Abstract

Recovery of emotional functioning following stroke has received limited attention in the neuropsychological literature. By emotional functioning, we refer to a range of processing modes, including perception, expression, experience, and behavior. The aim of the current study was to evaluate the course of prosodic emotional expression over time in individuals with stroke. Posed prosodic expression tasks from the New York Emotion Battery were administered to right brain-damaged (RBD), left brain-damaged (LBD), and demographically matched normal control (NC) participants at two separate testing times (median interval of 25 months). Posers (i.e., individuals producing the emotional expressions) were required to produce neutral-content sentences using four different emotional tones (happiness, sadness, anger, and fear). Raters judged poser output for accuracy, intensity, and confidence. For accuracy ratings, RBDs and LBDs were impaired relative to NCs at baseline. In terms of recovery, there was a tendency for LBDs to improve over time, and there was a significant decline for RBDs. Inspection of the group mean data suggested that frontal lesions had a negative impact on prosodic emotional expression in RBDs and that lesion extent did not systematically influence performance at baseline or over time. Participants maintained their relative standing on the NYEB expression tasks over time. Finally, no significant relationships were found between participant performance on prosodic emotional perception and expression tasks at either testing time, suggesting that these two processing modes are relatively independent.

Keywords: Stroke; Recovery; Emotion; Prosody; Expression; Hemispheres; Brain damage

1. Introduction

Despite an ever-increasing literature on the recovery of brain functions following stroke, there are relatively few investigations on the recovery of emotional functioning. Emotional processing is an integral component of behavioral and psychological adaptation necessary for learning, motivation, coping, and decision-making. Thus, increasing our understanding of emotional sequelae following stroke is important (e.g., Eslinger, Parkinson, & Shamay, 2002).
Previous research examining speech and language functions in aphasic patients (e.g., Fazzini, Bachman, & Alpert, 1986) has shown that whereas most spontaneous recovery occurs in the first 6 months following stroke, significant improvement can continue to take place several years after stroke (Kertesz, 1993). Moreover, neuroimaging studies have demonstrated a complex pattern of brain reorganization subsequent to recovery from stroke that can be viewed as a mechanism enabling recovery (e.g., Chollet et al., 1991; Weiller, 1995).

The course of functional recovery following stroke is uncertain and may depend on a number of factors, including lesion location (Nelson, Cicchetti, Satz, Sowa, & Mitrusina, 1994) and environmental variables (Eslinger et al., 2002). For instance, Nelson et al. (1994) assessed behavioral disturbance (e.g., depression, mania, and indifference) in left brain-damaged (LBD) and right brain-damaged (RBD) patients at 2-week, 2-month, and 6-month intervals. Their findings revealed differential recovery rates, depending on hemispheric side of lesion. Initially, LBDs exhibited a slower rate of recovery, as compared to RBDs; however, at 6 months post-stroke onset, the rate of recovery for the LBDs stabilized, whereas the RBDs continued to demonstrate functional decline.

Few studies have examined the recovery of prosodic emotional expression, however, aprosodia is a condition commonly observed in stroke patients. Although case reports have documented recovery of prosodic functioning, aprosodia can persist (Hughes, Chan, & Su, 1983). Ross and Mesulam (1979) described two patients with aprosodia following a right-hemisphere lesion. One regained the ability to express emotion 8 months later, but the second did not show improvement at a 5-year follow-up. Egelko et al. (1989) investigated the recovery of facial and prosodic affective comprehension in RBD, LBD, and normal control (NC) participants and reported improvements in facial perception in RBDs but not in LBDs. More recently, a study of facial, prosodic, and lexical emotional perception conducted in our laboratory (Zgaljardic, Borod, & Slivinski, 2002) revealed limited recovery, whereby RBDs significantly improved relative to LBDs and NCs, but only on lexical perception tasks. The current study extended previous work from our laboratory by focusing on the recovery of emotional expression. Posed prosodic emotional expression tasks from the New York Emotion Battery (NYEB; Borod, Welkowitz, & Ober, 1992) were administered, on two separate occasions, to individuals with unilateral stroke and to demographically matched NCs. The prosodic output was later evaluated by raters for accuracy and intensity of emotional expression.

A second objective of this study was to investigate brain lateralization of prosodic emotional expression functions. The literature on prosodic expression in brain-damaged patients points to the right hemisphere as dominant for this function (e.g., Blonder, Pickering, Heath, Smith, & Butler, 1995; Borod, Bloom, Brickman, Nakhutina, & Curko, 2002; Borod, Koff, Lorch, & Nicholas, 1985; Gorelick & Ross, 1987; Ross, 1993, 1997; Ross & Mesulam, 1979; Schmitt, Hartje, & Wilmes, 1997; Tucker, Watson, & Heilman, 1977). These findings have been corroborated by studies that have employed a wide variety of methods: (a) the Wada technique (Ross, Edmondson, Siebert, & Homan, 1988), (b) progressively reduced verbal-auraliterary conditions (Ross, Thompson, & Yenkosky, 1997), (c) acoustical analysis of fundamental frequency (Pell, 1999a, 1999b), and (d) the examination of the use of tonal languages, such as Chinese and Thai (Gandour, Larsen, Dechongkitt, Pinglarpisit, & Khunadorn, 1995).

When examining site of lesion, there is considerable literature implicating frontal brain structures in the expression of emotion (e.g., Hornak, Rolls, & Wade, 1996; Kolb & Taylor, 1990; Pick, Borod, Ehrlichman, & Bloom, 2003; Wasserman, Borod, & Winnick, 1998; Weddell, Miller, & Trevathan, 1980) and some specifically within the right hemisphere (Borod, 1993; Borod et al., 1985; Ross, 1985, 1997; Ross & Rush, 1981). In spite of these findings, the right-hemisphere hypothesis has not received unequivocal support (e.g., Borod, Bloom, et al., 2002; Bradwik et al., 1991; Davidson, 1984; Helfer, 1990; Kinzbourne & Bemporad, 1984). For instance, Van Lancker and Sidtis (1992) suggested that prosodic processes involve multiple functions that are distributed across the two cerebral hemispheres. Moreover, several brain structures, regardless of hemispheric location, have been implicated as playing an important role in the ability to express emotion through prosody. These include the supra-Sylvian region (Ross, 1985), deep white matter below the supplemental motor area (Ross et al., 1997), and the basal ganglia (Cancelliere & Kertesz, 1990).

Thus, identifying brain structures that are critical for prosodic emotional expression remains a relevant objective in emotion research. The current study will explore the role of intra-hemispheric sites, while focusing on investigating hemispheric specialization for this function.

The third objective of the current study was to examine the relationship between expressive and perceptual prosodic emotion. Research using brain-damaged and NC participants has demonstrated that a lesion may affect one mode but not the other (Borod, 1993; Borod, Koff, Lorch, & Nicholas, 1986; Gainotti, 1987; Ross, 1981; Ross & Mesulam, 1979). Furthermore, findings in RBDs have suggested a dissociation, whereby emotional expression may be subserved by anterior brain structures and emotional perception by posterior structures (Ross, 1985, 1997; Ross & Rush, 1981).
Table 1
Demographic information for each participant group at Time 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measure</th>
<th>Range</th>
<th>RBDs (N=9) mean/S.D.</th>
<th>LBDs (N=8) mean/S.D.</th>
<th>NCs (N=7) mean/S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Years</td>
<td>45–79</td>
<td>66.3</td>
<td>64.3</td>
<td>58.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10.3</td>
<td>11.4</td>
<td>10.3</td>
</tr>
<tr>
<td>Education</td>
<td>Years</td>
<td>4–20</td>
<td>13.3</td>
<td>13.0</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
<td>4.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Occupationa</td>
<td>9-Point scale</td>
<td>1–9</td>
<td>5.6</td>
<td>5.5</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td>2.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Months post-stroke</td>
<td>Months</td>
<td>2–49</td>
<td>18.3</td>
<td>18.0</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16.4</td>
<td>17.3</td>
<td>–</td>
</tr>
</tbody>
</table>

RBD: right brain-damaged participants; LBD: left brain-damaged participants; NC: normal control participants.

The relationship between posed prosodic emotional perception and expression was previously explored by Borod, Welkowitz, et al. (1990) in RBD, Parkinson’s disease, depressed, and schizophrenic patients, as well as healthy controls, but no significant relationships were reported. The current study examined this same relationship in RBDs, LBDs, and NCs, utilizing perception data from an earlier study (Zgaljardic et al., 2002).

In summary, the current study had the following objectives: (1) to examine the recovery of prosodic emotional expression function in stroke patients; (2) to investigate hemispheric lateralization for posed prosodic emotional expression; and (3) to examine the relationship between expressive and perceptual modes of prosodic emotional processing.

2. Method

2.1. Participants

Participants were 33 adults, including 24 posers (i.e., individuals producing the posed emotional expressions) and nine raters (i.e., individuals evaluating the posed expressions). All participants were right-handed, as assessed by a hand preference inventory (Coren, Porac, & Duncan, 1979), with no reported history of converting from left-handedness, and were native speakers of English or fluent in English by age seven.

2.2. Posers

Volunteers from the Mount Sinai Medical Center and New York City residents were recruited as posers. Posers were 24 adults, including eight LBDs (25% female), nine RBDs (66% female), and seven NCs (57% female). All posers were between the ages of 47 and 79 (overall $M=63.7$, $S.D. =10.8$), had an overall mean education level of 13.7 years ($S.D. = 3.6$), and had an overall mean occupation level of 5.9 ($S.D. = 2.0$) on the Hollingshead Scale (Hollingshead, 1977). No significant group differences ($p > .05$) were found for age, years of education, or occupational level at baseline (see Table 1).

2.2.1. Neurological symptomatology

All brain-damaged patients had experienced a unilateral stroke, confirmed by CT or MRI report and/or clinical neurological examination (see Table 2 for lesion descriptions). In one of the 17 cases, neither scans nor reports were available for direct verification of the lesion location; this poser was diagnosed by clinical neurological exam as having had a right middle cerebral artery infarct. The Fisher exact probability test (Siegel & Castellan, 1988) was used to examine the number of RBDs versus LBDs with or without a lesion in each site, at each level (i.e., cortical, subcortical, or cortical plus subcortical), and with each number of brain areas involved. None of the comparisons was statistically significant.
Table 2
Neurological symptomatology and lesion location for brain-damaged patients

<table>
<thead>
<tr>
<th>Lesion location</th>
<th>RBD group</th>
<th>LBD group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Temporal</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Parietal</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Occipital</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Corona radiata</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Internal capsule</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>External capsule</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Optic radiations</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Basal ganglia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Caudate</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Putamen</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Gisternum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Extreme capsule</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thalamus</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Number of sites involved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Two</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Three</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Four or more</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Neurological symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiparesis</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Facial paresis</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sensory loss</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Visual field deficits</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

RBD: right brain-damaged participants; LBD: left brain-damaged participants.
Quantities indicate the number of participants in each group falling into each lesion location and neurological symptoms subcategory; note that there can be more than one lesion site per subject.

2.2.2. Screening variables

All posers were screened in order to exclude those with a history of neurological disease (other than stroke), substance abuse, psychiatric disorder (SADS—Lifetime Version; Endicott & Spitzer, 1978), or mental retardation (Wechsler, 1981). Attention and memory subtests from the Mattis Dementia Rating Scale (Mattis, 1988) and selected subtests (e.g., Commands and Complex Ideational Material) from the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983) were administered to ensure that basic cognitive and linguistic abilities were sufficiently intact. Cutoff scores of 1–2 standard deviations (S.D.) below the normal mean were utilized for all screening measures.

2.3. Raters

Nine undergraduate students at Queens College served as raters; they had no positive history of substance abuse, neurological disease, psychiatric disorder, or learning disability. Five raters evaluated the emotion data, and four raters evaluated the non-emotional control data.

3. Experimental procedures

3.1. Expression data collection

Posers were administered emotional expression and perception tasks from the NYEB on two separate occasions, Time 1 (T1) and Time 2 (T2), with a median interval of 25 months (range = 13–63 months). As the time since stroke

1 The data from the perception tasks administered are not examined here (see Zgaljardic et al., 2002).
varied across patients, months post-stroke onset were examined to ensure that the patient groups did not differ at baseline; there was no difference between RBDS ($M = 18.3$, S.D. = 16.4) and LBDs ($M = 18.0$, S.D. = 17.3), $t(15) = 0.97$, $p > .05$. Posers were required to complete their first testing and return for a second testing at least 1 year, but no more than 24 months after initial testing. Due to participant attrition, some participants did exceed the 24-month time limit.

3.1.1. Experimental emotion task
In order to assess posed prosodic emotional expression, posers were administered the Prosodic Expression to Command task from the NYEB. The task utilizes four neutral content sentences (e.g., “She put it on the tray”), selected for comprehensibility and for similarity of grammar, rhythm, and length. Sentences were randomly presented using four different orders. Posers were asked to say a sentence using one of eight randomly presented emotions: three positive or pleasant (happiness, pleasant surprise, and interest) and five negative or unpleasant (sadness, disgust, unpleasant surprise, fear, and anger). Participants said each sentence twice while being audi-taped. They were instructed to exaggerate each of the emotional expressions as if they were an actor. Instructions to the participants were as follows, for example, for happiness: “When I say ‘ready go’, I would like you to say ‘They found it in the room’ in a happy tone of voice. Ready, go.” Finally, posers also produced a “neutral” expression, not using any emotional tone, for a non-emotional baseline.

3.1.2. Non-emotional control task
To control for aspects of prosodic expression not directly related to emotional communication, the Intonation Contours task from the NYEB was given. This task contains 12 items and requires posers to read nonsense syllable-strings (e.g., “ba-ta-ga”) in a tone of voice indicating non-affective prosody (i.e., question, statement, or command).

3.2. Rating procedures
The rating procedures, developed by Canino, Borod, Madigan, Tabert, and Schmidt (1999) involved the following stages: (a) preparation of the data for rating; (b) training the raters and establishing inter-rater reliability (IRR); and (c) rating sessions. To assess posers’ ability to communicate emotion through prosody, raters judged each expression for intensity, accuracy, and confidence. Intensity ratings assessed the degree of expressiveness and emotionality with which each intoned sentence was produced via a 7-point Likert scale. For the accuracy ratings, raters judged which emotion category best conveyed each intoned sentence, using a randomized list of the four emotions. A confidence scale (0–4) was also utilized in which raters indicated how confident they were in their accuracy rating. For Intonation Contours, the raters judged whether the intoned syllable string matched the target intonation (1 = correct, 0 = incorrect). Four cross-culturally validated emotions (Ekman & Friesen, 1975; Izard, 1977) were selected for expression ratings (i.e., happiness, fear, anger, and sadness). The poorly differentiated emotions, such as interest, were eliminated in an effort to simplify the task for the raters without compromising the quality of the information evaluated.

The recording used to rate the Prosodic Expression to Command expressions was created by copying each response in a randomized order with respect to participant group, emotion type, and individual poser. For the intensity analysis, the neutral expression was included as a baseline. Each expression was presented twice with 2 s between presentations and a 5-s interval between trials.

3.2.1. Rater training
Raters were trained to ensure high IRR and accurate understanding of the rating task. Training procedures were adopted from Canino et al. (1999), who demonstrated that the use of these procedures allowed for sufficient IRR. Training consisted of three parts: (a) Introduction—a description of the rating variables and rating instructions were provided, and relevant terms defined; (b) Presentation of Exemplars—posed vocal expressions produced by trained actors were presented (see Borod et al., 1998); and (c) Conferencing—conducted for practice ratings and review. This process continued until an intraclass correlation coefficient of 0.70 or a complete agreement of 70% was obtained for the ratings.

To assess IRR, materials were presented with 30 expressions produced by 30 different individuals reflecting the gender and ethnicity distributions of the three actual poser groups. IRR was evaluated using intraclass correlation for the variables that produced scaled data (i.e., expression intensity and confidence) and percent complete agreement for the variable that generated categorical data (i.e., expression accuracy). First, raters were trained for emotional intensity,
and then actual ratings for intensity were conducted. Next, training occurred for category accuracy, followed by actual ratings for the experimental data. Although no training for the confidence scale was required and raters were not held to a criterion here, the intraclass correlation for this variable (r = .75) was computed. Training procedures for the Intonation Contours Expression task were identical.

3.2.2. Experimental rating sessions

For the Prosodic Expression to Command task, raters were required to evaluate 240 expressions (24 posers × 2 testing times × 5 expressions [four emotions plus neutral]) for the intensity measure and 190 emotional expressions for the category accuracy and confidence measures (24 posers × 2 testing times × 4 emotional expressions). For the Intonation Contours control task, raters were presented with 576 posers’ non-emotional expressions (24 posers × 2 testing times × 3 contours × 4 trials) and a list of three targets. The posers’ expressions were judged correct (score = 1) or incorrect (score = 0) according to the target requested on the original task.

4. Results

4.1. Inter-rater reliability

Since IRR was substantial for all experimental and control variables, mean rating scores were computed across raters, separately, for each emotional parameter and across raters for each intonation contour (see Table 3).

4.2. Inter-hemispheric site of lesion

Repeated-measures ANOVAs were performed to assess recovery for prosodic emotional expression separately for intensity, accuracy, and confidence. For each variable, a 3 × 2 × 4 ANOVA was conducted with one between-subjects factor, Group (RBD, LBD, and NC), and two within-subjects factors, Time (T1 and T2) and Expression Type (happiness, anger, fear, and sadness). Post hoc tests were conducted for statistically significant findings.

Before conducting the experimental analyses, the non-emotional control tasks (i.e., neutral expression and Intonation Contours) were analyzed to see whether there were significant group differences. When one-way ANOVAs were computed for Group (NC, RBD, and LBD) at T1 and T2, none of the findings was significant. Thus, it was not necessary to covary for control task performance in the experimental task analyses to follow.

4.2.1. Intensity

For intensity, a significant main effect of Emotion was found, F (3, 63) = 38.53, p < .001, such that anger (M = 3.46, S.E. = .17) was expressed more intensely (p < .001) than happiness (M = 3.3, S.E. = .16), followed by fear (M = 3.08, S.E. = .12) and sadness (M = 2.16, S.E. = .11). Post hoc pairwise tests revealed significant differences (p < .001) for all comparisons except for two (anger versus happiness, and fear versus happiness). Although, the three-way interaction

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Emotion tasks</th>
<th>Intonation contours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accuracy (%)a</td>
<td>Intensity (%)b</td>
</tr>
<tr>
<td>Training trials</td>
<td>76</td>
<td>.95</td>
</tr>
<tr>
<td>Experimental trials</td>
<td>74</td>
<td>.82</td>
</tr>
</tbody>
</table>

a Intra-class correlations.
b Percent complete agreement.
Table 4
Means (and standard deviations) for the three parameters at Time 1 and Time 2 for RBDs and LBDs with frontal and non-frontal lesions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site of lesion</th>
<th>RBDs T1</th>
<th>RBDs T2</th>
<th>LBDs T1</th>
<th>LBDs T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>Non-frontal</td>
<td>0.51 (.11)</td>
<td>0.43 (.22)</td>
<td>0.43 (.10)</td>
<td>0.49 (.27)</td>
</tr>
<tr>
<td></td>
<td>Frontal</td>
<td>0.45 (.23)</td>
<td>0.33 (.20)</td>
<td>0.50 (.25)</td>
<td>0.61 (.20)</td>
</tr>
<tr>
<td>Intensity</td>
<td>Non-frontal</td>
<td>3.06 (.51)</td>
<td>3.15 (.70)</td>
<td>2.51 (.23)</td>
<td>2.86 (.63)</td>
</tr>
<tr>
<td></td>
<td>Frontal</td>
<td>2.93 (.77)</td>
<td>2.98 (1.12)</td>
<td>3.25 (.84)</td>
<td>3.06 (.35)</td>
</tr>
<tr>
<td>Confidence</td>
<td>Non-frontal</td>
<td>3.11 (.26)</td>
<td>3.41 (.20)</td>
<td>3.46 (.32)</td>
<td>3.31 (.13)</td>
</tr>
<tr>
<td></td>
<td>Frontal</td>
<td>3.33 (.36)</td>
<td>3.33 (.36)</td>
<td>3.50 (.42)</td>
<td>3.63 (.13)</td>
</tr>
</tbody>
</table>

revealed a statistical trend, $F(6, 63) = 2.09, p = .067$, protected $t$-test post hoc comparisons (Welkowitz, Ewen, & Cohen, 1976) did not reveal any evidence for recovery.

4.2.2. Accuracy
For accuracy, a significant main effect of Emotion was found, $F(3, 63) = 8.87, p < .001$, such that post hoc pairwise tests revealed significant differences ($p < .05$) among all comparisons except for two (anger [$M = .59, S.E. = .07$] versus happiness [$M = .48, S.E. = .06; p = .06$], and sadness [$M = .67, S.E. = .05$] versus anger [$p = .463$]). There was also a significant Group by Time interaction, $F(2, 21) = 4.46, p = .024$ (see Fig. 1). Using the protected $t$-test, when examining differences between testing times, LBDs demonstrated an increase ($p < .10$) from T1 ($M = .46, S.E. = .06$) to T2 ($M = .55, S.E. = .07$), whereas RBDs demonstrated a significant decrease ($p < .05$) from T1 ($M = .49, S.E. = .06$) to T2 ($M = .39, S.E. = .07$), and NCs showed no significant difference (T1: $M = .59, S.E. = .07$, and T2: $M = .59, S.E. = .08$). When examining group differences, for T1, RBDs and LBDs were each significantly ($p < .01$) less accurate than NCs. At T2, RBDs were significantly ($p < .01$) less accurate than both NCs and LBDs.

4.2.3. Confidence
For the confidence rating, there were no significant main effects or interactions. The main effect of Group was not significant, with group means as follows: RBDs ($M = 3.36, S.E. = .08$), LBDs ($M = 3.48, S.E. = .09$), and NCs ($M = 3.40, S.E. = .09$).

4.3. Intrahemispheric site of lesion

4.3.1. Frontal lobe involvement
We examined whether individuals with frontal lobe lesions (four RBD and four LBD) were more impaired than those without frontal lobe lesions (four RBD and four LBD), using visual inspection of group means (see Table 4). Using this

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3 Of note, the mean for Fear was .34 (S.E. = .05).
Table 5
Means (and standard deviations) for both patient groups at Time 1 and Time 2 for all three parameters as a function of the number of lesion sites (i.e., 1–2 vs. 3 or more)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number of lesion sites</th>
<th>RBDS T1</th>
<th>RBDS T2</th>
<th>LBDs T1</th>
<th>LBDs T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1–2</td>
<td>0.50 (.11)</td>
<td>0.39 (.18)</td>
<td>0.41 (.10)</td>
<td>0.53 (.27)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>3+</td>
<td>0.46 (.25)</td>
<td>0.36 (.25)</td>
<td>0.55 (.26)</td>
<td>0.58 (.24)</td>
</tr>
<tr>
<td></td>
<td>1–2</td>
<td>2.79 (.60)</td>
<td>3.03 (.66)</td>
<td>2.85 (.78)</td>
<td>2.97 (.59)</td>
</tr>
<tr>
<td>Intensity</td>
<td>3+</td>
<td>3.20 (.64)</td>
<td>3.10 (1.15)</td>
<td>2.93 (.68)</td>
<td>2.95 (.33)</td>
</tr>
<tr>
<td></td>
<td>1–2</td>
<td>3.08 (.23)</td>
<td>3.29 (.15)</td>
<td>3.54 (.33)</td>
<td>3.34 (.13)</td>
</tr>
<tr>
<td>Confidence</td>
<td>3+</td>
<td>3.36 (.34)</td>
<td>3.45 (.37)</td>
<td>3.36 (.45)</td>
<td>3.68 (.06)</td>
</tr>
</tbody>
</table>

The descriptive approach, the mean group performance of frontal patients was compared to that of non-frontal patients for each parameter at each testing time (3 × 2 comparisons). The data showed that in five out of six comparisons, RBDS with frontal lesions were more impaired than RBDS without frontal lesions. However, the opposite pattern occurred for LBDs, where in all six comparisons, patients with frontal pathology performed better than those without frontal lobe involvement.

4.3.2. Number of lesion sites

We also examined recovery, based upon the number of lesion sites involved. Table 5 provides the means and standard deviations for patient groups at T1 and T2 for all three emotion parameters as a function of the number of lesion sites (i.e., 1–2 versus 3 or more). Based on findings of Ross (1981) and Ross and Mesulam (1979), we expected that RBDS with fewer lesions would demonstrate greater recovery than RBDS with more extensive lesions. For this analysis, group performance at T1 was compared to group performance at T2 for each parameter, for each of the patient subgroups (i.e., 1–2 and 3 or more lesions; 3 × 2 comparisons). For RBDS with fewer lesions, there was improvement over time in two out of three comparisons. By contrast, for RBDS with more lesions, there was a decline in performance over time in two out of three comparisons. For LBDs, regardless of the number of lesion sites, in five out of six comparisons, there was improvement over time.

Finally, we looked at whether the number of lesion sites involved affected the level of performance on prosodic emotional expression tasks (see Table 5). Performance of the patients with 1–2 lesions was compared to the performance of the patients with 3 or more lesions for each parameter at each testing time, separately for each patient group (3 × 2 comparisons). When these comparisons were made, there were 8 out of 12 instances in which the patients with more lesion sites performed better than those with fewer sites. Thus, these data do not suggest that the more lesion sites involved, the poorer the performance on these emotional expression tasks.

4.4. Relationship between perception and expression

Pearson product–moment correlations were performed for all participants between performance accuracy on emotional expression and perception tasks at T1 and T2. Correlation coefficients, using the mean of the four emotions, were non-significant for both T1 and T2. Furthermore, when individual emotions were examined, none of the correlations between the processing modes was significant (see Table 6).

4.5. Supplementary analysis

On an exploratory basis, we correlated participants’ performance at T1 with their performance at T2 in order to examine the stability of individual performance relative to other group members on NYEB tasks over time. Examining this trajectory would further shed light on the course that emotional functioning takes following stroke. We predicted that if correlations were positive and significant, it would suggest that individuals maintained their relative standing on
Table 6

<table>
<thead>
<tr>
<th>Time of testing</th>
<th>Mean of four emotions</th>
<th>Happiness</th>
<th>Sadness</th>
<th>Anger</th>
<th>Fear</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>.27</td>
<td>.18</td>
<td>.03</td>
<td>−.23</td>
<td>.25</td>
</tr>
<tr>
<td>$p$</td>
<td>.20</td>
<td>.39</td>
<td>.88</td>
<td>.28</td>
<td>.24</td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>.32</td>
<td>.14</td>
<td>.23</td>
<td>.17</td>
<td>.06</td>
</tr>
<tr>
<td>$p$</td>
<td>.12</td>
<td>.53</td>
<td>.27</td>
<td>.44</td>
<td>.79</td>
</tr>
</tbody>
</table>

this expression task over time. Pearson product–moment correlations were computed between performance at T1 and T2 for all posers, separately for accuracy, intensity, and confidence. For all parameters, correlations were conducted using the average rating for the four emotions under study. Results indicated significant positive correlations for each parameter: accuracy: $r = .71$, d.f. = 22, $p < .001$; intensity: $r = .62$, d.f. = 22, $p < .001$; and confidence: $r = .45$, d.f. = 22, $p = .027$.

5. Discussion

In the current study, we examined recovery of prosodic emotional expression in patients with unilateral stroke. Our findings provide evidence of improvement in emotional expression functions for LBDs, but not for RBDs. In fact, for RBDs, the ability to produce accurate prosodic emotional expression decreased over time. When hemispheric specialization for prosodic emotional expression was investigated, at T1, both RBDs and LBDs were less accurate than NCs. However, at T2, RBDs were less accurate in emotional expression than LBDs and NCs, who did not differ significantly. In addition, visual inspection of group means revealed that having frontal pathology negatively impacted emotional expression functions in RBDs but not in LBDs. These analyses also showed that a greater number of lesions did not systematically lower performance. Finally, correlations between participant performance on NYEB perception and expression tasks indicated that the two processing modes are relatively independent.

5.1. Recovery

Accuracy ratings suggested an improvement for LBDs, but a decline for RBDs, demonstrating that the rate and quality of emotion recovery following stroke may be related to lesion side. This is consistent with findings from previous studies that have investigated the effects of lesion location on functional outcome after stroke. For example, Nelson et al. (1994) demonstrated that LBDs showed mood stabilization 6 months after stroke, whereas RBDs became progressively worse over time. They suggested that additional cognitive deficits may impede recovery in RBDs. In addition, Robertson, Ridgeway, Greenfield, and Parr (1997) examined recovery of motor functions in brain-damaged patients and reported that RBDs demonstrated less recovery than LBDs over a 2-year period. These differences were attributed to deficits in arousal and attention, particularly apparent in RBDs (Heilman & Valenstein, 1985).

As depression is common after stroke (Robinson & Manes, 2000) and can affect prosodic emotional utterances (Borod, Welkowitz, et al., 1990), on a post hoc basis, we examined posers’ performance on a measure of depression to determine whether depressive symptoms contributed to the decline in prosodic expression exhibited by the RBDs. We found that mean Beck Depression Inventory scores for all three groups at both testing times were quite low: Time 1 versus Time 2, respectively, for RBDs = 2.67 versus 5.67; for LBDs = 2.13 versus 3.13; and for NCs = 1.57 versus 3.29. When a two-way ANOVA was conducted on Participant Group (3) × Testing Time (2), a significant main effect of Time was found, $F(1, 47) = 4.49$, $p = .04$, such that for all groups, mean depression scores increased from Time 1 (2.17) to Time 2 (4.12). However, there was no significant main effect of Group ($p = .218$), and the interaction between Group and Time was not significant ($p = .636$). Thus, based on these findings, there was no evidence that depressive symptoms contributed to the decline in performance displayed by the RBDs.

Several other possibilities may explain the lack of significant recovery. First, in the current study, testing for brain-damaged participants at T1 took place, on average, 1–2 years post-stroke. Literature focusing on language functioning following stroke reports that most spontaneous recovery typically occurs 6–12 months post-stroke (e.g., Sarno &
Levita, 1979), although functional recovery has been documented several years following stroke (e.g., Kertesz, 1993). Future research should examine recovery for emotional expression closer to the onset of stroke. Second, the absence of a significant recovery finding may be attributed to our small sample size. Given the preliminary nature of this study, future research focusing on the recovery of emotional expression will need to use a larger number of participants.

Our finding that RBDs decreased in accuracy of expression is in contrast to findings from Zgaljardic, Borod, and Slivinski (2002) in which the accuracy of these RBDs’ emotional perception actually improved or did not change over time. Interestingly, this dissociation between expression and perception is reminiscent of the finding from the aphasia recovery literature that comprehension can recover more rapidly than expression (e.g., Borod, Carper, & Naeser, 1990; Lomas & Kertesz, 1978).

5.2. Hemispheric specialization

The confidence and intensity data did not provide support for the right-hemisphere hypothesis. For these two parameters, no significant differences between the performance of the RBDs and that of the NCs or LBDs were discovered. The results from the accuracy parameter did, however, appear to lend support to the right-hemisphere hypothesis at T2. Specifically, RBDs were significantly less accurate in producing prosodic emotional expressions than either NCs or LBDs. These results, however, are confounded by time. At T1, both RBDs and LBDs performed significantly lower than the NCs. This latter finding is consistent with other studies suggesting that brain-damaged patients with lesions of either hemisphere can demonstrate impairment in prosodic expression relative to NCs (e.g., Baum, Pell, Leonard, & Gordon, 1997; Cancelliere & Kertesz, 1990). For example, Baum et al. (1997) performed acoustical analyses and found that both RBD and LBD patients exhibited fewer of the expected acoustic patterns than did NCs.

5.3. Intra-hemispheric site of lesion

When lesion location was examined by visual inspection of group means, a number of interesting patterns emerged. First, RBDs with frontal lesions performed worse than RBDs without frontal lobe involvement. This is consistent with findings from previous work that has also examined the influence of intra-hemispheric lesion site on functional outcome (Borod et al., 1985; Ross, 1985, 1997; Ross & Rush, 1981; for review, see Borod, 1993). Of note, in our sample, LBDs demonstrated the opposite pattern, whereby those with frontal lesions performed better than those without such lesions. This finding had not been anticipated.

Second, when the number of lesion sites was examined, our descriptive analyses indicated no consistent pattern in the way that performance was affected. The fact that having more lesions sites did not lead to a greater degree of impairment in performance was interesting in light of the notion in the literature that neuropsychological deficits might be related to size of lesion rather than to lesion location. However, since volumetric data were not available in this sample of participants, we were unable to examine this issue in a more controlled manner. Interestingly, a previous study (Mandal et al., 1999), focusing on the perception of facial emotion in patients with unilateral brain damage, also found no relationship between lesion size and perceptual accuracy. In that study, volumetric data were available to characterize lesion size.

Finally, we explored whether those RBDs with more lesion sites would demonstrate less recovery at T2. Our results suggested that this was the case for two of the three variables. These exploratory findings are consistent with findings from Ross (1981) and Ross and Mesulam (1979). Future studies employing a larger sample size may be able to clarify the relationship between the number of lesion sites and recovery rate.

5.4. Relationship between emotional expression and perception

When the relationship between processing modes was examined, all correlations between expression and perception tasks were non-significant at both T1 and T2. These results are consistent with previous research with brain-damaged and normal participants, indicating that the two modes are independent (e.g., Borod, 1993; Borod, Welkowitz, et al., 1990; Borod et al., 1986; Gainotti, 1987; Ross, 1981; Ross & Mesulam, 1979). Furthermore, at the level of the individual emotion, there were also non-significant correlations. Previous work with RBDs has suggested dissociations whereby emotional expression may be subserved by anterior brain structures and emotional perception by posterior brain structures.
areas (Ross, 1985, 1997; Ross & Rush, 1981). In this study, visual inspection of group means indicated that in five of six comparisons among RBDs, participants with frontal pathology performed at lower levels on measures of emotional expression than did those without frontal pathology. These results appear to support previous findings implicating anterior regions in emotional expression (e.g., Hornak et al., 1996).

5.5. Methodological considerations

In the current study, we employed methods that utilized raters for judging posed prosodic expression data developed and piloted in our laboratory (Borod, Canino, Geraci, & Schmidt, 2002; Canino, 2001; Canino et al., 1999). One methodological aim of our study was to test the reliability of this rating methodology and to demonstrate that the high IRR achieved previously was not experimenter-specific. The substantial IRR scores achieved in the present study indicate that, in fact, this methodology can be used successfully by researchers in the future. In addition, because this methodology allows for direct comparisons of multiple channels of communication, researchers investigating facial and lexical emotional expression may have an opportunity to analyze comparisons between those channels and our findings for prosodic expression.

Our study design also afforded the opportunity to look at the level of stability of individual standing on prosodic expression measures. This is important in light of the fact that there is limited information regarding the course that individual emotional functioning takes following stroke. The stability of performance was recently examined using a majority of the current sample for facial, prosodic, and lexical emotion perception tasks (Zgaljardic et al., 2002), as well as for lexical emotion expression tasks (Zgaljardic, Nakhutina, Tabert, & Borod, 2001). These studies showed substantial consistency in individual scores for both sets of measures. In the current study, our findings have also revealed that individuals maintained their relative standing on NYEB prosodic expression measures over time. The finding is important in increasing understanding among medical professionals that some form of intervention is required in order to improve emotional functioning after stroke.

Acknowledgements

This research was supported, in part, by NIH R01 DC01150 subcontract and MH42172 grant and by Professional Staff Congress—CUNY Research Award Nos. 65621-00-34 and 66712-00-35 to Queens College. We are grateful to Dr. Martin Sliwinski for assistance regarding research design in the initial phase of this project.

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