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Perceptual and acoustic correlates of affective prosody repetition in transcortical aphasias

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Abstract
Perceptual judgements and acoustic analyses of affective prosody during sentence repetition were examined in four patients with transcortical aphasias and in two normal controls. Although all aphasic patients had a relative preservation of sentence repetition, perceptual ratings revealed that they repeated using correct affective intonation significantly less frequently than normal control subjects. Acoustic analysis revealed that patients with transcortical aphasias were unable to impart angry and happy intonation during repetition, producing flat intonation contours in most sentences. Restricted modulation of FO and flat declinations of repeated utterances were found in patients with transcortical aphasias caused by lesions within the left perisylvian language area as well as outside this area. These findings suggest that repetition of affective prosody in transcortical aphasias is usually disrupted regardless of the intrahemispheric location (perisylvian or extraperisylvian) of the lesion, and that an adequate repetition of affective prosody may require bilateral, simultaneous hemispheric processing.

Introduction
Prosody refers to variations in rhythm, pitch, distribution of stress, and melodic contours in language (Monrad-Krohn 1947). Although there has been considerable research on prosodic deficits after lateralized brain damage, the hemispheric specialization of speech prosody still remains a controversial issue (Ross 1988, Ryalls 1988, Van Lancker and Sidtis 1992, Heilman 1993). Some authors argue that affective prosody is strongly lateralized to the right hemisphere, whereas linguistic aspects of prosody are lateralized, but not exclusively, to the left hemisphere (Ross 1988). On the other hand, based on the multifaceted nature of prosody and on instances of negative evidence (e.g. patients with spared affective prosody despite an appropriate right hemisphere lesion—Lebrun et al. 1985, Brådvik et al. 1990), some authors view prosody as a diffusely distributed communicative function without a specific pattern of brain organization (Ryalls 1988, Van Lancker and...
Sidtis 1992). Finally, others even suggest that the brain lateralization of prosody may vary according to the affective or linguistic content of the message (Shipley-Brown et al. 1988).

Damage to the left hemisphere usually induces deficits in the production of prosody in addition to aphasia (Monrad-Krohn 1947). However, since aphasia may mask concurrent prosodic production deficits, there are few systematic studies of prosody in aphasics. In these studies the analysis of acoustic parameters was focused on the linguistic aspects of prosody (e.g. Danley and Shapiro 1982, Kent and Rosenbek 1982, Ryalls 1982, Cooper et al. 1984, Gandour et al. 1989).

There are isolated reports dealing with the evaluation of prosodic production of aphasic patients in affective contexts (Speedie et al. 1984, Ross 1992). Ross (1992) evaluated the production of affective prosody in various clinical types of aphasia (Broca's, Wernicke's, and global), and compared the patient's performance on a quantitative verbal-articulatory task with those obtained from a group of right brain-damaged patients with aprosodia. Ross concluded that deficits in the production of affectively intoned speech in aphasics with left hemisphere damage are probably secondary to articulatory-verbal disturbances, and not due to deficits in affective prosody. Speedie et al. (1984) studied the perceptual correlates of repetition of affective prosody in two patients who had mixed transcortical aphasia in association with lesions of the left hemisphere located outside the perisylvian language area (PLA) (frontoparietal white matter in Patient 1 and parieto-occipital in Patient 2). These authors found that both patients could repeat propositional language verbatim, but they were unable to impart affective intonation, and they repeated almost all sentences in a monotone (Speedie et al. 1984). Based on perceptual judgements (acoustic analysis was not performed) and radiological findings, Speedie and co-workers hypothesized that these two patients could repeat propositional language because the left PLA was intact, but that they were unable to repeat imparting affective tone because the intact left PLA was disconnected from the right hemisphere, which is dominant for affective prosody.

Although transcortical aphasia (TA) is usually produced by lesions located outside the left PLA (Rubens and Kertesz 1983), in a recent review of the literature of acute TA we found that in a considerable number of patients it resulted from damage to the PLA (see Berthier et al. 1991a). Moreover, in three patients with TA and PLA involvement bilateral amytal injections (Wada test) demonstrated that word and sentence repetition were subserved by the contralateral hemisphere (Bando et al. 1986, Berthier et al. 1991a). Therefore, while the mechanism of disconnection might explain the pattern of impaired repetition of affective prosody in Speedie et al.'s patients, it remains to be determined if the repetition of affective prosody is also disrupted in patients who develop TA after extensive damage to the left PLA, and if these two TA groups (with or without left PLA involvement) have similar or different patterns of impairment in the repetition of affective prosody.

In the present study we investigated several issues left unaddressed in previous research. First, we examined the perceptual as well the acoustic correlates of affective repetition in TA. Secondly, we investigated whether impaired affective repetition was also present in other clinical types of TA (transcortical motor aphasia and transcortical sensory aphasia). Finally, we investigated whether impaired affective repetition in TA was restricted to patients with lesions that spared the left PLA, or whether it can also occur in those patients who have lesions involving the left PLA.
Methods

Patients

Four right-handed aphasic patients (two women and two men) with unilateral thromboembolic strokes participated in this study. Formal language examination was carried out in all patients by a behavioural neurologist (M.L.B.) with training in the assessment of aphasia using the Western Aphasia Battery (WAB) (Kertesz 1982). All patients were also examined with a shortened version of the Token Test (De Renzi and Faglioni 1978), and experimental tests of word and sentence repetition (Berthier et al. 1993). According to taxonomic criteria of the WAB, two patients were classified as having transcortical motor aphasia (TMA) (Patients 1 and 2), another patient as having mixed transcortical aphasia (MTA) (Patient 3), and the remaining patient as having transcortical sensory aphasia (TSA) (Patient 4).

Language disturbances were studied in the acute period (within 2 months post-onset) in two cases (Patients 1 and 3) and in the chronic period in the remaining two cases (Patients 2 and 4). Demographic and clinical characteristics of patients are summarized in Table 1.

To examine the potential role of lesion location on repetition of affective prosody, we selected two patients with lesions involving the left PLA and two patients with lesions sparing it. Lesion location was documented by high-resolution computed tomography (CT) and/or by magnetic resonance imaging (MRI) scans. The damaged area was localized in specific brain regions with the aid of an atlas (Matsui and Hirano 1978). The two patients with PLA involvement had TMA. One of these cases (Patient 1) had a large ischaemic infarction involving the frontocentral operculum and subjacent basal ganglia, while the other case (Patient 2) had an ischaemic infarction involving the whole PLA with extension into the basal ganglia and internal capsules. One of the two cases with lesions sparing of the PLA (Patient 3) had a MTA in association with an ischaemic infarction in the territory of the anterior cerebral artery involving the superior mesial frontoparietal region, while the remaining case (Patient 4) had a TSA in association with two simultaneous but separate ischaemic infarctions involving the white matter anterolateral and superior to the left frontal horn and the temporoparieto-occipital junction. None of the four patients had radiological evidence of right hemisphere damage. Neuroradiological findings are shown in Figure 1.

Controls

Two healthy adults (one male and one female) were selected as controls from the hospital staff. Patients and control subjects were monolingual native Spanish speakers with similar regional accents.

Stimuli and procedure

Comprehension of affective prosody

The four aphasic patients listened to 20 tape-recorded sentences read by a professional actress with either sad, angry, happy or neutral intonations, and were asked to identify on a response card (with vertically arranged photographs of happy, angry, sad and neutral faces, and the word of each emotion typed
Table 1. Demographic characteristics and language test scores of patients with transcortical aphasias

<table>
<thead>
<tr>
<th>Patients</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Age (years)</td>
<td>68</td>
<td>38</td>
<td>71</td>
<td>66</td>
</tr>
<tr>
<td>Handedness</td>
<td>Right</td>
<td>Right</td>
<td>Right</td>
<td>Right</td>
</tr>
<tr>
<td>Education (years)</td>
<td>7</td>
<td>12</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Months post-stroke onset</td>
<td>2</td>
<td>19</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>Western Aphasia Battery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information content</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Fluency</td>
<td>4</td>
<td>5.8</td>
<td>3.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Comprehension</td>
<td>9.2</td>
<td>4</td>
<td>7.4</td>
<td>8</td>
</tr>
<tr>
<td>Repetition</td>
<td>7.6</td>
<td>7</td>
<td>5.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Naming</td>
<td>7.4</td>
<td>62.4</td>
<td>48.4</td>
<td>65.4</td>
</tr>
<tr>
<td>Aphasia quotient</td>
<td>70</td>
<td>62.4</td>
<td>48.4</td>
<td>65.4</td>
</tr>
<tr>
<td>Token Test (max. 36)</td>
<td>17</td>
<td>14.5</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>Word Repetition (120 nouns) (percentage correct)</td>
<td>92</td>
<td>97</td>
<td>87</td>
<td>96</td>
</tr>
<tr>
<td>Sentence Repetition (10 sentences) (percentage correct)</td>
<td>90</td>
<td>100</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 1. Schematic diagrams of CT/MRI scans showing the cross-sectional localization of brain lesions in patients with transcortical aphasias.

underneath the corresponding affective face) which of the four target affective intonations was most like the sentence listened to (Heilman et al. 1984). The patients listened to the 20 stimulus sentences in a sound-treated booth. These tapes were played on a stereophonic recorder and presented binaurally at a comfortable listening level. Patients were asked to respond either verbally or by pointing to the appropriate photograph on the response card. The average score on this task for normals was 18.6 with a SD of 1.5 (Berthier 1995). Consequently, a score below 17 points was considered to be abnormal.

Repetition of affective prosody

For the experimental tasks the subjects were told that we were interested in how they repeated sentences imparting four different affective intonations. The four patients and the two control subjects were instructed to repeat a set of 20 stimulus sentences. Target stimuli were semantically neutral sentences such as ‘Mañana voy a viajar a Málaga’ (‘Tomorrow I’m leaving for Malaga’) that conveyed mood to
modulation of tone-of-voice. These sentences were specifically constructed to facilitate the measurement of acoustic variables (sentence length ranged from four to seven words). These 20 sentences were tape-recorded by a professional actress with either happy, sad, angry and neutral intonations. The stimuli were presented to a group of 10 undergraduate students to validate the accuracy of the intended affective intonation for each sentence. There was a correct match between the stimuli and intended intonation in almost all (93.5%) instances. Because three of the four patients had impaired auditory comprehension, a card (with a photograph of a face depicting one of the four emotions and the word of the corresponding emotion typed underneath) was presented while the patients listened to the stimulus sentences. Four practice trials (one for each affective intonation) were performed. Patients and control subjects were tape-recorded in a sound-treated booth using a professional quality audiocassette recorder (Marantz CP 430).

Perceptual analysis. Perceptual judgements of affective prosody during repetition by the patients and control subjects were rated by five undergraduates from the Laboratory of Phonetics at the University of Barcelona. All these subjects reported no speech or hearing problems, and none of them had extensive experience in rating pathological voices. The perceived intonation was classified by the raters using a four-point rating scale. The raters were required to assign one of the four affective tones: (1) happy, (2) angry, (3) sad, and (4) neutral to each sentence repeated by the patients and control subjects. Inter-rater agreement was calculated by using the following formula (total agreements/(total agreements + total disagreements) x 100) (Nicholas and Brookshire 1993).

Acoustic analysis. Samples of affective prosody repetition were processed with a Computer Speech Lab (CSL) 4300 B (Kay Elemetrics, New Jersey), at the Laboratory of Phonetics at the University of Barcelona. Acoustic variables were measured by using the procedure described by Ryalls et al. (1987). The following five acoustic parameters of the pitch plot were measured: average fundamental frequency (F0), F0 range, adjusted F0 range, F0 slope, and duration (see Figure 2). The overall average F0 was measured by tracing a horizontal line which passed through most points on the plot. The difference between highest and lowest F0 values in each utterance was taken as the F0 range. Given the fact that the difference between the highest and lowest points does not always reflect the general plot tendency, the adjusted F0 range was also measured. The slope (or declination) was measured by a line which passed through the majority of pitch points. The duration of speech segments was measured from the start to the end point of the pitch contour.

Statistical analysis. Within-group and between-group comparisons were computed from the five acoustic variables that represented the mean data from each affective intonation. Within-group comparisons were carried out with a Friedman two-way ANOVA. If a significant main effect was found, between-variable comparisons were carried out with non-parametric Wilcoxon paired tests. Between-group comparisons were carried out with Wilcoxon–Mann–Whitney U-tests.
Results

Repetition of propositional language

The four patients repeated most stimulus sentences verbatim (Patient 1: 19/20 correct; Patient 2: 19/20 correct; Patient 3: 16/20 correct; Patient 4: 18/20 correct). There were occasional instances of inadequate repetition of sentences due to aborted phrases, word perseverations or paraphasias, but no dysarthric productions. All patients had a normal performance on experimental tasks of word and sentence repetition (Table 1). The two control subjects repeated the 20 sentences flawlessly.

Comprehension of affective prosody

Three patients had impaired comprehension of affective prosody (Patient 1: 10/20 correct; Patient 3: 13/20 correct; Patient 4: 14/20 correct), whereas normal scores were obtained by the remaining patient (Patient 2: 18/20 correct).

Repetition of affective prosody

Perceptual analysis

As a group the patients with TA were perceived to repeat sentences using correct affective intonations significantly less frequently than the control subjects (TA patients = 0.35 correct; control subjects = 0.88 correct; \( p < 0.001 \)). Inter-rater
Table 2. Means and standard deviations of acoustic measures in patients with transcortical aphasias (TA) and controls

<table>
<thead>
<tr>
<th>Measure</th>
<th>Intonation</th>
<th>TA patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0 (Hz)</td>
<td>Happy</td>
<td>170±16</td>
<td>184±30</td>
</tr>
<tr>
<td></td>
<td>Angry</td>
<td>164±25</td>
<td>170±13</td>
</tr>
<tr>
<td></td>
<td>Sad</td>
<td>164±24</td>
<td>162±14</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>168±23</td>
<td>163±20</td>
</tr>
<tr>
<td>Adjusted F0 range (Hz)</td>
<td>Happy</td>
<td>78±10**</td>
<td>113±23</td>
</tr>
<tr>
<td></td>
<td>Angry</td>
<td>70±11*</td>
<td>97±18</td>
</tr>
<tr>
<td></td>
<td>Sad</td>
<td>80±23</td>
<td>68±07</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>73±13</td>
<td>71±8</td>
</tr>
<tr>
<td>Declination (degrees)</td>
<td>Happy</td>
<td>7.4±1.8*</td>
<td>11.5±0.7</td>
</tr>
<tr>
<td></td>
<td>Angry</td>
<td>6.6±2.7*</td>
<td>11.7±0.1</td>
</tr>
<tr>
<td></td>
<td>Sad</td>
<td>8.4±3.6</td>
<td>8.9±3.2</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>7.4±1.7</td>
<td>9.7±2.4</td>
</tr>
<tr>
<td>Duration (s)</td>
<td>Happy</td>
<td>2.0±0.5</td>
<td>1.4±0.1</td>
</tr>
<tr>
<td></td>
<td>Angry</td>
<td>1.8±0.7</td>
<td>1.2±0.2</td>
</tr>
<tr>
<td></td>
<td>Sad</td>
<td>1.9±0.6</td>
<td>1.3±0.1</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>1.9±0.6</td>
<td>1.4±0.2</td>
</tr>
</tbody>
</table>

* p < 0.03; ** p < 0.02 (Mann-Whitney U-test)

percentage agreement for the entire database was good for the aphasic patients (69%) (angry = 62%; happy = 73%; sad = 73%; neutral = 70%) and excellent for the controls (91.2%) (angry = 95%; happy = 95%; sad = 80%; neutral = 95%).

Acoustic analysis

Means and standard deviations of acoustic analysis variables in the four affective intonations for the TA patients and controls are shown in Table 2 (since values from F0 range and adjusted F0 range were identical, only data from the latter were included in Table 2). Pitch contours of sentences repeated with happy and angry intonations by the TA group showed significantly narrower adjusted range of F0 and less marked F0 declination than those repeated by the controls (Figure 3). There were, however, no significant between-group differences in sentences repeated with neutral and sad intonations. Although the TA group showed a lengthening in the duration of segments relative to the normal control subjects, this difference failed to reach statistical significance. Within-group comparisons also failed to reveal significant differences (TA group: p = n.s.; normal controls: p = n.s.).

Discussion

In the present study we examined the perceptual and acoustic correlates of affective prosody repetition in four patients with TA. There were several important findings. First, all patients were impaired in the repetition of affective sentences, though the repetition of propositional language was relatively preserved. Secondly, impaired repetition of affective prosody was documented in all three clinically
established varieties of TA (TMA, TSA and MTA). Finally, poor affective repetition was present in TA patients with lesions sparing or involving the left PLA.

Before further discussion some methodological limitations should be pointed out. First, the present study was based on a small group of patients with TA, so that statistical analysis with such a small sample have an increased risk for type II errors. Secondly, since the four patients were aphasic, another possible limitation could be that the patients did not understand that they had to imitate the affective intonation of each stimulus. However, two of the four patients had TMA with discrete or no deficits in auditory comprehension, and during the repetition task all aphasic patients were given non-linguistic cues to overcome auditory comprehension deficits. Moreover, in recent perceptual and acoustic studies of expressive dysprosodia in recovered non-fluent aphasic patients \((n = 7)\) who did not have auditory comprehension deficits, we found that all patients were unable to impart affective tone during speech production tasks (spontaneous speech, repetition and oral reading) (Berthier 1989, Berthier et al. 1991b), demonstrating that poor repetition of affective prosody did not depend upon deficits in auditory comprehension.

Speedie et al. (1984) reported impaired repetition of affective prosody in two patients with MTA. Based on perceptual judgements they found that 'patients with
transcortical aphasia employed neutral intonation in virtually all of their intonations (96%). In agreement with these results we found that our four patients with different clinical types of TA repeated sentences with affective intonation significantly poorer than the normal control subjects. Moreover, acoustic analysis revealed significant between-group differences in the configuration of F0 contours (adjusted F0 range and declination) of sentences repeated with happy and angry intonations, but not in sentences repeated with either sad or neutral intonation. Acoustic analysis in normal speech conditions reveals that sentences intoned with happy and angry mood are usually pronounced with a higher pitch, a greater intonation range, and more variability of the speech curve than are sentences pronounced with sad or neutral intonations (Lieberman and Michaels 1962, Ladd et al. 1985). Therefore, when acoustical parameters of our TA patients were compared with those from normal control subjects, differences reached statistical significance only in those sentences that require a greater modulation of prosody.

Another implication of our study was that repetition of affective prosody by patients with TA and left hemisphere lesions that spared the PLA was not significantly different from the repetition of TA patients with left hemisphere lesions that involved the PLA. These findings argue against the mechanism of 'disconnection' between the intact left PLA and the right hemisphere proposed by Speedie and co-workers (1984) to explain abnormal repetition of affective prosody in TA. Since the two patients reported by Speedie et al. had left hemisphere lesions that spared the PLA, it could be argued that the functional mechanism suggested by these authors might be applicable only to those patients with TA caused by lesions located outside the left PLA. However, recent studies using in-vivo functional brain imaging (PET, SPECT) demonstrated that patients who develop TA after having left hemisphere lesions located outside the PLA (whether cortical or subcortical) have a significant decrease of perfusion in structurally undamaged sites of the left PLA (Perani et al. 1987, Case 1), Berthier et al. 1991a, 1993). Therefore, our present results suggest that the production of affective prosody is disrupted by anterior left hemisphere damage. Moreover, these findings may indicate that, after extensive structural or functional damage to the left PLA, the intact right hemisphere is inefficient to modulate affective prosody properly during repetition tasks.

Regional cerebral blood flow (rCBF) studies performed during automatic speech (number and word-repetition) and humming revealed a significantly activation in both cerebral hemispheres involving the posterior–inferior frontal regions, the sensorimotor cortices, and supplementary motor areas (Larsen et al. 1978, Ryding et al. 1987). These findings, taken together with both the reported impaired production of affective prosody in recovered aphasics with discrete left frontal damage (Berthier 1989, Berthier et al. 1991b) and the results of the present study, suggest that in normal conditions the modulation of affective prosody may require a simultaneous processing in both cerebral hemispheres.

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