history of electroconvulsive therapy, and (g) less than normal or corrected-to-normal visual acuity. Controls were also excluded if they had personal or family history of psychosis or bipolar disorder.

Procedure

All participants were assessed with the following measures: (a) the Structured Clinical Interview for the *DSM–IV–TR* (First, Gibbon, Spitzer, & Williams, 2002) to assess for *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision; *DSM–IV–TR*; American Psychiatric Association, 2000) diagnoses, (b) the Positive and Negative Syndrome Scale (PANSS; Kay, Fizbein, & Opler, 1987) as a measure of current psychosis-related symptomatology, and (c) the Social Functioning Scale (SFS; Birchwood, Smith, Cochrane, Wetton, & Copestake, 1990) as a measure of current functioning in the community. On a second day, participants completed the Bubbles Facial Emotion Perception Task (hereafter referred to as the *Bubbles task*), as well as the Vocabulary and Matrix Reasoning subtests from the Wechsler Abbreviated Scale of Intelligence to estimate IQ (Psychological Corporation, 1999), and a test of visual acuity.

The Bubbles task was adapted from that of Gosselin and Schyns (2001, Experiment 2), and used a selective visual masking procedure to determine which areas of a face were used by participants in making correct discriminations between emotional states of faces across four bands of spatial frequency. Facial stimuli were generated using PsychToolbox-3 (Brainard, 1997; Pelli, 1997) for Matlab, and were shown to participants on a 13.3-in. WXGA TruLife display with a resolution of 1,280 × 800 pixels, a refresh rate of 60 Hz, and an average luminance of 220 cd/m^2 at a distance of approximately 50 cm. Parts of the underlying faces appeared through an opaque field permeated with randomly placed Gaussian apertures or "bubbles" on five bands of spatial frequency. Photographs of 20 males and 20 females exhibiting both angry and neutral expressions were adapted from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt, & Ohman, 1998). These 80 photographs (256 × 256 pixels; approximately 6.55° × 6.55° of visual angle) were converted to grayscale and centered in an oval frame such that main facial features were aligned, and hair, neck, and shoulders were removed from the stimuli.

In four blocks, each consisting of 320 trials (total of 1,280 trials), participants were asked to determine via button press whether the presented face was demonstrating an angry or neutral expression. Stimuli were displayed until participants pressed one of the two button options. The task was adaptive, such that the amount of visual facial information being presented continually varied (via the QUEST algorithm; Watson & Pelli, 1983) throughout the testing based on individual participants' performance. In this way, accuracy was kept constant at 75–80%, making the number of bubbles the main dependent variable of task performance rather than task accuracy. This procedure allowed for the identification of facial regions and spatial frequencies critical for correct emotion recognition and subsequent comparison between the two groups. Reaction time (RT) data were also recorded.

Administration of the Bubbles task took approximately 35–50 min per participant and was well tolerated in both groups. Only one participant from the clinical sample was unable to complete the task, mainly due to problems with dexterity.

Data Analysis

To determine whether participants in the clinical group needed more visual facial information than controls to attain 75–80% accuracy on the Bubbles task (Hypothesis 1), we carried out an independent samples *t* test on the average total number of bubbles presented to each participant across all bands of spatial frequency across each of the 1,280 trials.

To determine whether schizophrenia patients and controls used different areas of the face in identifying angry and neutral faces (Hypothesis 2), we analyzed data from the Bubbles task via cluster analysis using the Stat4Ci toolbox for Matlab (Chauvin, Worsley, Synchs, Arguin, & Gosselin, 2005). Specifically, classification images for each participant at each of the tested spatial frequency bands were produced by performing multiple linear regressions on the sampled facial information and accuracies for each emotion and each group. Stated differently, this amounts to calculating two scores for each pixel—one indicating the number of times that pixel was displayed through the bubbles (i.e., not masked) on correct trials, and one indicating essentially the number of times that pixel was displayed through the bubbles on incorrect trials. A large difference between these two scores (calculated for each pixel) indicates that participants systematically responded correctly when facial information was presented by that pixel, and at chance, if not, for each spatial frequency band. Conversely, small differences between these probabilities indicate that the pixel was not particularly discriminative between correct or incorrect trials and can be interpreted as not important or facilitative for correct identification of angry and neutral faces. To determine significantly discriminative areas of the face (rather than individual pixels) while controlling for multiple comparisons, we transformed the classification images into *z*-scores and then subjected them to a cluster test (Chauvin et al., 2005) to determine the number of adjacent pixels that needed to be above an arbitrary threshold for these pixels to be statistically significant, given a prespecified *p* value. Here, we used a threshold *z*-score of 2.7 and a *p* value of .05 (one-tailed, Bonferroni-corrected for the four scales, $S_r = 65{,}536$; the cluster size thresholds were equal to 129, 377, 958, and 1,631, from the finest to the coarsest scale). The final result of these cluster analyses can be displayed visually to highlight the areas of the face used significantly by members of each group in identifying each emotion separately and/or combined to display areas of the face significantly used to discriminate between neutral and angry faces. Here, we carried out both styles of analysis.

Last, to test the relationship between aberrant use of facial information and social functioning in the clinical group (Hypothesis 3), we correlated smoothed combined-emotion classification images (i.e., Figure 1, Row C) for each patient, in two dimensions, with smoothed classification images representing the average of all 20 controls at each of the four bands of spatial frequency. The result of this process was one number ranging from −1 to 1 representing the overall similarity between each patient's use of facial information, and the average of the control group, for each level of spatial frequency. These two-dimensional correlation values for each patient were then correlated with the average of all SFS subscales and PANSS scores to reveal the relationship between divergent use of facial information and overall social functioning and symptom severity.

Results

Participant Characteristics

Table 1 displays the demographic and clinical characteristics of the sample. The control and clinical groups were comparable in terms of age, $t(38) = -0.39$, $p = .70$; gender, $\chi^2(1) = 0.00$, $p = 1.00$; estimated IQ, $t(32) = 0.60$, $p = .55$; level of education, $t(38) = 0.46$, $p = .65$; as well as levels of parental education: father, $t(33) = -0.63$, $p = .53$; mother, $t(33) = -0.66$, $p = .52$. As expected, however, the groups did differ significantly in terms of social functioning as measured by the SFS, $t(38) = 5.10$, $p < .001$. Furthermore, as expected, overall symptom severity (i.e., PANSS total) and social functioning were highly correlated within the patient group ($r = -.70$, $n = 20$, $p = .001$). Recognition accuracy for each emotion ranged between the expected 75–80%, and was comparable across groups: angry, $t(38) = 1.02$, $p = .32$; neutral, $t(38) = -1.67$, $p = .10$.

Bubbles Task

Consistent with our first hypothesis, results from the Bubbles task revealed that the clinical sample required a significantly greater amount of facial information to maintain 75–80% performance accuracy (average number of bubbles: 71.10 vs. 98.59), $t(38) = -2.56$, $p = .01$. However, contrary to our expectations, there was not a significant difference between the RTs of the clinical and control groups, $t(38) = -0.56$, $p = .58$. These basic differences between groups remained essentially unchanged when participants with schizoaffective disorder were excluded from the analysis. The amount of visual facial information required by participants was not significantly correlated with age ($r = .04$, $N = 40$, $p = .83$), estimated IQ ($r = -.05$, $n = 34$, $p = .79$), nor were there significant differences between genders, $t(38) = -0.97$, $p = .34$. However, age was found to be significantly correlated with RT ($r = .35$, $N = 40$, $p = .03$).

Cluster analyses of the data from the Bubbles task revealed differential patterns of facial information usage across the two groups and for each emotion. Figure 1 displays these results graphically. Although both the clinical and control groups used

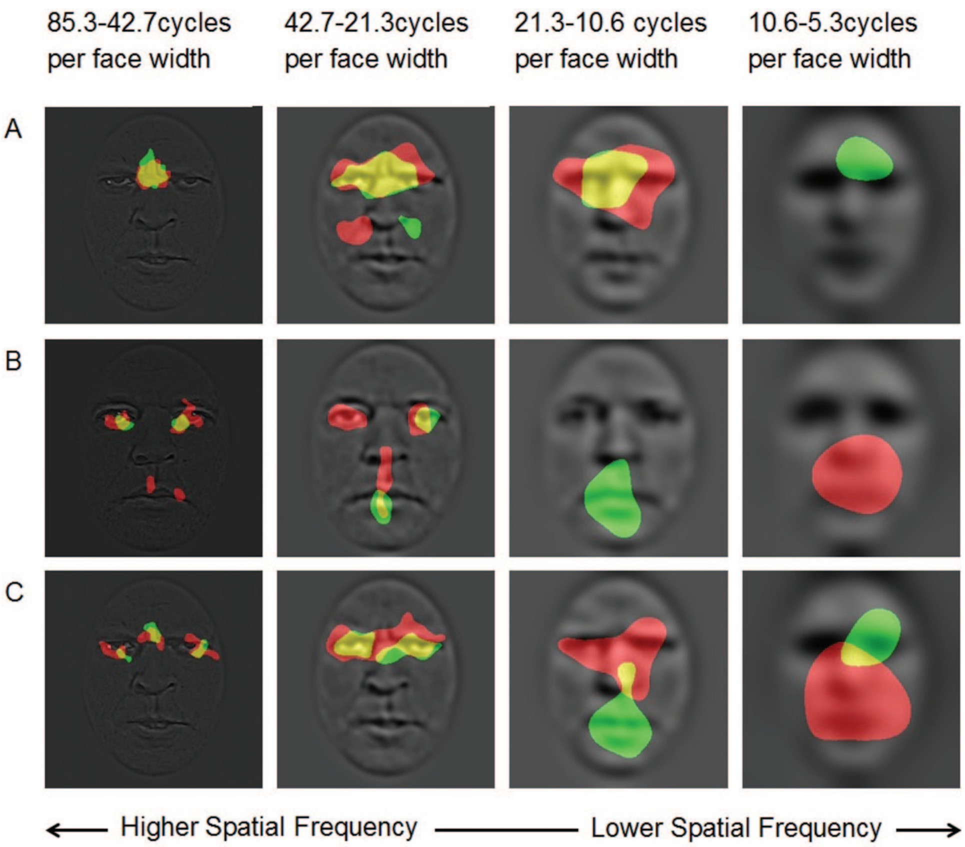

Figure 1. Rows A and B display areas of the face significantly used by controls (red) and schizophrenia patients (green; yellow represents overlap) in identifying angry (A) and neutral (B) expressions. Row C combines the results from above (i.e., does not separate emotions) to reveal areas of the face significantly used by controls (red) and schizophrenia patients (green; yellow represents overlap) in differentiating between angry and neutral faces.

similar areas of the face at the highest levels of spatial frequency for the correct identification of both angry and neutral expressions (see Figure 1, Rows A and B), information use varied between groups to a much greater extent at each of the three lower bands tested. Specifically, at the second highest band, schizophrenia patients appeared to use less information than the control group around the eye region in identifying both angry and neutral expressions and less information from the midface region in identifying neutral expressions. This pattern appeared magnified at the second lowest band, with patients using still less visual information than controls from around the eye region in identifying anger, and they appeared to rely on information from the mouth region that controls did not in identifying neutral expressions. Finally, at the lowest band of spatial frequency tested, there was a complete lack of overlap in significant areas between groups; patients both used information from the eye region in identifying anger that controls did not, and they failed to use information from the nose and mouth regions in identifying neutral expressions that control participants did use.

The above analyses were combined into additional classification images (i.e., emotions not separated) to reveal significant areas of the face used by each group in differentiating between emotions (see Figure 1, Row C). Here again, although both the clinical and control groups appeared to utilize similar amounts of information scattered around the eye regions on the highest level of spatial frequency, information usage varied to a much greater extent at each of the three lower bands tested. Specifically, at the second highest band, control participants used only the area surrounding the eyes. In contrast, the clinical group used a noticeably smaller area around the eyes and also a portion of the mouth area. This pattern appeared magnified in the second lowest band, with controls using most of the information contained in the eye, nose, and the upper portion of the mouth regions, and those in the clinical group using primarily the nose and mouth regions. Furthermore, at the lowest band of spatial frequency tested, controls were found to successfully use information from almost the entire face area below the eyes, whereas those in the clinical group were found to use only one small lateral eye region. These differences between groups confirmed our second hypothesis—that schizophrenia patients use visual facial information differently from controls in discriminating between angry and neutral emotional faces.

Last, in comparing the degree to which each participant in the clinical group used visual facial information similarly or dissimilarly to the control group, it was found that there was not a significant correlation between this degree of similarity and each patient's overall social functioning as measured by the SFS ($r =$

Table 1
Participant Characteristics

Variable	Group: Schizophrenia ($n = 20$)	Group: Control ($n = 20$)	Statistic
Demographic and clinical characteristics			
Mean age (years)	42.05	40.75	$t(38) = -0.39$, $p = .70$
Gender (male/female), *n*	12/8	12/8	$\chi^2(1, N = 40) = 0.00$, $p = 1.00$
Mean education (years)	14.20	14.60	$t(38) = 0.46$, $p = .65$
Mean father's education (years)	14.11	13.35	$t(33) = -0.63$, $p = .53$
Mean mother's education (years)	14.00	13.35	$t(33) = -0.66$, $p = .52$
Mean FSIQ-2 (WASI) score	102.07	104.58	$t(32) = 0.60$, $p = .55$
Mean of SFS scaled scores	113.46	124.74	$t(38) = 5.10$, $p < .001$
Mean PANSS total score	54.50		
Positive	14.95		
Negative	13.05		
General	26.50		
Bubbles task data			
Mean number of bubbles	98.59	71.10	$t(38) = -2.56$, $p = .01$
Accuracy for angry stimuli, %	75	77	$t(38) = 1.02$, $p = .32$
Accuracy for neutral stimuli, %	80	78	$t(38) = -1.67$, $p = .10$
Mean reaction time (s)	1.42	1.33	$t(38) = -0.56$, $p = .58$

Note. FSIQ-2 = Full Scale Intelligence Quotient, based on Vocabulary and Matrix Reasoning subtests; WASI = Wechsler Abbreviated Scale of Intelligence; SFS = Social Functioning Scale; PANSS = Positive and Negative Syndrome Scale.

.15, $n = 20$, $p = .26$). However, exploratory post hoc analysis of more specific areas of the facial stimuli revealed that there was a significant correlation between the degree of similarity each clinical participant shared with the control group average for only the top half of the combined-emotion classification images (eye regions) and their overall social functioning when using a one-tailed test ($r = .42$, $n = 20$, $p = .03$). Interestingly, the degree to which schizophrenia patients used information from the eye region similarly or dissimilarly to controls was also negatively correlated with overall symptomatology as measured by the PANSS total score ($r = -.56$, $n = 20$, $p = .01$). These findings provide some support for our third hypothesis—that the degree to which a schizophrenia patient uses visual facial information differently from the control average is correlated with lower functioning.

Discussion

This study examined visual facial information usage in schizophrenia by assigning credit of discrimination performance to specific facial features and spatial frequencies, specifically for affective states thought to be salient to social interaction, and functional outcome (angry and neutral). Results indicated that schizophrenia patients do indeed appear to be exhibiting specific and meaningful deficits in usage of visual facial information usage compared to controls. Schizophrenia patients were found to require more visual facial information to successfully discriminate between angry and neutral faces; furthermore, these participants appeared to rely on different areas of the presented faces compared with controls—increasingly so at lower levels of spatial frequency. Last, novel evidence was found to support the notion that aberrant usage of visual facial information is correlated with overall social functioning in schizophrenia.

These findings are consistent with previous research in this area. First, similar to Lee and colleagues (2011), who used the same procedure with happy and fearful facial stimuli, present results revealed that when compared with controls, the clinical group generally underutilized the eye region for negative affective states, overutilized the nose and mouth regions, and largely ignored almost all information presented at the lowest band of spatial frequency across both styles of analysis presented in Figure 1. However, given the predominant view that lower spatial frequency information is generally processed before higher spatial frequency information, it remains unclear whether patients' underutilization of lower spatial frequency information actively interferes with utilization of information at higher spatial frequency later in the visual process. For example, Laprévote, Oliva, Delerue, Thomas, and Boucart (2010) found preferential use of lower spatial frequency facial information in a time-limited emotion categorization paradigm. This suggests a deficit in the ability of schizophrenia patients to integrate lower spatial frequency information with higher spatial frequency information when it becomes available shortly after, rather than a deficit lower spatial frequency information perception or usage itself. This question notwithstanding, the present findings lend support to the notion that deficits in facial information usage in schizophrenia are persistent across a range of emotional valences, including those salient to effective social functioning in everyday interactions (i.e., angry and neutral).

Second, as expected, successfully differentiating between angry and neutral facial stimuli is a demonstrably more difficult task than successfully differentiating between happy and fearful facial stimuli. Where Lee et al. (2011) found that controls and patients needed an average of 38.2 and 68.7 bubbles per image respectively to maintain 75–80% performance accuracy on the Bubbles task, both groups in the present study were found to require considerably more visual facial information: 71.1 and 98.6 bubbles, respectively.

Finally, the present results are largely consistent with the schizophrenia literature specifically related to eye-tracking and scanpath paradigms. In a broad review of the area, Toh, Rossell, and Castle (2011) found a general consensus indicating that schizophrenia patients typically demonstrate a restricted scanning strategy involving shorter scanpath lengths, fewer fixations, increased fixation duration, and notable avoidance of relevant facial features irrespective of emotional valence. Consistent with deficits in early stage low spatial frequency integration, results from this area have suggested that patients have difficulties in conceptualizing an "initial face," predisposing them to fragmented sequential processing of all features of the face, rather than gestalt perception of the face and its particularly salient emotional features.

The present study has a number of strengths that help resolve previously open questions in the literature. For example, where Lee and colleagues (2011) were unable to measure RT, the present study did measure this variable and found no difference between groups. Contrary to our expectations, this would seem to indicate that schizophrenia patients are able to make decisions about facial affect as quickly as controls, but they need more visual facial information to do so. In addition, where Lee and colleagues used highly emotionally divergent facial stimuli to detect different aberrant usage of visual facial information in schizophrenia patients, the present study was able to find similar results with much more nuanced facial stimuli.

However, a number of limitations warrant elucidation here. First is the degree to which the results from the current investigation hold in more ecologically valid viewing conditions. In real-world viewing situations, people have a wide array of contextual information at their disposal that might facilitate disambiguation of possible emotional states of other people in the environment. Or people may choose not to look at faces at all (or very little) while interacting with others. Contrary to this, the Bubbles task does not present participants with this additional contextual information or the option not to look at the face. For example, the color of the face might be an important indicator of anger, whereas the stimuli in the Bubbles task were converted to grayscale. In this way, the Bubbles task may be detecting patterns of facial information usage prevalent in highly contrived viewing conditions (but see Spezio, Huang, Castelli, & Adolphs, 2007).

Another important question is whether or not the present results would hold if participants were given more than two emotions to differentiate, as would be the case in any real-world interaction. Chan et al. (2010) summarize a small literature indicating that patients with schizophrenia perform better on dichotomous-choice facial emotion perception tasks compared with multiple-choice facial emotion perception tasks (especially when presented with six or seven choices), which are certainly more representative of real-world social interactions in which any number of facial expressions could be expressed within a given interaction. Smith, Cottrell, Gosselin, and Schyns (2005) implemented the Bubbles task with seven response options in a control population; however, the effects that these additional affective options have on facial emotion perception in patients with schizophrenia remain to be measured and evaluated.

These limitations aside, the current study adds to the present understanding of emotion perception deficits in schizophrenia in several important ways. First, patients not only need more visual facial information to discriminate between angry and neutral faces, but we now know that patients use this visual facial information in a rather "abnormal" fashion. Furthermore, the degree to which these patients use facial information abnormally is now at least tenuously linked to their overall social functioning in the community. Future research should seek to focus on these factors in testing behavioral eye gaze interventions that might reliably guide patients' visual focus to the most meaningful areas of the face, as well as measure potential impacts on social interaction, social functioning, and functional outcome.

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