Analysis of Face Gaze in Schizophrenia:
Use of Facial Features and Spatial Frequencies

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY
CALGARY, ALBERTA
SEMTEMBER, 2012

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Abstract

Deficits in facial emotion perception have been linked to deficits in functional outcome in schizophrenia. However, the specific ways in which emotion perception is abnormal in schizophrenia and its relationship to functional outcome remain poorly understood. To better determine the nature of facial emotion perception deficits in schizophrenia, we utilized 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 relied on different facial features and spatial frequencies to differentiate these facial expressions. Additionally, a positive relationship of moderate strength was found between the degree of divergence from ‘normal’ visual facial information usage and lower overall social functioning.
Acknowledgements

For their unrelenting assistance and support in completing this thesis, I would like to thank my supervisor Dr. Vina M. Goghari for providing a near optimal environment in which to conduct this research, and all the members of my cohort – with whom it has been my special fortune to share these formative experiences in graduate school.
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<tr>
<td>PANSS</td>
<td>Positive and Negative Syndrome Scale</td>
</tr>
<tr>
<td>SCID</td>
<td>Structured Clinical Interview for the DSM</td>
</tr>
<tr>
<td>SFS</td>
<td>Social Functioning Scale</td>
</tr>
<tr>
<td>WASI</td>
<td>Wechsler Abbreviated Scale of Intelligence</td>
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</tbody>
</table>
CHAPTER 1: INTRODUCTION

In addition to the symptoms required for a diagnosis, it is well accepted that schizophrenia is associated with reliable deficits in social cognition (Green et al., 2008; Ziv, Leiser, & Levine, 2011). Recent investigations have supported the notion that social cognitive factors (such as the ability to perceive emotion, ascertain social cues from behaviour, and understand the mental states of others) are better predictors of overall functional outcome in schizophrenia patients than either neurocognitive factors (such as overall intellectual ability, psychomotor speed, and memory) or psychiatric symptoms. Furthermore, the variance in functional outcome explained by psychiatric symptoms and neurocognition together has been found to almost completely overlap with that explained by social cognitive factors. This indicates that when social cognition is included as a predictor, neurocognition and psychiatric symptomatology make no unique contributions to the prediction of functional outcome (Pijnenborg et al., 2009; Pinkham & Penn, 2006). These recent findings highlight the importance of investigating social cognition in schizophrenia.

One particularly important sub-domain 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 (Kohler, Walker, Martin, Healy, & Moberg, 2010; Chan, Li, Cheung, & Gong, 2010; Green, Kern, Braff, & Mintz, 2000). Several recent meta-analytic reviews point to large and robust deficits in facial emotion perception in schizophrenia. Kohler and colleagues (2010) conducted a meta-analytic review of 86 studies published between 1970 and 2007. Results indicated large overall effect sizes for
deficits in facial emotion tasks involving both identification ($d = -0.89$) and differentiation ($d = -1.05$) of facial emotions. Several demographic and illness-related factors were associated with greater impairment, including being an inpatient, later age of onset, greater age, greater number of symptoms, and being unmedicated. Similarly, Chan and colleagues (2010) examined 28 studies published between 1984 and 2007 and also found a moderate to severe impairment in facial emotion perception in schizophrenia ($d = -0.85$). Taken together, these results summarize a considerable body of literature which strongly suggests that deficient facial emotion perception in schizophrenia is a highly robust finding, regardless of task type (Kohler et al., 2010; Chan et al., 2010; Couture et al., 2006; Edwards, Jackson, & Pattison, 2002; Mandal, Pandey, & Prasad, 1998).

These results suggest an important role for social cognition, and particularly facial emotion perception as a potential determinant of poor functional outcome. In support of this, Bell and colleagues (2008) found via a path analysis that social cognitive deficits contributed significantly to social discomfort in employment situations, which then negatively affected rehabilitation outcomes. This model is consistent with an earlier model of social cognition and functional outcome proposed by Couture, Penn, & 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 leads 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.
In addition to these well documented deficits in facial emotion perception, schizophrenia patients also demonstrate specific visual impairments in the early stages of visual processing, including deficits in processing spatial frequency (see Butler & Javitt, 2005 for a review) which 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 (Butler et al., 2009), and is amongst the earliest features processed by the visual system. Visual input is first decomposed into bands of spatial frequency ranging from blurry blobs of light and darkness conveying broad spatial characteristics at low spatial frequencies, to sharp edges conveying detail and texture at high spatial frequencies. Under normal ecological viewing conditions in healthy populations, these spatial frequency bands are then naturally integrated into coherent precepts (Laprevote, Oliva, Delerue, Thomas, & Boucart, 2010), which are thought to be the base components of higher level operations such as image categorization and recognition. Upon seeing an image, lower spatial frequencies are generally thought to be processed more quickly than higher spatial frequencies, and serve as a kind of primary sketch of the image which information from higher spatial frequencies can then build upon shortly thereafter (Morrison & Synchs, 2001).

Several studies employing ‘simple’ stimuli (i.e. not faces) have reported that schizophrenia patients demonstrate specific deficits in contrast sensitivity (i.e. the lowest contrast at which one is able to detect a grating, or, difference between light and dark) at low levels of spatial frequency, despite relatively intact contrast sensitivity at higher levels of spatial frequency (O’Donnell et al., 2002; Martinez et al., 2008). Results from two recent studies employing more natural (i.e. 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 natural image recognition or classification, or which bands of spatial frequency are integrated in schizophrenia patients to form a coherent percept. Lee and colleagues (2011) investigated this issue by using the Bubbles Facial Emotion Perception Task (see below) to conduct a detailed analysis of facial information usage in schizophrenia patients in relation to controls, while differentiating between happy and fearful faces. For these emotions, they found that patients not only required more visual information than controls in order to make correct discriminations, but also utilized atypical strategies for collecting visual information from faces. For example, for the correct detection of fearful affect, 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 than controls. However, further questions remain regarding the specific ways in which patients use facial information differently from controls, and particularly so with emotions that are exceedingly important to differentiate in everyday social interaction. Lee and colleagues (2011) chose to investigate differential patterns of facial feature and spatial frequency usage for happiness and fear because these two emotions have been associated with the most distinct use of facial visual information (Smith, Cottrell, Gosselin, & Synchs, 2005). However, as suggested by Couture et al. (2006), differentiation of neutral faces from subtly negative affective states might represent a more salient ability for everyday interaction, leading to success or failure in social interactions, and subsequent functional outcome.
The current study employed the Bubbles Facial Emotion Perception Task to further investigate abnormal facial information usage in schizophrenia. By using angry and neutral facial stimuli, and also measuring overall social functioning, the current study allows for further exploration of the differences in facial information usage in schizophrenia, and particularly its relation to deficits in functional outcome. Given the above literature, 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 utilize 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.
CHAPTER 2: METHODS

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 anti-psychotic medication at time of testing. Twenty healthy control participants were recruited from the community via postings. Exclusion criteria for all participants included: 1) age under 18 years, or over 60 years; 2) mental retardation as defined by an estimated intelligence quotient (IQ) less than 70; 3) history of a neurological illness, or loss of consciousness greater than 20 minutes; 4) uncorrected ophthalmologic illness; 5) current substance abuse or dependence; 6) history of electroconvulsive therapy; 7) current or past nervous system condition; 8) less than normal, or corrected-to-normal visual acuity (assessed via performance on a Snellen chart test). 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: 1) The Structured Clinical Interview for the DSM-IV-TR (SCID; First, Gibbon, Spitzer, & Williams, 2002) to assess for DSM-IV diagnoses; 2) The Positive and Negative Syndrome Scale (PANSS; Kay, Fizbein, & Opler, 1987) as a measure of current psychosis-related symptomatology, and; 3) 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 (WASI; The Psychological Corporation, 1999), and a test of visual acuity. Assessment
measures were administered and scored by a team of three researchers: two graduate students, and one undergraduate-level full-time research assistant. Case conferences were held monthly and as needed to ensure reliability of diagnoses and subjective ratings. Additionally, all three raters involved with the project were officially certified to use the PANSS via the PANSS Institute.

The Bubbles task was adapted from that of Gosselin and Schyns (2001, experiment 2), and utilized a selective visual masking procedure to determine which areas of a face were utilized 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 (version R2011a), and shown to participants on a Dell XPS m1330 laptop with a 13.3 inch WXGA TruLife display with a resolution of 1280 x 800, a refresh rate of 60Hz, and an average luminance of 220 cd/m² at a distance of approximately 50cm. Parts of the underlying faces appeared through an opaque field permeated with randomly placed Gaussian apertures or “bubbles” on five bands of spatial frequency (85.3-42.7, 42.7-21.3, 21.3-10.6, 10.6-5.3, and 5.3-2.6 cycles per face width). Photographs of 20 males and 20 females exhibiting both angry and neutral expressions were randomly chosen from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt, & Ohman, 1998). Facial stimuli in this database were constructed via photographs of amateur actors who were instructed to practice making each of the six basic emotions (anger, fear, happiness, sadness, disgust, and surprise) for one hour prior to photographing them. Neutral expressions were also photographed. A total of 80 photographs (256 x 256 pixels; approximately 6.55 x 6.55° of visual angle) were converted to greyscale and centered in an opaque 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 (4x80) trials (total of 1280 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, which were counterbalanced between subjects to eliminate any possibility of systematic error due to handedness. The task was adaptive, such that the number of randomly placed bubbles (i.e. 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 relatively constant at 75-80%, making the number of bubbles the main dependent variable of task performance rather than task accuracy. By statistically analyzing where on the face at each of the four levels of spatial frequency the bubbles were located when participants correctly classified faces, this procedure allows for the identification of facial regions and spatial frequencies critical for correct emotion recognition, and subsequent comparison between the two groups. Reaction time data (seconds) was also recorded.

**Data Analysis**

To determine whether participants in the clinical group needed more visual facial information than controls in order to attain 75-80% accuracy on the bubbles task (hypothesis 1), a simple independent samples t-test was carried out on the average total number of bubbles presented to each participant across all bands of spatial frequency across each of the 1280 trials. To determine if schizophrenia patients and controls used differential areas of the face in discriminating between neutral and angry faces (hypothesis 2), data from the bubbles task was analyzed 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 group. Stated differently, this amounts to calculating two probabilities for each pixel – one indicating the probability of that pixel being displayed through the bubbles (i.e. not masked) on all correct trials, and one indicating the probability of that pixel being displayed through the bubbles on all incorrect trials. A large difference between these probabilities indicates that participants systematically responded correctly when facial information was presented by that pixel, and incorrectly 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 of correct discrimination between the angry and neutral faces. In order to determine significantly discriminative areas of the face (rather than individual pixels) while controlling for multiple comparisons, the difference maps were transformed into z-scores and then subjected to a Cluster test (Chauvin et al., 2005) to determine the number of adjacent pixels that need to be above an arbitrary threshold in order for these pixels to be statistically significant, given a pre-specified p-value. Here, we used a critical z-score of ±2.58 (p<0.05). 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 discriminating between neutral and angry faces.

Last, in order to test the relationship between aberrant use of facial information and social functioning in the clinical group (hypothesis 3), smoothed classification images for each schizophrenia patient were correlated, 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 which represents the overall similarity
between each patient’s use of facial information, and the average of the control group, for each level of spatial frequency. This yields a measure of how similarly or dissimilarly each patient utilized visual facial information compared to the control group as a whole. These 2D-correlation values for each patient were then correlated with the average of all Social Functioning Scale sub-scales to reveal the relationship between divergent use of facial information and overall social functioning.
CHAPTER 3: RESULTS

Participant Characteristics

Table 1 displays the demographic and clinical characteristics of the sample.

Table 3.1: Participant Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Schizophrenia</th>
<th>Controls</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Demographic &amp; Clinical Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>42.05 (11.22)</td>
<td>40.75 (9.88)</td>
<td>$t_{38} = -0.39, p = .70$</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>12/8</td>
<td>12/8</td>
<td>$\chi^2 (1, N = 40) = 0.00, p = 1.00$</td>
</tr>
<tr>
<td>Education (years)</td>
<td>14.20 (3.35)</td>
<td>14.60 (1.96)</td>
<td>$t_{38} = 0.46, p = .65$</td>
</tr>
<tr>
<td>Father’s Education (years)</td>
<td>14.11 (3.05)</td>
<td>13.35 (4.03)</td>
<td>$t_{33} = -0.63, p = .53$</td>
</tr>
<tr>
<td>Mother’s Education (years)</td>
<td>14.00 (3.55)</td>
<td>13.35 (2.06)</td>
<td>$t_{33} = -0.66, p = .52$</td>
</tr>
<tr>
<td>FSIQ-2 (WASI)</td>
<td>102.07 (10.49)</td>
<td>104.58 (13.33)</td>
<td>$t_{33} = -0.64, p = .53$</td>
</tr>
<tr>
<td>Average of SFS Scaled Scores</td>
<td>113.46 (8.29)</td>
<td>124.74 (4.86)</td>
<td>$t_{38} = 5.10, p &lt; .001$</td>
</tr>
<tr>
<td>PANSS Total</td>
<td>54.50 (14.21)</td>
<td>32.60 (5.72)</td>
<td>$t_{38} = -6.39, p &lt; .001$</td>
</tr>
<tr>
<td>Positive</td>
<td>14.95 (5.68)</td>
<td>7.60 (1.05)</td>
<td>$t_{20.29} = -5.69, p &lt; .001$</td>
</tr>
<tr>
<td>Negative</td>
<td>13.05 (5.18)</td>
<td>7.25 (0.72)</td>
<td>$t_{19.73} = -4.96, p &lt; .001$</td>
</tr>
<tr>
<td>General</td>
<td>26.50 (6.30)</td>
<td>18.10 (3.93)</td>
<td>$t_{31.84} = -5.06, p &lt; .001$</td>
</tr>
<tr>
<td><strong>Bubbles Task Data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Bubbles</td>
<td>98.59 (39.03)</td>
<td>71.10 (27.84)</td>
<td>$t_{38} = -2.56, p = .01$</td>
</tr>
<tr>
<td>Reaction Time (seconds)</td>
<td>1.42 (0.59)</td>
<td>1.33 (0.35)</td>
<td>$t_{38} = -0.56, p = .58$</td>
</tr>
</tbody>
</table>

Note. PANSS, Positive and Negative Syndrome Scale; SFS, Social Functioning Scale; WASI, Wechsler Abbreviated Scale of Intelligence. Values are given as mean (SD).

The control and clinical groups were comparable in terms of age ($t_{38} = -0.39, p = .70$); gender ($\chi^2 = 0.00, df = 1, p = 1.00$); estimated IQ ($t_{33} = 0.64, p = .53$); 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 symptom severity as measured by the PANSS (positive, $t_{20.29} = -5.69, p < .001$; negative, $t_{19.29} = -4.96, p < .001$; general, $t_{31.84} = -5.06, p < .001$), and 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 ($r = -.70, n = 20, p = .001$).
**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 in order to maintain 75% performance accuracy (average number of bubbles: 71.10 versus 98.59; $t_{38} = -2.56, p = .01$). However, contrary to our expectations, there was not a significant difference between the reaction times 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 ($r = .04, n = 40, p = .83$), IQ ($r = -.05, n = 35, p = .76$), nor were there significant differences between genders ($t_{38} = -.97, p = .34$).

However, age was found to be significantly correlated with reaction time ($r = .35, n = 40, p = .03$).

Cluster analyses of the data from the Bubbles task revealed differential patterns of facial information usage across the two groups. Figure 1 displays these results graphically.
Figure 3.1: Differential Usage for Visual Facial Information

<table>
<thead>
<tr>
<th>Spatial Frequency</th>
<th>Controls</th>
<th>Schizophrenia Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.3-42.7 cycles per face width</td>
<td>Utilized only area surrounding the eyes</td>
<td>Utilized area around the eyes and also a portion of the mouth area</td>
</tr>
<tr>
<td>42.7-21.3 cycles per face width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.3-10.6 cycles per face width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.6-5.3 cycles per face width</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Areas of the face significantly utilized by controls (A) and schizophrenia patients (B) in differentiating between angry and neutral facial expressions.

While both the clinical and control group 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 utilized only the area surrounding the eyes. In contrast, participants in 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 utilizing most of the information contained between the eyes and the upper portion of the mouth, and those in the clinical group utilizing primarily the nose and mouth regions.

Furthermore, at the lowest band of spatial frequency tested, participants in the control group were found to successfully utilize information from almost the entire face area below the eyes,
while those in the clinical group were found to utilize only one small lateral eye region. These differences between groups confirmed our second hypothesis – that schizophrenia patients utilize visual facial information differently than controls in discriminating between angry and neutral emotional faces.

Last, in comparing the degree to which each participant in the clinical group utilized 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 ($r = .15, n = 20, p = .26$). 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 images (eye regions) and their overall social functioning when using a 1-tailed test ($r = .42, n = 20, p = .03$). Interestingly, the degree to which schizophrenia patients utilized information from the eye region similarly to controls was also negatively correlated with overall symptomatology as measured by the PANSS ($r = -.56, n = 20, p = .01$). These findings provide some support for our third hypothesis – that the degree to which a schizophrenia patient utilizes visual facial information differently from the control average, is reliably correlated with lower functional outcome scores.
CHAPTER 4: 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 aberrant usage of facial information compared to controls. Specifically, schizophrenia patients were found to require more visual facial information to successfully discriminate between angry and neutral faces, and furthermore these participants appeared to rely on different features of the presented faces compared to controls. Schizophrenia patients appeared to use mouth regions that controls did not use at the second highest band of spatial frequency, rely on the nose and mouth regions rather than the eyes at the second lowest band of spatial frequency, and use virtually none of the information presented at the lowest band of spatial frequency. Last, novel evidence was found to support the notion that aberrant use of visual facial information is correlated with overall social functioning in schizophrenia. Of course, causality cannot be established using the present methods, and the relationship is likely bidirectional wherein emotion perception deficits contribute to lower social ability and functioning, and prolonged diminished social functioning also likely contributes to emotion perception deficits.

Overall, these findings are consistent with previous research in this area. The first and perhaps most important way in which these results follow from previous investigations is in the particular areas of the face found to be significantly useful in differentiating expressions across bands of spatial frequency. Similar to Lee and colleagues (2011) who used the same procedure with happy and fearful facial stimuli, present results revealed that when compared to controls, participants in the clinical group generally underutilized the eye region for negative affective states, over-
utilized the nose and mouth regions, and largely ignored almost all information presented at the
lowest band of spatial frequency when differentiating between angry and neutral stimuli.
Interestingly, the fact that patients underutilized information from the lowest band of spatial
frequency makes intuitive sense given the basic early stage visual deficits associated with
schizophrenia (Butler et al., 2009). However, given the predominant view that lower spatial
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 frequencies later in the visual process.
This question notwithstanding, these 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. This increase is readily explainable in
terms of the happy and fearful facial stimuli used by Lee and colleagues (2011) being more
discrepant on the range of all possible facial emotions, whereas angry and neutral expressions are
considerably closer on that spectrum (Smith et al., 2005). For example, while it would be a rare,
if not a completely erroneous expression of fear to display upturned corners of the mouth (as in
happiness), someone with naturally downward-sloping eyebrows when emoting a neutral
expression might be more easily be considered angry when viewed out of context with the rest of

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their facial features. Angry and neutral expressions are inherently more similar, and thus, inherently more difficult to differentiate. However, the very fact that they are difficult to differentiate could make their differentiation more salient to social interaction and consequently functional outcome. In this sense, ensuring that the differences in facial information usage strategies adopted by people with schizophrenia are similar under more realistic social conditions is vital to our understanding of these processes in relation to overall social functioning. The results of this study confirm that patients with schizophrenia do indeed show demonstrable deficits in facial information usage with at least these more socially realistic stimuli.

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 and colleagues (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.

Limitations

The present study has a number of strengths which help to resolve previously open questions in the literature. For example, where Lee and colleagues (2011) were unable to measure reaction time, 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 just need more visual facial
information to do so. Additionally, where Lee and colleagues used highly emotionally divergent facial stimuli to detect differences aberrant usage of visual facial information in schizophrenia patients, the present study was able to find similar results with much more socially relevant 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. For example, in real-world viewing situations, people have at their disposal a wide array of contextual information which 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 these conditions, the Bubbles task does not present participants with this additional contextual information, or the option not to look at the face. For example, the colour of the face might be an important indicator of anger, whereas the stimuli in the Bubbles task were converted to greyscale. 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). Similarly, different spatial frequencies may be differentially utilized at different physical distances, as would be the case when rough information in lower spatial frequencies changes into increasingly sharp edges utilizing higher spatial frequencies as others walk toward us.

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 to 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 et al. (2005) implemented the Bubbles task with seven response options in a control population, however, the affects that these additional affective options have on facial emotion perception in patients with schizophrenia remain to be measured and evaluated.

Another limitation faced by this study is a relative paucity of medication information collected for schizophrenia patients. While all patients were instructed to have their drug dosage information available for the interview day, very few participants actually did so, making it difficult to compare medication usage to task performance via typical standardization techniques such as chlorpromazine (CPZ) equivalents, or defined daily dosage (DDD).

**Future Directions**

Aside from ameliorating the above limitations of this study by approximating more realistic social interactive situations, future research might focus on bringing what is now known about aberrant visual facial information usage in schizophrenia to bear in augmenting existing social cognitive treatments for schizophrenia. For example, it remains an open empirical question whether or not helping or training patients with schizophrenia to use visual facial information more similarly to controls is possible, and if so, how. Assuming that it is possible to correct, errant patterns of facial information usage, it further remains unknown whether or not such improvements would aid in increasing social functioning, as is intuitively the case. In this sense, the more robust the finding of aberrant face gaze in schizophrenia becomes, the more the research emphasis must shift from confirming this fact to applying it to efforts to promote recovery from the disorder.
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