An analysis of categorical perception of facial emotion in schizophrenia

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Received 3 November 2005; received in revised form 26 May 2006; accepted 5 June 2006
Available online 21 July 2006

Abstract

Background: Emotion perception deficits have been extensively documented in schizophrenia and are associated with poor social functioning. Yet fundamental questions about the nature and scope of these impairments remain unanswered from commonly used experimental tasks. An alternative categorical perception paradigm that focuses on distinguishing boundaries between emotions was used to evaluate whether schizophrenia patients demonstrate atypical patterns of categorical perception and a negativity bias in the identification of ambiguous facial expressions.

Method: 47 schizophrenia outpatients and 31 nonpsychiatric controls completed a forced-choice emotion identification task. Stimuli consisted of a series of digitized facial images that were morphed in 10% signal intensity increments along continua between pairs of emotions (happy→sad; fearful→happy; angry→fearful; angry→sad) and presented in a random order. For each emotion continuum, measures of the response slope and the location of the boundary shift point between emotions were calculated for each group.

Results: The schizophrenia group demonstrated significantly shallower response curves than controls across all emotion continua. Despite these generally less precise demarcations between emotions, patients did not significantly differ from controls in the location of the shift point between emotions on any of the continua.

Conclusions: Schizophrenia patients demonstrated impaired categorical perception of facial expressions with generally less sharp categorizations of ambiguous stimuli to one emotion category or another. However, patients did not demonstrate a negativity bias in their processing of ambiguous facial expressions. The emotional continuum paradigm can help to clarify the nature and boundaries of affect perception deficits in schizophrenia.

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Keywords: Schizophrenia; Categorical perception; Facial emotion; Affect perception

1. Introduction

Research over the past two decades has established that individuals with schizophrenia generally are less accurate than nonpatient controls in their ability to
identify and discriminate among emotional expressions in still photographs of faces (Mandal et al., 1998), voice tones (Kerr and Neale, 1993), videotaped monologues (Bryson et al., 1997), and videotaped social interactions (Bellack et al., 1996). These impairments are evident in first-episode patients (Edwards et al., 2001) and, among more chronically ill patients, are present during periods of clinical remission (Kohler et al., 2003) and relatively stable over time (Addington and Addington, 1998; Streit et al., 1997). Emotion perception deficits are not fully attributable to antipsychotic medications or their side effects (Kerr and Neale, 1993; Salem et al., 1996) and are not consistently associated with clinical symptoms (Edwards et al., 2002; Bozikas et al., 2004). Furthermore, these deficits appear to have considerable functional relevance, as worse affect perception is associated with lower levels of interpersonal, social, and work functioning in schizophrenia (Brekke et al., 2005; Green, 2001; Ihnen et al., 1998; Kee et al., 2003; Mueser et al., 1996; Penn et al., 1996, 1997; Poole et al., 2000).

Despite growing interest in this area, fundamental questions remain unanswered. It is not yet known if individuals with schizophrenia exhibit a bias towards misidentifying certain types of emotions more than others or if they demonstrate the typical pattern of categorical (rather than continuous) perception of emotion found in non-clinical samples (discussed further below). For facial affect perception, studies have considered whether there is an emotion-specific perceptual deficit. Several of these studies suggest that, in addition to an overall deficit in emotion recognition, patients may show a relatively larger impairment in the identification of unpleasant emotions, including fear, disgust, and sadness (e.g., Archer et al., 1994; Bellack et al., 1996; Edwards et al., 2001; Gaebel and Wolwer, 1992; Kohler et al., 2003; Phillips et al., 1999; Schneider et al., 1995). Along these lines, Kohler et al. (2003) conducted an analysis of errors involving misattribution of emotion to neutral facial displays on an emotion identification task. Compared to healthy controls, schizophrenia patients tended to over-attribute disgust and under-attribute happiness to neutral displays as compared to controls, suggesting that patients may over-identify certain unpleasant emotions. While these studies can address the question of whether patients have poorer accuracy on some emotions compared with others, they do not directly address the issues of whether patients show a bias for seeing certain emotions more than others.

One experimental paradigm that directly addresses these issues focuses on the boundaries between emotions, rather than accuracy of recognizing certain emotions, by presenting facial stimuli that vary along continua between "pure" emotions. In the emotional continuum paradigm, continua of facial images between pairs of prototype facial expressions of different emotions (e.g., 100% happy to 100% sad) are constructed using computer morphing techniques such that each adjacent face represents an equivalent (e.g., 10%) physical change. These stimuli are then used in identification or discrimination tasks to evaluate whether facial affect perception occurs in a categorical or continuous manner.

Research in healthy subjects demonstrates that within a series of facial expression stimuli differing by equal physical increments, the probability of identifying the expression as a particular emotion does not vary linearly across the series from one endpoint to the other (as would be expected if emotions are perceived continuously). That is, continuous perception of emotion would yield a flat response curve or a straight line, rising at equivalent levels across the facial emotion images. Instead, small physical differences in pairs of facial stimuli that straddle a subjective boundary between two emotion categories are identified much more accurately than the same size differences between faces within the same category (e.g., Bimler and Kirkland, 2001; Calder et al., 1996; de Gelder et al., 1997; Etoff and Magee, 1992; Pollak and Kistler, 2002; Young et al., 1997). In other words, facial stimuli within an emotion category are perceived as more similar to each other than to facial stimuli belonging to a different category, even if the physical differences between them are equal. This categorical aspect of emotion perception is typically revealed on graphs as a sharp boundary near the midpoint of the continuum. Categorical perception of emotion is evident very early in development (e.g., Kotsoni et al., 2001), and it has been proposed that this process is an adaptive feature of perception that evolved to facilitate rapid and appropriate responding to cues in the social environment (e.g., Ekman and Davidson, 1994; Etoff and Magee, 1992).

In addition to testing categorical versus continuous models of perception, the emotional continuum paradigm can be used to rigorously examine whether clinical groups demonstrate differential patterns and biases in the perceptual processing of pleasant and unpleasant facial expressions. For example, Pollak and Kistler (2002) found that children with histories of severe physical abuse demonstrated a selective pattern of abnormal emotion perception using continua spanning the categories of happiness, anger, sadness, and fear; the abused children significantly over-identified anger as...
compared to fear and sadness (i.e., the location of category boundaries systematically shifted toward anger versus both sadness and fear).

Morphed images have been used previously in schizophrenia research. A study by de Gelder et al. (2005) utilized a continuum paradigm of morphed facial expression images. However, the goal of that study was to examine the cross-modal effects (visual on auditory in one experiment and auditory on visual in another) in patients and controls. In contrast, the goal of the current study is to examine categorical boundaries in different emotional dimensions in patients and controls.

Specifically, in the present study, schizophrenia outpatients and healthy controls completed an emotional continuum task involving four continua (happy–sad, fearful–happy, angry–fearful, angry–sad) to address two issues that emerged from previous research findings. First, we sought to determine whether schizophrenia patients demonstrate typical patterns (i.e., pattern and steepness of slopes) of categorical perception of facial expressions. Based on evidence of particularly poor discrimination between unpleasant emotions in schizophrenia reviewed above, it was predicted that patients would show less clear demarcations (i.e., shallower slopes) for continua involving unpleasant emotions (angry–fearful, angry–sad) than controls. Second, we tested whether schizophrenia patients demonstrate a bias toward over-identifying unpleasant emotions (i.e., shift in the category boundaries). Based on the results described above (e.g., Kohler et al., 2003), we expected patients to demonstrate a shift in category boundaries towards unpleasant versus pleasant expressions (i.e., happy–sad, fearful–happy continua) compared to controls.

2. Method

2.1. Participants

Forty-seven schizophrenia outpatients, who were participating in a larger NIMH-funded study (MH43294, M.F. Green, PI), were recruited from the outpatient clinics of the VA Greater Los Angeles Healthcare System and from residences in the community. All patients met criteria for schizophrenia based on the Structured Interview for DSM-IV (SCID; First et al., 1996a). Forty-six of the 47 patients were taking antipsychotic medications at clinically determined dosages (n=33 for atypical; n=8 for conventional; n=5 for both types). Psychiatric symptoms were assessed using the 24-item Brief Psychiatric Rating Scale (BPRS; Ventura et al., 1993). This outpatient sample exhibited mild levels of symptoms on the BPRS total score (M=44.14, SD=13.44), a global measure of positive symptoms (hallucinations, unusual thought content, and conceptual disorganization; M=2.45, SD=1.45), and an index of negative symptoms (blunted affect, emotional withdrawal, and motor retardation; M=1.86, SD=0.89).

Nonpatient controls were recruited through newspaper advertisements and flyers posted in the local community. Control subjects were screened with the SCID and SCID-II (First et al., 1996b) and were excluded if they met criteria for any psychotic disorder, recurrent depression, bipolar mood disorder, substance dependence, or selected Axis II personality disorders (i.e., avoidant, borderline, paranoid, schizoid, and schizotypal). Potential control subjects were also excluded if there was a history (according to subject report) of psychotic disorder among their first-degree relatives.

Additional exclusion criteria for all participants included: age less than 18 or over 55 years, active substance use disorder in the past six months, identifiable neurological disorder, mental retardation, or seizure disorder. Diagnostic interviewers were trained to a minimum Kappa of 0.75 for rating psychotic and mood symptoms. Ratings on the BPRS were a minimum ICC of 0.80. Training on interviews was conducted by the Treatment Unit of the VISN 22 Mental Illness Research, Education, and Clinical Center (MIRECC, S.R. Marder, P.I.). Written informed consent was obtained from each participant. Clinical ratings of symptoms were completed within one week of the performance measure, and in most instances, they were assessed on the same day.

2.2. Materials and procedure

2.2.1. Emotional continuum task

In this facial emotion identification test adapted from Pollak and Kistler (2002), subjects were presented with a series of 352 digitized facial images of two posers (a female and a male). These facial images were created from a set of black and white photographs, developed by Ekman and Friesen (1976), which depict differing expressions including happy, fearful, angry, and sad. Using a computer algorithm, the prototype photographs were morphed to create a linear continuum of nine facial images between two endpoints (e.g., 100% angry and 100% fearful). Each intermediate image was transformed by a 10% increment (shown in Fig. 1). Details of the morphing technique are provided in Pollak and Kistler (2002). For the present study, we used the same continua that were used in Pollak and Kistler (2002):
happy—sad, fearful—happy, angry—fearful, and angry—sad. These four continua were selected because they represent basic dimensions: pleasant–unpleasant (happy—sad, fearful—happy) and approach–avoidance (angry—fearful, angry—sad).

Prior to testing, definitions of the four emotions were presented in written form and read aloud to the subjects. During testing, a central fixation cross was presented for 250 ms at the start of each trial on the computer screen. Then a facial image was presented in the middle of the screen with two different labels of emotion appearing beneath the image. The subjects selected the one emotion that best described the facial expression by touching the label on the screen with their index finger. Although there was no time limit for responses, subjects were prompted to respond as quickly as possible to maintain focus on the task and so the decision approximated real life timing of judgements. The facial image remained in view until a response was made. At the end of each trial, the subjects were told to rest their hands on the table before the next image appeared. Testing took between 20 to 30 min to complete.

There were 88 facial stimuli (11 images within each of the 4 continua with 2 posers) that appeared as targets, each presented 4 times in random order, yielding a total of 352 trials. These trials were administered in two separate blocks of 176, separated by a rest period. For each continuum, the dependent variable was the proportion of correct identifications at each signal strength from one prototypical facial emotion to the other (signal strengths 1–11). The proportion of correct responses is expected to approach 100% near the two endpoints (e.g., 100% angry and 100% fearful) and to diminish near the middle of the continuum where the facial expressions “switch” from one category to the other.

3. Data analyses

We initially attempted to analyze the emotional continuum task data using the procedure described by Pollak and Kistler (2002) in their study of abused and non-abused children. This approach involved fitting separate logistic function models for each emotion continuum to the data from each individual participant, deriving estimates of category shift points and slopes for each individual, and comparing group means on these parameters. These logistic functions fit the control subjects’ data very well, but it was not possible to fit 15–20% of the patients’ data on each of the emotional continua with these functions (i.e., the logistic functions produced parameter values that fell outside the range of possible scores or infinite values). Furthermore, visual inspection of the data suggested that a logistic model fit the response patterns poorly for approximately 15% of the patients even when the parameters could be estimated, and the results appeared to be valid. For these reasons, we used an alternative data analytic approach that did not involve fitting separate models for each participant, but rather based parameter estimates on data from the entire group. This procedure estimates the same function, but is much less sensitive to outliers data points or trajectories of individual subjects.

Data were modeled at the group level using two complementary methods. The task presented participants with sets of 11 photos at 11 “signal strengths,” as described above. During the entire session, each participant ultimately classified 8 photos (4 from each of 2 posers) at each of the 11 signal strengths, for a total of 88 classifications. For analyses, the 8 photos at each signal strength were collapsed into a summary score representing the proportion of times the photo was classified into the higher (right-end) emotional category.
These scores thus ranged from 0.0 to 1.0 in increments of 0.125.

We first analyzed these scores using a series of generalized linear mixed model regressions based on all available data points. The analyses used the SAS GENMOD procedure with autoregressive covariance structure, correcting for over-dispersion using the deviance method. Separate regression analyses were done for each of the four emotion continua. Subject group (schizophrenia, control) was the independent grouping variable, signal strength was a within-subjects repeated measures factor with 11 levels, and subject was included as a random effect to account for the non-independence resulting from use of multiple records from individuals. These analyses evaluate group differences in the overall profiles in emotion classifications across signal strengths, but they do not estimate the shift point and slope parameters used by Pollak and Kistler (2002). Those logistic parameters parsimoniously characterize the emotion identification task performance data with the following logistic function model:

\[ y = \frac{a + b/(1 + e^{-x/c})}{d} \]

In this equation, \( y \) = probability of identification, \( x \) = signal strength, \( a \) = lower asymptote, \( b \) = difference between upper and lower asymptotes, \( c \) = signal threshold at midpoint, \( d \) = slope, and \( e \) = exponential function. The "shift point" is the point on the signal strength continuum at which the most likely choice of emotion shifts from the emotion at the left pole to the emotional on the right. The slope indicates how abruptly this change happens. A high value for the slope indicates a clear and relatively abrupt shift from classifying photos as being at one emotional pole rather than the other. A flatter slope indicates more ambiguity in the shift from one emotional pole to the other. The slope and shift parameters were derived from the regression outputs using simple algebraic transformations of the formula presented above.

The slope and shift point estimates are thus algebraically derived parameters, and the generalized mixed effects regression models do not evaluate the statistical significance of group differences directly. For this reason, a bootstrap randomization method (Efron, 1979) was used to: a) confirm the parameter estimates derived from the regression models and b) generate empirical standard error estimates to evaluate group differences on these parameters. This procedure was performed by randomly choosing sets of 74 records (with replacement) from all available records, calculating the shift points and slopes for each set, and repeating this procedure 100 times. The final shift point and slope estimates from the bootstrap procedure were, as expected, highly similar to those generated from the output of the generalized mixed model regressions, demonstrating good convergence across methods. The standard deviations of these estimates in the bootstrap replication samples were taken as their empirical standard errors for significance testing.

Results are presented in three stages. First, between-group comparisons on demographic characteristics and descriptive data on the clinical characteristics of the schizophrenia group are presented. Second, the main findings from the generalized mixed model regressions for each emotion continuum are presented. Third, group differences in the switch points and slopes from these regressions are evaluated using the bootstrap standard errors. Supplemental analyses were done to examine possible effects of age and sex on performance of the emotional continuum task because those characteristics were confounded with group.

4. Results

4.1. Participant characteristics

As shown in Table 1, the schizophrenia group was older and included a higher proportion of males than the control group. The groups did not significantly differ in education level or ethnicity. The schizophrenia patients were generally chronically ill with a mean duration of illness of 19.44 years (SD = 8.06).

4.2. Performance on the emotional continuum task

The regression analyses revealed significant group x signal strength interaction effects for each of the four emotional continua, indicating that the shapes of the

| Table 1 | Demographic data for the schizophrenia (n=47) and control (n=31) groups |
|---------|-----------------|-----------------|---------------|
|         | Schizophrenia   | Control         | Statistic     |
| Age (M, SD) | 48.00 (8.82)    | 41.32 (7.15)    | t=-3.51*     |
| Sex (% male) | 94              | 61              | Y^2 = 12.57*  |
| Education (M, SD) | 13.75 (1.88)    | 13.90 (1.96)    | t=-1.02      |
| Ethnicity (%): |                |                 | Y^2 = 3.36    |
| Caucasian   | 38              | 45              |               |
| African American | 47             | 35              |               |
| Hispanic    | 9               | 7               |               |
| Asian       | 2               | 4               |               |
| Other       | 4               | 10              |               |

* p < 0.05.
response curves differed between groups. The magnitudes of these effects were large as reflected in the following Z-scores: anger–fear: $Z=3.64$, $p<0.001$; anger–sad: $Z=3.14$, $p<0.005$; fear–happy: $Z=4.59$, $p<0.001$; happy–sad: $Z=2.47$, $p<0.005$. These interaction effects are displayed graphically in Fig. 2. The panels in this figure correspond to the four emotional continua, with the schizophrenia group represented with solid lines and the control group with dashed lines. For each continuum (e.g., happy–sad), the ordinate refers to the proportion of trials in which the second emotion (e.g., sad) was identified. The abscissa refers to the stimulus intensity or signal strength. Both groups showed the expected sigmoidal curves with emotion identification approaching 100% near the endpoints of

Fig. 2. Performance on the emotional continuum task for the schizophrenia and control groups. For each continuum (e.g., angry–fearful), the ordinate refers to the proportion of trials in which the second emotion (fearful) was identified relative to the first emotion (angry). The abscissa consists of the signal strength.

the continua, although the slopes of the curves appeared generally less steep in the schizophrenia group. Note that the general pattern would not change if the poles were reversed (i.e., a flatter function would remain flatter even if displayed as a mirror image).

To evaluate the group x signal strength interactions, the groups were compared on the shift points and slopes for each of the emotional continua. Descriptive data and results of statistical tests are presented in Table 2. The schizophrenia group demonstrated significantly smaller slopes than controls across all four emotional continua. The steep slopes in the control group provide evidence for categorical perception, whereas the flatter slopes in the schizophrenia group suggest that the patients perceived emotion in a
less discrete, more continuous, fashion. Thus, the boundaries appeared generally less sharp in the schizophrenia group, with little evidence of any specific disturbance in perceiving switches between any particular pair of emotions.

The groups did not significantly differ on the shift points for any of the emotional continua. However, the between-group difference for the angry–fearful continuum showed a non-significant trend in which schizophrenia patients displayed a tendency to over-identify angry versus fearful expressions. This tendency for the schizophrenia group to over-identify angry expressions was not apparent for the angry–sad continuum.

4.3. Supplemental analyses

In light of the group differences in age and sex, the effects of these potential confounds on the group × signal strength interactions were evaluated. The generalized mixed model regressions reported above were re-computed for each of the four emotional continua, with age and sex effects entered into the regression equations. The age effect was significant for only the fear–happy continuum, Z = 2.37, p < 0.05, and there were no significant sex effects (all ps > 0.10). The group × signal strength interactions found for all four of the emotional continua in the primary analyses remained statistically significant after including age and sex as independent variables. Thus, the overall pattern of group differences was not attributable to age or sex differences.

5. Discussion

An emotional continuum paradigm was used to test whether schizophrenia patients demonstrate atypical patterns of categorical perception or biases in the perception of unpleasant and pleasant facial expressions of emotion. While the logistic functions used in previous research (Pollak and Kistler, 2002) to model the performance data of individuals on this paradigm worked very well for participants in the healthy control group, it was not well suited for a substantial number of schizophrenia patients. Instead, we used an alternative data analytic approach that focused on modeling performance at the group (rather than the individual) level. The control group demonstrated the expected sigmoidal curves with emotion identification approaching 100% consistency near the endpoints of the four continua, which is characteristic of the typical pattern of categorical perception of emotion. The performance data for the schizophrenia group also resembled a sigmoidal function form (rather than a clearly flat or continuous form) and did not significantly differ from controls in terms of switch points between emotions. However, the main finding for the patient group was a generally less clear demarcation between emotions compared to the control group across the four continua. This pattern was not attributable to potential confounds of age or sex. Contrary to our expectations, we did not find evidence of emotion-specific perceptual disturbances in schizophrenia in terms of categorical processing.

While impaired accuracy on standard emotion identification and discrimination tasks have been extensively documented in schizophrenia (see Mandal et al., 1998; Edwards et al., 2002 for reviews), these tasks do not directly evaluate the fundamental issues of whether patients demonstrate typical patterns of categorical perception or emotion-specific biases in perception. The application of the emotional continuum paradigm to schizophrenia in the current study permitted these issues to be directly evaluated. Regarding categorical perception in schizophrenia, the generally shallower slopes in the schizophrenia group indicate that in the range of ambiguous facial
stimuli (i.e., between the two prototype expressions) patients were significantly less sharp in their categorizations of ambiguous stimuli to one emotion category or the other.

Interestingly, young adults with high functioning autism have been found to demonstrate a similar pattern of shallower response slopes than controls on a comparable paradigm (for angry–sad and angry–afraid, but not happy–sad, continua; Teunisse and Gelder, 2001). In that study, shallower response curves significantly correlated with lower social IQ scores in the individuals with autism. It is possible that the impaired perceptual boundaries shown by the patients in the current study might also contribute to the difficulties in social competence that individuals with schizophrenia commonly experience. Categorical perception of emotion appears to be a fundamental feature of perception that presumably enables people to rapidly and appropriately respond to cues in the social environment that are critical for adaptive functioning (e.g., Ekman and Davidson, 1994; Etoff and Magee, 1992). The generally less clear demarcations between emotions shown by the schizophrenia group may render patients prone to misinterpreting the intended meanings of subtle or ambiguous emotional cues during their daily interactions with others. In addition, unlike the emotional continuum task, which did not impose a time limit on participants’ responses, emotional displays in daily life are often relatively brief and require rapid decoding. Mismatches between intended and perceived meanings of facial displays of emotion may contribute to communication breakdowns, misunderstandings, and ineffective interpersonal problem solving. The categorical boundary disturbances identified in this initial study may be informative in the search for determinants of poor functional outcome in schizophrenia (Green et al., 2000) and contribute to the development of psychosocial treatments aimed at improving affect perception and daily functioning (e.g., Wolwer et al., 2005).

While the perception of facial expressions was generally less clearly defined in the schizophrenia group, the patients did not demonstrate a systematic negativity bias in identifying ambiguous faces (unlike the previous finding with abused children from Pollak and Kistler, 2002). The presence of such a bias was inferred from analyses of emotion identification errors involving misattribution of emotions to neutral faces (Kohler et al., 2003). There was some evidence of a tendency for patients to over-identify ambiguous faces as angry in the angry–fear continuum. However, this tendency did not appear to map onto a general bias to over-identify anger or approach-related emotions, as no trend toward between-group differences was evident on the angry–sad continuum. Thus, the evidence was not convincing for any emotion-specific bias in the interpretation of ambiguous faces in the schizophrenia group.

A limitation of the current study is that a non-emotional categorical perception task was not administered, leaving open the question of whether the impaired boundary definitions shown by the schizophrenia group reflect a more general face processing or non-specific perceptual deficit. It would be beneficial for future studies to include morphed images of non-emotional faces (i.e., neutral expression) in a linear continuum between two endpoints (such as from 100% female to 100% male or 100% young to 100% old) as a comparison to the morphed images of facial expressions of emotion. For example, patients demonstrated a similarly abnormal pattern of a shallower response curve, but a similar category boundary location compared to healthy controls in the perception of non-emotional speech sounds (Cienfuegos et al., 1999). Further clarification of this issue may be useful in elucidating the neuropsychological mechanisms that contribute to poor facial affect perception in schizophrenia.

The current study has some additional limitations. First, the patient and control groups were not matched for age and sex, although supplemental analyses indicated that the pattern of results was not attributable to these potential confounds. Second, because our patient sample was clinically stabilized without prominent positive or negative symptoms at the time of testing, we were not able to examine the associations between psychiatric symptoms and performance in the categorical perception of emotion. Third, our reliance at the group level (as opposed to the individual level) of analysis leaves open the possibility that the group differences were carried by a small number of outliers among the patients. Although visual inspection of the individual data suggests that all of the patients showed the expected pattern, this remains a possibility. Fourth, concerns have been raised that the two-way forced-choice identification method used in this research could artificially produce results that are consistent with categorical perception. However, an alternative discrimination approach (ABX task) has shown good convergence with the forced-choice method used in this study (e.g., Calder et al., 1996, Etoff and Magee, 1992; Pollak and Kistler, 2002; Young et al., 1997), making it unlikely that the current results reflect a statistical artifact. Despite these limitations, we
conclude from this study that schizophrenia patients as a group showed generally less sharp demarcations than controls in their categorical perception of boundaries between key emotions.

Acknowledgements

Funding for this project was supported by the National Institute of Mental Health Grant MH-43292 and MH 65707 (M.F. Green, P.I.) and the Department of Veteran Affairs, VISON 22 Mental Illness Research, Education, and Clinical Center (MIRECC, S.R. Marder, P.I.). The authors wish to thank Mark McGee, Bi-Hong Deng, and Poornang Nori for their assistance in data collection and data management, and Brett Lewis for programming the task. The authors also would like to thank Seth D. Pollak, Ph.D. and Paul Ekman, Ph.D., for permission to use their measures. Data analyses were conducted by Sun Sook Hwang, M.S., M.P.H., of the Biostatistics Core of the UCLA Neuropsychiatric Institute.

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