Areas of Right Hemisphere Ischemia Associated with Impaired Comprehension of Affective Prosody in Acute Stroke

Although the left hemisphere is widely believed to be dominant in syntactic and phonological processes underlying language comprehension, the right-hemisphere may be essential for comprehension of affective prosody (Ross & Monnet, 2008; Heilman, Bowers, Speedie, & Coslett,1984). In particular, the right posterior-superior temporal region has been implicated in the comprehension of affective prosody (Meyer, Alter, Friederici, Lohmann, & Cramon, 2002; Ross & Monnot, 2008). However, not all patients with damage to this area have impaired comprehension of prosody, and some patients with damage to other areas (e.g. thalamus, frontal cortex) have impaired prosodic comprehension, so it is unclear what areas are essential for comprehension of prosody. One limitation of most previous studies is that they have studied patients relatively late after stroke, after potential recovery and reorganization of structure-function relationships. Patients may have had impaired comprehension of prosody immediately after the lesion, but recovered. Therefore, we studied patients acutely, before the opportunity for recovery or reorganization. We also evaluated areas of hypoperfused (dysfunctional) brain tissue, as well as infarcted tissue that might account for the deficit.

Method

We enrolled a consecutive series of consenting participants with symptoms of acute right hemisphere acute ischemic stroke (n=42) along with age and education-matched hospitalized controls with normal MRI (n = 17). Exclusion criteria are listed in Table 1. An Aprosodia Battery (Ross, Thompson, & Yenkowsky, 1997), described below, was administered and MRI was obtained within 24 hours from onset of symptoms (for stroke patients).

Attitudinal Prosody: Each participant was instructed to listen to recordings of 40 randomized statements and asked to decided if each statement was either sincere (n = 20 items) or sarcastic (n = 20 items) (e.g. “This looks like a safe boat”).

Prosody Identification: This task consisted of 3 affective-prosodic comprehension stimuli, including sentences (“I am going to the other movies.” n = 24 items), monosyllabic utterance (“ba ba ba ba ba ba;” n = 24) and asyllabic utterances (“aaaaahhhhh;” n = 24). Each participant was instructed to listen to recordings and asked to identify the affective meaning intoned in each sentence or utterance using six written choices such as neutral, happy, angry, sad, disinterested, or surprised. Each choice was also presented with facial line drawings to further reflect each affective meaning. The intonations of each sentence or utterance were presented in randomized order.

Prosody Discrimination: The stimuli for this task were the same as the sentence stimuli used for the Prosody Identification task. Participants were instructed to listen to a recording of sentence pairs and asked to identify if each had the same or different emotion. Each sentence pair was presented in a randomized order, 12 with the same affective intonation but different stress patterns (an early word in the sentence or a late word in the sentence was stressed) and 12 with different intonations but the same stress pattern (n = 24 items total).

The number of correct responses was scored for each stimuli set. Normative data by age range were used to compute Z-scores (Ross, Thompson, & Yenkowsky, 1997)

MRI Protocol.

Patients had T2, FLAIR, Susceptibility Weighted Images, Perfusion Weighted Imaging (PWI), Diffusion Weighted Imaging (DWI). Technicians, blinded to the performance on the Aprosodia Battery scored images for infarct (bright on DWI) and/or hypoperfusion (>4 sec delay on PWI) in the following regions of interest: Brodmann's areas 4, 6, 10, 11, 18, 19, 20, 21, 22, 37, 38, 39, 40, 44, 45, 46, cerebellum, thalamus, basal ganglia and sub-cortical white matter.

Statistical Analysis:

We first determined whether or not there were significant differences between right hemisphere stroke participants and non-brain damaged control participants on prosodic comprehension tests.

To identify areas essential for prosodic comprehension, we dichotomized behavioral and imaging variables, and used chi square tests to evaluate associations between ischemia in each ROI and impaired performance (≥2 standard deviations below the mean for the individual's age, using normative data from Ross & Monnot, 2008) on each of the identification and discrimination tasks.

For each analysis reported, data for right-handed and left-handed participants were analyzed separately. There were no significant associations for left-handed patients (perhaps because of inadequate power), so only results for right-handed patients are reported.

Results

There were significant differences between participants with and without stroke on all types of prosodic comprehension (Table 2).

Identification of attitude (sarcastic vs. sincere) from sentences was associated with ischemia in BA 6 (chi squared=6.2; df1; p<0.013) and thalamus (chi square =4.91; df1; p=0.027). Discrimination (same/different) of prosody was associated with ischemia in BA 44 (chi square=6.65; df1; p=0.010) and thalamus (chi square=4.1; df1; p=0.043). These analyses indicated that BA 6, 37, 44 and thalamus might be critical areas for identification of affective prosody. We ran ANOVA to compare mean scores on each of the tasks for patients with and without ischemia in each of these regions. See Figure 1 for mean scores for each task by those with and without ischemia in each region.

Patients with ischemia in right BA 6 were significantly more impaired than those with intact BA 6 in identification of attitude of sentences [F (1,38) = 6.82; p=0.013], identification of affective prosody in sentences [F (1,38) = 15.55; p<0.0001], monosyllabic utterances (F (1,38) = 21.78; p <0.0001], and asyllabic utterances [F (1,38) = 13.74; p=0.001].

Patients with ischemia in right BA37 were significantly more impaired than those with intact BA 37 in identification of attitude of sentences [F (1,38) = 6.84; p=0.013], identification of affective prosody in sentences [F (1,38) = 19.4; p<0.0001], monosyllabic utterances [F (1,38) = 27.5; p<0.0001], and asyllabic utterances [F (1,38) = 13.9; p=.001].

Patients with ischemia in BA44 were significantly more impaired than those with intact BA 44 in identification of affective prosody in sentences [F (38, 1) = 5.07; p<0.03], monosyllabic utterances (F (38, 1) = 10.83; p=0.002], and asyllabic utterances [F (38, 1) = 5.62; p=0.023].

The z-scores of right handed patients with ischemia in the thalamus were significantly different from the z-scores of patients without thalamic ischemia in identification of affective prosody in sentences [F (1, 31) =5.72; p=0.023] and monosyllables [F (1, 31) =5.31 p=0.028], and discrimination of affective prosody [F (1, 21) =5.71; p=0.024).

Discussion:

Ischemia in BA6, 37, 44 and/or thalamus was associated with impaired identification of affective prosody of sentences, monosyllabic utterances, and asyllabic utterances. Ischemia in BA 6 and 37 was also associated with impaired identification of sarcasm in sentences and ischemia involving the thalamus was associated with impaired discrimination of affective prosody. These finding indicate that the posterior frontal cortex (BA44 and BA6) and inferior temporal cortex (BA 37) cortex and thalamus are areas necessary for identifying the affective meanings intoned in speech. Results confirm findings from previous studies of chronic strokes in which some patients with lesions in posterior frontal cortex, temporal cortex, or thalamus had impaired comprehension of prosody. However, we did not find that acute lesions of the insula, putamen, or parietal operculum were associated with impaired comprehension of prosody as observed in some patients in the study by Ross and Monnot (2008). It is likely that patients with chronic stroke with prosodic comprehension deficits whose lesions involved these areas also had lesions extending to frontal or temporal cortex or thalamus that might better account for their deficits.

References

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Table 1. Exclusion Criteria for Stroke Patients

- Altered level of consciousness
- Ongoing sedation
- Inability to understand the tasks
- Previous symptomatic stroke
- Previous neurological or psychiatric disease
- Known uncorrected hearing loss
- Known uncorrected visual loss
- Contraindication for MRI or Gadolinium
- Lack of premorbid proficiency in English

Table 2 Performance for Affective Prosody Comprehension Task. Mean and Standard Deviation Scores and Demographics for Participants with and without Right Hemisphere Ischemia.

	Age	Educ-ation	Altitudinal Prosody	Prosody Identification			Discrimination Prosody
				Sentence	Mono-syllabic	Asyllabic	
Right Hemisphere Stroke	58.4 ±12.9	13.6 ±5.3	27.20 ± 2.588	12.0 ± 4.796	10.60 ± 4.690	9.200 ± 3.420	14.00 ± 3.559
Controls	56.3 ±10.7	16.9 ±5.4	31.94 ± 6.13	19.71 ± 3.88	19.17 ± 4.30	16.11 ± 5.06	18.00 ± 5.96
F	3.7	.97	5.8	8.9	10.2	7.7	4.4
p-value	ns	ns	0.02	0.005	0.003	0.009	0.04

Figure 1: Mean and Standard Deviation Scores for Each Task by Those With and Without ischemia in each region.