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Cerebral mechanisms for understanding emotional prosody in speech

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Abstract

Hemispheric contributions to the processing of emotional speech prosody were investigated by comparing adults with a focal lesion involving the right ($n = 9$) or left ($n = 11$) hemisphere and adults without brain damage ($n = 12$). Participants listened to semantically anomalous utterances in three conditions (*discrimination*, *identification*, and *rating*) which assessed their recognition of five prosodic emotions under the influence of different task- and response-selection demands. Findings revealed that right- and left-hemispheric lesions were associated with impaired comprehension of prosody, although possibly for distinct reasons: right-hemisphere compromise produced a more pervasive insensitivity to emotive features of prosodic stimuli, whereas left-hemisphere damage yielded greater difficulties interpreting prosodic representations as a code embedded with language content.
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1. Introduction

Accumulating data from a variety of sources affirm that the right hemisphere in humans is critical to functions for understanding emotional *prosody*—the melodic and rhythmic components of speech that listeners use to gain insight into a speaker's emotive disposition. These data exemplify a right-lateralized response to emotional prosody during dichotic listening (Grimshaw, Kwasny, Covell, & Johnson, 2003; Ley & Bryden, 1982) and during recording of event-related brain potentials (Pihan, Altenmuller, Hertrich, & Ackermann, 2000). Frequent reports also indicate a relative increase in hemodynamic flow in the right hemisphere during tasks of judging emotional prosody (Buchanan et al., 2000; Gandour et al., 2003; George et al., 1996; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). Finally, many adults with focal right cerebrovascular lesions are known to exhibit impaired behavioral responses to the emotional features of prosody in speech (Blonder, Bowers, & Heilman, 1991; Breitenstein, Daum, & Ackermann, 1998; Heilman, Bowers, Speedie, & Coslett, 1984; Pell, 1998; Ross, 1981; Wunderlich, Ziegler, & Geigenberger, 2003). Current research is exploring whether a right-sided advantage for emotional prosody is directed by the functional status of emotional cue sequences as meaningful, non-linguistic entities (Bowers, Bower, & Heilman, 1993; Gandour et al., 2003; Van Lancker, 1980), by preferred auditory processing characteristics of the right hemisphere (Meyer, Alter, Friederici, Lohmann, & von Cramon, 2002; Meyer, Steinhauer, Alter, Friederici, & von Cramon, 2004; Poppel, 2003; Zatorre, Belin, & Penhune, 2002), or perhaps *both* perceptual (bottom-up) and functional (top-down) properties of prosodic displays (Pell, 1998; Pihan et al., 2000; Sidtis & Van Lancker Sidtis, 2003).

While there is little debate about the right hemisphere's central involvement in decoding emotional prosody, most researchers regard right-hemisphere structures as part of a distributed and bilateral neural

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system engaged during the processing of emotionally laden speech (Adolphs, Damasio, & Tranel, 2002; Gandour et al., 2004; Kotz et al., 2003; Sidtis & Van Lancker Sidtis, 2003). This view reflects a growing consensus that the right hemisphere's participation in emotional prosody constitutes a *relative* rather than an *absolute* dominance in this processing domain (Friederici & Alter, 2004; Pell, 1998; Pell & Baum, 1997; Pihan et al., 2000). As such, efforts to document the relationship between the right hemisphere and complementary regions within a brain network for understanding emotional prosody are concurrently underway. For example, based on growing evidence that the basal ganglia and/or fronto-striatal pathways serve an important role in interpreting emotional prosody (Blonder, Gur, & Gur, 1989; Breitenstein et al., 1998; Cancelliere & Kertesz, 1990; Kotz et al., 2003; Pell, 1996), Pell and Leonard (2003) have proposed that the basal ganglia (striatum) is necessary for promoting the salience of long-term prosodic variations in speech, owing to the sequential nature of this decoding. As envisioned, this subcortical mechanism acts to potentiate associative functions at the cortical level which derive an interpretation of emotional cue sequences in prosody (see also Meyer et al., 2004, for a related suggestion).

In addition to subcortical contributions, cortical regions of the left hemisphere are likely to share the responsibility of retrieving meaningful information from emotional cues in speech. This claim is substantiated by numerous clinical group studies that have reported deficits in the ability to judge emotional prosody in adults with focal left-hemisphere lesions and aphasia (Adolphs et al., 2002; Breitenstein et al., 1998; Cancelliere & Kertesz, 1990; Charbonneau, Scherzer, Aspirot, & Cohen, 2003; Kucharska-Pietura, Phillips, Gernand, & David, 2003; Pell, 1998; Schlanger, Schlanger, & Gerstman, 1976; Seron, Van der Kaa, Vanderlinden, Remits, & Feyereisen, 1982; Tompkins & Flowers, 1985; Van Lancker & Sidtis, 1992). Functional neuroimaging studies also commonly describe *bilateral* left- and right-hemisphere areas of activation during the perception of emotional tone (Buchanan et al., 2000; Gandour et al., 2003; Imaizumi et al., 1997; Kotz et al., 2003; Mitchell et al., 2003; Wildgruber et al., 2004; Wildgruber, Pihan, Ackermann, Erb, & Grodd, 2002). While the clinical research implies that emotional prosody comprehension is not always disturbed in patients with left (Blonder et al., 1991; Heilman et al., 1984) and sometimes right (Pell & Baum, 1997) hemisphere lesions, the bulk of the findings nonetheless argue that left *and* right cortical regions share the burden of extracting meaning from emotional tone in speech. However, descriptions of the inter-hemispheric dynamics that characterize this form of information processing are still under-developed.

For the most part, the left hemisphere's contribution to emotional speech processing has been viewed as independent of (mostly right lateralized) functions which conduct an emotional analysis of prosodic features; rather, these left-sided contributions are typically characterized as a product of "effort allocation" during prosody tasks, possibly attributable to linguistic processing demands evoked by experimental stimuli and/or explicit task parameters when judging prosody (Friederici & Alter, 2004; Gandour et al., 2003; Karow, Marquardt, & Marshall, 2001; Kotz et al., 2003; Mitchell et al., 2003; Wunderlich et al., 2003). These ideas imply a more integrative function for the left hemisphere which may be instrumental to combine the products of emotion- or pitch-related processes for prosody in the right hemisphere, with the products of verbal–semantic processes which rely on perisylvian regions of the left hemisphere (e.g., see Friederici & Alter, 2004 for a recent model).

In our attempts to elucidate hemispheric contributions to emotional prosody, there are signs that differences in task parameters and/or experimental design may be promoting some confusion in this literature. Current knowledge of prosody–brain relationships is largely derived from studies which have *selectively* administered one of several perceptual judgement tasks for evaluating underlying abilities; these judgements tap the ability to discriminate emotion features of prosody from paired events (emotion discrimination), to identify the emotional meaning of prosodic cues in reference to a corresponding verbal label or facial expression (emotion identification), or to execute a graded judgement about a prosodic stimulus along meaningful emotional dimensions such as valence or intensity (emotion rating). Several researchers have highlighted that the ability to execute prosodic judgements varies for left- and right-brain-damaged patients if one examines these abilities in multiple and distinct processing environments which naturally vary incidental task-processing requirements (Denes, Caldognetto, Semenza, Vagges, & Zettin, 1984; Kucharska-Pietura et al., 2003; Tompkins, 1991; Tompkins & Flowers, 1985). For example, Tompkins and Flowers (1985) required LHD and RHD patients to discriminate and then identify the meaning of emotional prosody from an increasing set of response alternatives; they concluded that LH involvement was largely indexed by their four-choice emotional identification task which had the greatest "verbal-associative task demands" (i.e., elevated demands to associate prosodic cues with verbal information in the form of emotion "labels"; see related patient data by (Charbonneau et al., 2003)). The influence of task parameters was also underscored recently to explain lateralized brain responses to emotional prosody using ERP's and functional MRI (Kotz et al., 2003; Pihan et al., 2000; Plante, Creusere, & Sabin, 2002). These investigations imply that different emotional prosody tasks and associated demands may be coloring how we characterize the relationship of the right and left hemispheres in this processing, and that further comparison of the major task processing contexts for inferring hemispheric contributions to emotional prosody decoding is warranted.

Thus, the aim of this study was to evaluate how LHD, RHD, and healthy control (HC) participants are able to discriminate, identify, and rate the emotional meanings of prosody when the number of emotional response categories and the specific items across task levels were highly controlled. This approach will permit a relatively comprehensive test of whether RHD and/or LHD patients present basic difficulties in associating prosodic stimuli with their underlying emotional meanings in three related but distinct processing environments, potentially revealing whether explicit task parameters are important in characterizing hemispheric contributions to aspects of emotional prosody decoding. Although there was no firm way to establish which of our three prosody judgement tasks was more "difficult" in general processing terms, available literature indicates that emotion identification—which imposes a relatively high burden on concurrent abilities for verbal processing and association, as well as storage—should be more demanding for many brain- (particularly left-hemisphere-) damaged adults than emotion discrimination (Charbonneau et al., 2003; Pell & Leonard, 2003; Tompkins & Flowers, 1985) and probably than emotion rating. Although few researchers have examined the capacity of brain-damaged listeners to rate prosodic cues in reference to a predetermined emotional meaning (Adolphs et al., 2002; Geigenberger & Ziegler, 2001), this task is likely to mitigate certain working memory constraints and verbal-associative demands at the response selection stage (Pell & Leonard, 2003), and as such, offers the potential to index relatively subtle deficits in emotional processing for our two brain-damaged groups, if indeed present. The possibility of emotion-specific deficits on judgements of emotional prosody following left- or right-hemisphere lesions, although poorly supported in the present literature, was also monitored in our different task conditions.

2. Method

2.1. Subjects

Three groups of right-handed, English-speaking adults were studied. Two participant groups had suffered a single, thromboembolic event resulting in lesion of the right ($n = 9$) or left ($n = 11$) hemisphere of the brain. A third group was composed of healthy, normally aging adults without neurological damage ($n = 12$) who were entered into the study to match demographic characteristics of the patient groups. Right-hemisphere-damaged and left-hemisphere-damaged participants were recruited from Montreal-area rehabilitation centres, whereas participants in the healthy control group were recruited from the community through local advertisements. Participants in the three groups were roughly comparable in age (HC: $M = 66.3 \pm 9.5$; RHD: $M = 64.2 \pm 16.6$; LHD: $M = 62.0 \pm 13.4$), years of formal education (HC: $M = 14.3 \pm 2.4$; RHD: $M = 11.9 \pm 1.5$; LHD: $M = 12.9 \pm 3.7$), and in the ratio of male to female participants (HC: 6:6; RHD = 4:5, LHD = 5:6). Differences in age [$F(2,29) = 0.32$, $p = .73$] and education [$F(2,29) = 1.92$, $p = .16$] were not statistically significant across the three groups. All patient and control subjects passed a puretone audiometric screening prior to the study to ensure acceptable hearing thresholds at frequencies important to speech intelligibility (minimum 35 db HL at 0.5, 1, 2, and 4 kHz, in the better ear).

Table 1 summarizes the clinical profile of individuals within the LHD and RHD groups. For each RHD and LHD participant, the occurrence and origin of unilateral hemispheric lesion was confirmed by the residing neurologist following CT or MRI scan and behavioural testing; all details about lesion location were obtained by the investigators, whenever available, from medical records at the rehabilitation centre. Unilateral lesion was also confirmed by the presence of corresponding neurologic signs such as contralateral hemiparesis and aphasia (consult Table 1). Two RHD participants (R5 and R6) but no LHD participant exhibited contralateral visual neglect following administration of the Behavioral Inattention Test (Wilson, Cockburn, & Halligan, 1987). The nature of language impairment in each LHD participant with respect to severity and "fluency" of aphasia was determined by an experienced Speech–language pathologist following administration of the Boston Diagnostic Aphasia Exam (Goodglass, Kaplan, & Barresi, 2001). To ensure that no participant would have basic difficulties following detailed task instructions, individuals in the LHD group were constrained to those who averaged above the 80th percentile in combined Auditory Comprehension subtests of the BDAE. Evidence of multi-focal damage, implication of the brainstem/cerebellum, the existence of past or current, major neurological conditions (including psychiatric illness), moderate-to-severe impairment in auditory language comprehension, or a history of substance abuse served as exclusionary criteria during patient recruitment. Participants in the control group were also questioned by the examiners to rule out a possible history of major neurologic or psychiatric disease. All patients were studied in the chronic stage of their stroke (minimum 1 year post-onset), which varied for individual participants within the RHD ($M = 5.3$ years ± 2.7, range = 1.0–10.9) and LHD ($M = 6.4$ years ± 3.6, range = 1.9–13.7) groups, although the mean post-onset of participants in the two patient groups did not statistically differ [$t(18) = 0.78$, $p = .44$].

Table 1
Basic demographic and clinical features of the RHD and LHD participants (age and post-onset of stroke indicated in years)

S	LHD				RHD			
	Sex/age	Post-onset	Lesion information	Major clinical signs	Sex/age	Post-onset	Lesion information	Major Clinical Signs
1	M/73	6.2	(L) MCA (thrombosis)	(R) hemiparesis, mild-mod. fluent aphasia	F/60	10.9	(R) posterior(hemorrhage)	(L) hemiparesis,'flat affect'
2	M/70	5.1	(L) parietal(thrombosis)	mild fluent (anomic) aphasia	F/44	4.3	(R) MCA	(L) hemiparesis
3	F/70	8.3	Large (L) fronto-temporo-parietal (hemorrhage)	(R) hemiparesis, mod-severe nonfluent aphasia, mild-mod apraxia of speech	F/67	7.0	large (R) internal capsule, (R) basal ganglia (hemorrhage)	(L) hemiplegia, 'flat affect'
4	F/49	10.2	(L) frontoparietal with subcortical extension (thrombosis)	(R) hemiplegia, severe nonfluent aphasia	M/89	4.2	(R) MCA (hemorrhage)	(L) hemiparesis
5	M/73	4.0	(L) frontoparietal	(R) hemiparesis, moderate fluent aphasia, paraphasias	M/80	3.8	Large (R) temporo-parietal	(L) hemiplegia, (L) visual inattention
6	M/61	2.9	(L) MCA (thrombosis)	(R) hemiparesis, moderate nonfluent aphasia	F/67	4.9	large (R) MCA (thrombosis)	(L) hemiparesis, (L) visual neglect
7	F/70	6.6	Large (L) fronto-parietal (thrombosis)	(R) hemiparesis, severe nonfluent aphasia, apraxia of speech	F/35	6.3	(R) parietal (embolism)	(L) hemiparesis
8	M/54	13.7	(L) parietal	(R) hemiparesis, mild-mod nonfluent aphasia	M/65	1.0	(R) corona radiata	(L) hemiparesis
9	F/74	8.4	(L) parietal (thrombosis)	(R) hemiparesis, mild nonfluent aphasia	M/71	5.0	(R) thalamus (hemorrhage)	(L) hemiparesis
10	F/57	1.9	Unavailable	(R) hemiparesis, mild fluent (anomic) aphasia				
11	F/31	2.7	(L) basal ganglia	(R) hemiparesis, mild fluent (anomic) aphasia				

Neuropsychological background tests were administered to supply a context for understanding the results of emotional prosody tasks. To ensure that participants understood verbal labels of the five emotions evaluated in our prosody tasks and could interpret these emotions from other forms of communicative stimuli, each subject listened to a series of verbal scenarios (10 trials) or were presented static facial expressions (40 trials, Pell, 2002) for identification of the emotion conveyed. The ability to process non-emotional speech and face information was briefly evaluated by requiring each listener to discriminate phoneme pairs (Benton phoneme subtest, 30 trials) and to match faces bearing the same physical identity (Benton face subtest, 54 trials). Finally, an estimate of auditory working memory capacity was derived for all brain-damaged adults who fit the criteria of an adapted listening span task (Tompkins, Bloise, Timko, & Baumgaertner, 1994); subjects made simple true/false judgements about sentences while recalling the final word of each sentence, within sets that increased in number (42 trials). Background characteristics of the three groups following administration of these various tasks are summarized in Table 2.

2.2. Materials

Prosody stimuli employed in each task were selected from a published inventory, following extensive work to perceptually characterize defining affective and emotion features of tokens within this inventory (see Pell, 2002, for details). Briefly, all tokens were short, digitally recorded utterances produced by four male and four female actors in two distinct forms: as "nonsense" speech which could be intoned with different emotional qualities in the absence of a semantic context to bias the emotional interpretation (e.g., *Someone migged the pazing* spoken in a happy or sad tone); or as "semantically biased," well-formed English sentences of comparable length (e.g., *I didn't make the team* spoken in a congruent, sad tone). Most of the current tasks employed the emotionally inflected "nonsense" utterances owing to the purview of this study on how prosodic cues *alone* are harnessed to interpret the emotional significance of speech. For both types of prosody stimuli, tokens that successfully conveyed one of five distinct emotions (*happiness*, *pleasant surprise*, *anger*, *disgust*, and *sadness*) when produced by the male and female actors were selected for the current investigation. The choice of these five, purportedly 'basic' emotional expressions allowed our tasks to be balanced as closely as possible for the positive ($n = 2$) versus negative ($n = 3$) valence of emotion targets within our emotion set. Only tokens recognized by at least 70% of perceptual raters in the perceptual validation study (i.e., untrained, healthy young listeners) were considered acceptable, where chance recognition was 14% (Pell, 2002).

Table 2
Neuropsychological performance measures obtained for the healthy control (HC), left-hemisphere-damaged (LHD), and right-hemisphere-damaged (RHD) groups ($M \pm SD$, converted to percent correct)

Measure	Group			Sig.
	HC ($n = 12$)	LHD ($n = 11$)	RHD ($n = 9$)	
Mini-mental state exam (/30)	—	91.3 ± 7.1	90.7 ± 7.2	—
Auditory working memory—words recalled (/42)[a]	—	50.6 ± 16.9	51.4 ± 11.1	—
Benton phoneme discrimination (/30)	92.8 ± 6.8	87.0 ± 7.3	82.6 ± 10.1	b
Benton face discrimination (/54)	87.2 ± 7.1	85.5 ± 8.9	77.8 ± 6.5	b
Identifying emotion from faces (/40)	87.1 ± 15.4	70.7 ± 27.6	68.6 ± 27.3	c
Identifying emotion from verbal scenarios (/10)	88.0 ± 11.4	76.0 ± 16.3	64.0 ± 25.5	b

[a] Excludes three LHD (L3, L6, and L10) and four RHD (R3, R7, R8, and R9) patients who were unable or unwilling to complete this task.
[b] RHD < HC, $p < .05$.
[c] RHD = LHD < HC, $p < .05$.

2.3. Emotional prosody tasks

Three tasks varied how brain-damaged listeners were required to judge the emotional significance of prosodic information in speech. The three tasks utilized a common set of stimuli produced by the male and female actors in relatively equal proportions.

2.3.1. Emotion discrimination

A single task evaluated how accurately participants could discriminate nonsense utterance pairs according to the emotion expressed by the prosody of each utterance. Subjects listened to 30 distinct trials (15 "same" and 15 "different" emotion pairings) and executed a same/different judgement about the prosody for each trial. The two utterances assigned to each trial were presented serially separated by a one second inter-stimulus interval; "same" trials were composed of three distinct combinations of exemplars for each of the five emotions, whereas "different" trials were constructed by randomly combining exemplars of each emotion category with those for every other category at least once. Utterances within each trial were always identical items spoken by a member of the same sex but not the same actor. Accuracy of the same/different response was recorded.

2.3.2. Emotion identification

Two tasks required participants to identify (categorize) the emotional meaning expressed by a series of spoken utterances, using a multiple choice response format with a closed set of five verbal labels (*happiness*, *pleasant surprise*, *anger*, *disgust*, and *sadness*). In one identification task, participants listened to nonsense utterances which required them to name the emotion based strictly on available prosodic features ('pure prosody' identification). A second identification task required listeners to name the emotion from semantically biased utterances produced by the same actors, which also contained a lexical–semantic context from deriving emotion ('prosody-semantic' identification). With the exception of the type of stimulus presented, each task was constructed in an identical manner with eight items representing each of the five emotions (40 trials/task). Participants were instructed to choose the emotion that "best" corresponds with the expression of the speaker and the accuracy of the response was recorded.

2.3.3. Emotion rating

The rating task required participants to listen to the set of the 40 items presented in the 'pure prosody' identification task, plus 12 filler items, on five new and separate occasions; on each occasion, they judged the emotional significance of each trial in reference to a single, pre-determined emotion using a six-point continuous scale of increasing "presence" of the target emotion (e.g., Adolphs & Tranel, 1999). Specifically, participants were instructed to judge "how much of the target emotion was being expressed" on a scale from 0 ("not at all") to 5 ("very much"). For example, on separate occasions participants would indicate through their numerical ratings how *happy* or how *sad* each of the 52 utterances sounded, when played in a randomized list. This process was repeated five times to index how sensitive a subject was to the intended emotional meaning of each prosody stimulus. The number rating assigned to each trial in the context of judging each of the five emotions was recorded.

2.4. Procedure

Ethical approval of the study was granted by the McGill Faculty of Medicine Institutional Review Board, and informed written consent was obtained from each subject prior to testing. Participants were tested individually, in a quiet room of their home (RHD, LHD) or in a laboratory testing room (HC). Testing began with the audiometric screening and neuropsychological tests, followed by the emotional prosody and emotional face processing tasks intermixed in a quasi-random order over two testing sessions of approximately one hour each. Tasks within each emotional prosody condition (i.e., identification, rating) were separated whenever possible and assigned to different sessions to minimize stimulus repetition during a single session, and to limit possible fatigue or complacency induced by extended involvement in a particular task. Each session was also separated by an interval of at least one week to mitigate familiarity with prosodic stimuli that often repeated across task conditions. Task randomization order was varied within each patient group and then matched as much as possible to participants in the HC group to achieve equivalent task administration conditions across groups. Presentation of emotional stimuli within prosody (and face) tasks was automatically randomized by Superlab software (Cedrus, USA). Prosody stimuli were played by a portable computer over high quality, volume adjustable headphones, and responses were collected directly by the computer with a Cedrus 6-button response pad. Subjects were free to indicate a response verbally or by pointing to a list of alternatives on the computer screen in front of them, although the latter occurred rarely; no time limitations were imposed on emotional judgements in any condition. All tasks were preceded by a verbal explanation of task requirements and a brief practice block which allowed subjects to adjust the headphones to a comfortable listening level. Subjects were paid a nominal fee (CAD $10/h) at the end of testing for their participation.

3. Results

The patients' understanding of emotional prosody for purposes of discrimination, identification, and rating was first analyzed separately by task condition, as described below. Data were then compared across conditions to obtain a portrait of overall emotional prosody comprehension abilities in our three participant groups, and to understand the relationship between performance measures in our tasks. Table 3 furnishes a detailed summary of group performance in tasks of discriminating, identifying, and rating emotional prosody.

3.1. Emotional prosody decoding by task

3.1.1. Emotion discrimination

The ability to discriminate the emotional meaning of utterances from underlying prosodic features was compared across the three groups in a one-way analysis of variance (ANOVA). The effect of Group was significant [$F(2,29) = 8.17$, $p = .002$]. Tukey's post hoc comparisons ($p < .05$) of the conditional means pointed to less accurate performance in the LHD ($M = 61.7\%$) and RHD ($M = 68.7\%$) patient groups, which did not significantly differ, than in the healthy control group ($M = 80.0\%$). Based on the range of scores observed in the HC group (range = 63.3–93.3% correct), examination of individual accuracy scores within the two patient groups revealed that three of the nine RHD patients (R2, R5, and R6) and six of the eleven LHD patients (L1, L3, L7, L8, L10, and L11) exhibited marked impairments for discriminating emotional prosody, performing outside the lower end of the HC group range. The group and individual performance patterns for discrimination are illustrated in Fig. 1.

Table 3
Comprehension of emotional prosody by condition by individuals in the healthy control (HC), left-hemisphere-damaged (LHD), and right-hemisphere-damaged (RHD) groups ($M \pm SD$)

Condition/measure	Group		
	HC ($n = 12$)	LHD ($n = 11$)	RHD ($n = 9$)
Emotion discrimination			
Total correct (/30)	24.0 ± 2.8	18.5 ± 3.6	20.6 ± 3.5
Emotion identification			
Pure prosody-total correct (/40)	28.3 ± 9.0	18.3 ± 8.5	17.6 ± 11.1
Prosody-semantic-total correct (/40)	32.6 ± 7.4	23.3 ± 11.1	26.0 ± 10.4
Emotion rating			
Target = Happiness			
Mean target rating (scale 0–5)	3.42 ± 0.75	3.11 ± 0.95	2.90 ± 1.41
Proportion "4 + 5" target ratings	0.53 ± 0.31	0.40 ± 0.29	0.44 ± 0.37
Target = Pleasant surprise			
Mean target rating (scale 0–5)	3.70 ± 1.02	2.82 ± 1.14	3.11 ± 1.26
Proportion "4 + 5" target ratings	0.66 ± 0.37	0.31 ± 0.34	0.51 ± 0.38
Target = Anger			
Mean target rating (scale 0–5)	3.76 ± 0.75	3.33 ± 1.23	3.30 ± 0.92
Proportion "4 + 5" target ratings	0.64 ± 0.40	0.54 ± 0.34	0.53 ± 0.26
Target = Disgust			
Mean target rating (scale 0–5)	3.89 ± 0.65	2.91 ± 1.28	3.31 ± 1.23
Proportion "4 + 5" target ratings	0.68 ± 0.27	0.40 ± 0.37	0.57 ± 0.39
Target = Sadness			
Mean target rating (scale 0–5)	3.49 ± 1.03	2.57 ± 1.29	2.74 ± 1.19
Proportion "4 + 5" target ratings	0.58 ± 0.32	0.30 ± 0.31	0.40 ± 0.28

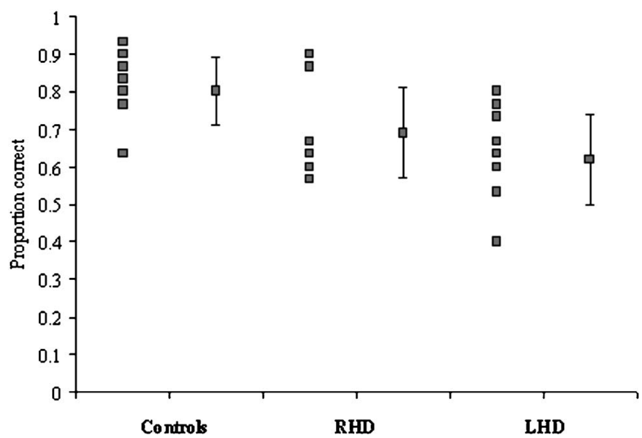

Fig. 1. Proportion of correct responses in the emotional prosody discrimination task, by group (mean + *SD*) and showing the individual distribution within each group.

3.1.2. Emotion identification

The ability to identify the emotional meaning of utterances with and without congruent lexical–semantic cues was analyzed by entering the proportion of correct responses in the 'pure prosody' and 'prosody-semantic' tasks ('Task' factor) as repeated measures with 'Emotion' (*happy*, *pleasant surprise*, *anger*, *disgust*, and *sad*) in a combined 3 × 2 × 5 mixed ANOVA involving Group, Task, and Emotion. The ANOVA yielded significant main effects for Group [$F(2,29) = 8.35$, $p < .001$], Task [$F(1,29) = 49.29$, $p < .001$], and Emotion [$F(4,116) = 5.43$, $p < .001$] and a significant interaction of Task by Emotion [$F(4,116) = 5.09$, $p = .001$]. Post hoc Tukey's comparisons performed on the interaction ($p < .05$) established that all emotions were named more accurately in the 'prosody-semantic' than in the 'pure prosody' task, with the exception of *sad* which was associated with high identification rates in both tasks, and *pleasant surprise* which yielded relatively low identification rates in both tasks. Based on prosody alone ('pure prosody' task), *sad* was identified significantly better than all other emotions (which did not differ). When lexical–semantic information was redundant with the prosody ('prosody-semantic' task), *happy* and *sad* displayed the highest identification rates whereas *pleasant surprise* was identified more poorly than all other emotions.

Of greater interest here, post hoc inspection of the Group main effect revealed that both the LHD (52.0%) and RHD (54.4%) patients performed at an inferior level to healthy control subjects (76.2%) in the identification condition overall. Differences between the two patient groups were not statistically reliable overall, nor did the Group factor interact with either Emotion or Task in the form of significant two- or three-way interactions for this analysis (all Fs < 2.24, ps > .13). Based on the HC group's accuracy range for pure prosody (36.7–90.0%) and prosody-semantic (65–97.5%) identification, it was noted that 3/9 RHD patients (R3, R5, and R6) and 4/11 LHD patients (L1, L5, L7, and L10) were impaired for pure prosody emotion identification. A substantially greater ratio of LHD (8/11: L1, L2, L3, L4, L5, L6, L7, and L10) than RHD (4/9: R4, R5, R6, and R8) participants performed outside the normal range in the prosody-semantic task. The added benefits of presenting emotion-related semantic content over pure prosody on accuracy scores for the LHD group (+12.5%) were much less than that witnessed for participants in our RHD group (+21%). Fig. 2 plots the individual accuracy scores for participants within each group for the pure prosody and the prosody-semantic identification tasks, in relation to the respective group mean and *SD*.

3.1.3. Emotion rating

The ability to detect the presence of a pre-determined emotion signalled by prosody was analyzed by focusing on the subset of ratings collected when subjects judged the *intended* emotional meaning of utterances (e.g., those ratings on the six-point scale that represented how "happy" a speaker sounded when the actual target of the item was *happiness*, and so forth). If target emotions were correctly recognized, a high frequency of ratings at the upper end of the ordinal scale was expected, due to

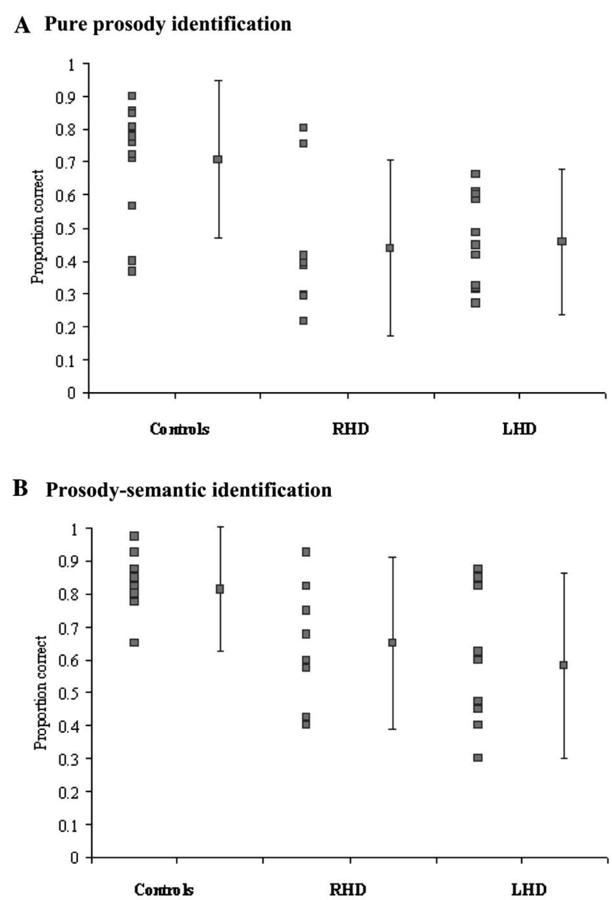

Fig. 2. Proportion of correct responses in the (A) pure prosody and (B) prosody-semantic identification tasks, by group (mean + *SD*) and showing the individual distribution within each group.

the preselection of emotionally unambiguous prosodic stimuli. χ^2 analyses examined the frequency *distribution* of responses assigned at each interval of the six-point rating scale for each group, summed across target emotions (involving 492, 409, and 369 observations for the HC, LHD, and RHD groups, respectively). Data for one LHD participant (L4), who likely failed to understand the goals of the rating task and produced almost no responses greater than "1" for all target emotions, were excluded from this analysis (this participant performed within expected limits for discriminating and identifying "pure prosody" stimuli, implying that this highly aberrant pattern was not emotion-dependent).

When compared to performance of the healthy adults, the pattern of ratings assigned to emotional prosody was significantly different overall in adults with RHD [$\chi^2(5) = 62.52$, $p < .001$] and LHD [$\chi^2(5) = 36.76$, $p < .001$]. The distribution of responses assigned by RHD versus LHD patients was also statistically independent [$\chi^2(5) = 53.77$, $p < .001$], as illustrated for all three groups in Fig. 3 (excluding data for L4). Qualitative inspection of the group response tendencies implies that, whereas healthy adults show the expected trend for assigning an increasing number of higher ratings to prosodic stimuli when judging the actual target meanings present, the LHD patients' ratings exhibited a notable reduction in the proportion of responses recorded at the upper end of the ordinal scale (i.e., "4" and especially "5" ratings). The RHD patients exhibited an entirely distinct pattern characterized by very little differentiation of rating responses to target meanings *except* at the highest interval of the ordinal scale ("5"), where the proportional frequency of their responses to target emotions resembled that of the HC participants. Based on the mean target ratings recorded within the HC group overall (range = 2.70–4.37; see Table 3), it was noted that 4/9 RHD patients (R2, R5, R7, and R9) and only one of the remaining LHD patients (L9) were "impaired" to detect target emotions in the rating task.

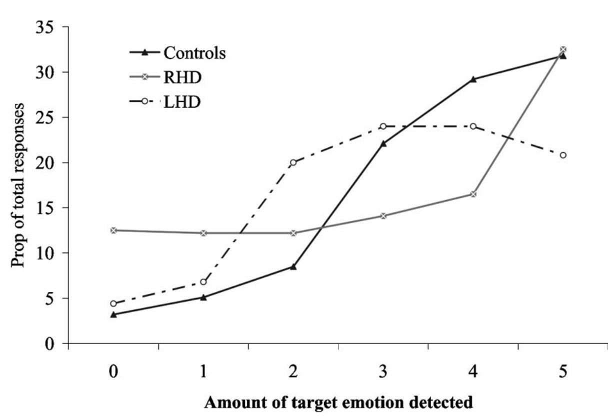

Fig. 3. Proportional distribution of group responses in the emotion rating task at each interval of the six-point scale of increasing presence of the target emotion.

3.2. Emotional prosody decoding across conditions

A final analysis undertook a direct comparison of prosody decoding abilities in the RHD, LHD (including L4), and HC groups across the three task levels, employing those measures which tapped how participants interpreted emotion from prosodic cues alone (i.e., when listening to emotionally inflected nonsense utterances). Discrimination and identification abilities were represented in this analysis by the proportion of correct responses in each condition, whereas rating abilities were represented by the proportion of combined "4" and "5" responses that each participant assigned when judging intended target emotions (these data are furnished in Table 3). A 3×3 mixed ANOVA involving Group (HC, RHD, and LHD) with repeated measures on Task (discrimination, identification, and rating) revealed significant main effects for both Group [$F(2,29) = 10.74$, $p < .001$] and Task [$F(2,58) = 11.39$, $p = .001$]. Tukey's post hoc comparisons of the Group main effect indicated that lesion to the right or left hemisphere had a significant, negative impact on the processing of emotional prosody across conditions when compared to matched healthy controls (RHD = 53.9%, LHD = 48.8%, and HC = 70.8%). Recognition accuracy of the two patient groups did not significantly differ overall. Post hoc inspection of the Task main effect indicated that overall "accuracy" in the discrimination task (70.5%) tended to be more reliable for all participants than in the identification (54.7%) or rating (50.3%) tasks, which did not significantly differ. Prosody recognition scores did not significantly vary as a combined function of Group by Task [$F(2,58) = .67$, $p = .56$, n.s.].

Overall, the ability to recognize emotional prosody in discrimination versus identification tasks bore a strong relationship [$r = 0.73$, $p < .001$], although performance in each of these tasks was not significantly associated with a tendency to assign high ratings to the same stimuli through graded judgements (both $ps > .69$). When individual performance decrements identified earlier were compared across tasks, it was noted that R5 was the only participant who performed poorly in all of our task conditions. Four additional patients (R6, L1, L7, and L10) were impaired in all conditions of discriminating and identifying emotional prosody but demonstrated normal sensitivity when rating emotions from prosody, and three other participants (R7, R9, and L9) were uniquely impaired for rating but not discriminating/identifying emotional prosody. The performance of members within the RHD group demonstrated a uniquely bimodal distribution in the "pure prosody" discrimination and identification tasks, owing to two RHD patients—R1 and R7—who exhibited few difficulties in these conditions which tended to be problematic for the remaining RHD patients.

4. Discussion

Approximately three decades of formal research has considered how adults with focal brain damage interpret emotion from the prosodic content of speech. In that time, a majority of studies that have assessed the impact of focal right- as well as left-hemisphere lesions on the comprehension of emotional prosody has documented abnormalities in *both* patient groups in some or all of their prosody tasks (Adolphs et al., 2002; Bowers, Coslett, Bauer, Speedie, & Heilman, 1987; Breitenstein et al., 1998; Cancelliere & Kertesz, 1990; Darby, 1993; Denes et al., 1984; Kucharska-Pietura et al., 2003; Pell, 1998; Ross, Thompson, & Yenkosky, 1997; Schlanger et al., 1976; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994; Tompkins & Flowers, 1985; Van Lancker & Sidtis, 1992). Despite exceptions to this pattern (Blonder et al., 1991; Charbonneau et al., 2003; Heilman et al., 1984), our data strongly reinforce the position that damage to either hemisphere can reduce how well affected patients recognize the emotional significance of prosody in speech, a conclusion that could be drawn here from three distinct contexts for judging prosody and as a general index of emotional prosody comprehension across tasks. The recurrent finding that damage to both hemispheres interrupts processing of emotional prosody in speech underscores the importance of determining how cortical regions of each hemisphere may be contributing to different stages of this processing (e.g., Friederici & Alter, 2004), or perhaps, are differentially triggered by task- or stimulus-related properties during prosody decoding.

4.1. Effects of task on emotional prosody decoding in LHD and RHD patients

When the group patterns were compared, both of our patient groups were poor at discriminating prosodic emotions and also exhibited marked difficulties in identifying the emotion represented by the same semantically anomalous items when presented in our "pure prosody" identification task (see Ross et al., 1997, for similar cross-task results). A relative sparing of abilities to *discriminate* as opposed to *identify* (categorize) emotions in matched prosody tasks by LHD aphasic adults has been described on previous occasions (Breitenstein et al., 1998; Denes et al., 1984; Tompkins & Flowers, 1985). These researchers witnessed more prevalent deficits in their LHD group on tasks which required patients to explicitly associate emotional features of prosody with their verbal meaning, a deficit that was attributed to elevated verbal-associative demands imposed by the identification paradigm (Denes et al., 1984; Tompkins & Flowers, 1985).

A reason that LHD patients tested here may have been poor at both discriminating and identifying emotional prosody is that our prosody stimuli, in fact, were associated with relatively high demands for concurrent verbal-auditory processing when compared to many previous studies which presented low-pass filtered utterances (Pell & Baum, 1997; Tompkins & Flowers, 1985) or sustained vowels (Denes et al., 1984) as a carrier for the emotive content. The "pseudo-language" stimuli presented in our tasks, while semantically anomalous (e.g., *I nestered the flugs*), were meaningfully encoded for phonological and certain lexical–grammatical features of English. One can argue that concurrent demands for phonological and lexical encoding, and the temporary storage of phonological information in these events during emotional discrimination, yielded disproportionate difficulties for our LHD participants owing to the speech-like properties of our auditory materials (Friederici & Alter, 2004; Hsieh, Gandour, Wong, & Hutchins, 2001; Kotz et al., 2003). Compared to all previous studies in the literature, our prosodic stimuli were also elicited from a far larger number of distinct male and female 'encoders', a factor which could also have invoked greater left-hemisphere involvement of auditory–verbal processes directed to segmental as well as suprasegmental features of discrimination tokens. These findings emphasize that differences in stimulus-related properties—i.e., the manner by which researchers attempt to "isolate" prosodic features in receptive tasks—may act as a major determinant of inter-hemispheric responses to emotional prosody. It is possible that variation in stimulus parameters accounts for some of the "effort allocation" frequently attributed to left-hemisphere regions during emotional prosody decoding (Kucharska-Pietura et al., 2003; Plante et al., 2002; Wunderlich et al., 2003).

Another way to characterize the effects of verbal-associative processes on prosody comprehension is to present utterances with meaningful lexical–semantic content that supports or conflicts with the emotional interpretation of prosody (i.e., tasks which tap the interface between processing for prosody and language content). We evaluated these effects in our "prosody-semantic" identification task which tested how brain-damaged participants recognized the five emotions when prosody and semantic content jointly biased the correct emotional judgement. As expected, when listeners were presented two congruent channels for identifying emotions in speech, accuracy rates tended to increase for all participant groups relative to performance in the pure prosody task (Pell & Baum, 1997). However, there were clear indications that adults with left- rather than right-hemisphere lesions benefitted substantially less as a group when presented emotion-related semantic content in addition to prosodic features, and a large proportion—nearly three-quarters—of LHD individuals were deemed "impaired" according to the expected normal range when both channels signalled the target emotion. These data exemplify that many LHD patients were unsuccessful at harnessing multiple sources of emotion-related cues to arrive at a unitary perspective about the speaker's emotion (Bowers et al., 1987; Seron et al., 1982). Given that our LHD participants exhibited good auditory comprehension abilities, and that the LHD and HC groups did not differ significantly in the ability to infer emotions from verbal scenarios in our background testing (review Table 2), it is unlikely that basic defects in auditory language processing explained the poorer performance of the LHD group in the prosody-semantic task. Rather, our data imply that for many LHD aphasic individuals, some of their difficulties on prosody comprehension tasks occur at the point of comparing and *integrating* information between the prosodic and semantic channels in speech (Geigenberger & Ziegler, 2001; Paul, Van Lancker-Sidtis, Schieffer, Dietrich, & Brown, 2003).

A final task which presented our 'pure prosody' stimuli required participants to *rate* utterances according to intended emotional qualities of the prosody, using an ordinal scale of increasing "presence" or intensity of a pre-designated emotion (Adolphs et al., 2002; see also Geigenberger & Ziegler, 2001; Wunderlich et al., 2003 for a related approach). Consistent with group differences we observed for discriminating and identifying 'pure prosody' stimuli, the pattern of rating responses obtained for each patient group diverged significantly from that of the HC group, each in a qualitatively distinct manner. When healthy listeners rated the intended emotional meanings of prosody, the vast majority of their ratings occurred in the upper half of the six-point emotion scale (where "5" = very much of the emotion was recognized) and the frequency of these responses increased consistently at higher intervals of the scale. The LHD group also exhibited a clear tendency for recognizing target emotions by assigning an increasing proportion of high ratings to these expressions, although they executed selectively fewer judgements at the highest intervals ("4" and "5") of the emotional rating scale. These rating patterns imply that LHD patients retained a broad sensitivity to the relative presence of emotional meanings encoded by prosody, but that they tended to "hear" less of the intended emotions or considered these expressions less "intense" and emotionally significant than the HC group. Results of our rating task thus serve to qualify the initial assumption that LHD patients failed to recognize emotions from the same prosodic stimuli based on their performance in the discrimination and identification tasks.

For the RHD group, the distribution of ratings assigned to target emotions was entirely distinct from the HC (and LHD) groups, supplying strong indications that these patients failed to normally appreciate relative differences in the presence/intensity of prosodic expressions of emotion. Ratings obtained for the RHD group exhibited virtually no differentiation in their relative frequency at the five lowest intervals of the six-point emotion scale, a pattern that deviated significantly from the increasing trend of the other two groups. We further noted that almost half (4/9) of individual RHD patients, but only 1/11 of LHD patients, were characterized by "impaired" comprehension of emotional prosody in the rating task overall. These findings underscore that many of the RHD patients were insensitive to relative differences in the emotive force of prosodic cues that were readily detected by aging adults without brain damage, and which appeared to be registered in certain measure by LHD aphasic patients, reinforcing initial assumptions that the comprehension of emotional prosody by RHD patients was aberrant based on discrimination and identification tasks.

Curiously, if one looks solely at the frequency of "5" responses in the rating task, RHD patients appeared to recognize the intended emotions of prosody in a manner than resembled healthy adults (review Fig. 3). Following more detailed inspection of individual performance features in this task, this group effect is probably due to heterogeneity in response strategies applied by members of our RHD group; more than two-thirds of all "5" responses for the RHD group as a whole were accounted for by three of the five "unimpaired" RHD patients (R1, R4, and R6). These three participants appeared to signal their recognition of the intended emotions in an atypical and seemingly categorical manner by almost exclusively assigning "5" ratings to these stimuli, a tendency that was not commonly observed in individuals in the HC or LHD groups. These additional observations, although they pertain to three of the "unimpaired" RHD patients on the rating task, appear to actually strengthen the claim that RHD adults were least likely to retain normal sensitivity to emotional prosody as indexed uniquely by the rating task, pending further research that employs the rating paradigm.[1]

[1] As suggested by an anonymous reviewer, the increased proportion of "5" ratings within our RHD group–which were executed in reference to a horizontally arranged numerical scale–may have indexed subtle deficits in visual inattention or neglect to the left side of the scale in this task (especially for R5 and R6 who performed poorly on the Behavioral Inattention Test). To test this possibility, the ratings data were carefully re-examined to determine whether any RHD individuals were systematically attending to only a specific portion of the numerical scale, including for those trials in which the patient was *not* judging the target emotion of the prosody (e.g., when rating how "happy" an angry stimulus was, which should elicit use of the left side of the scale with many "0" and "1" responses). These analyses established that all RHD patients, including R5 and R6, demonstrated broad use of the rating scale between 0 and 4 in response to many of these trials, implying that a persistent inattention to the left side of the rating scale did not directly explain the nature of ratings collected in the emotion rating condition overall.

4.2. Hemispheric contributions to understanding emotional prosody in speech

If one compares prosody comprehension abilities across the three task-processing levels, certain arguments can be made about the origins of prosodic deficits exhibited by each of our patient groups. First, it merits underscoring that focal, unilateral brain damage was responsible for abnormalities in discriminating, identifying *and* rating emotional prosody irrespective of lesion side, as determined by three ubiquitous measures of prosody comprehension in the literature. Thus, our comprehensive testing reinforces that brain systems for understanding emotional prosody in speech involve significant *bilateral* contributions of right and left neocortex (Gandour et al., 2004; Kotz et al., 2003; Pell, 1998; Wildgruber et al., 2002).

We did not find any direct evidence that manipulating the task processing mode for rendering explicit judgements of emotional prosody selectively disadvantaged either of our patient groups, although modifying task parameters was instrumental in furnishing insights about the underlying nature of difficulties experienced by members of each lesion group. In particular, results of our rating task suggested that most LHD patients were sensitive to emotional meanings that they could not accurately discriminate or identify in parallel tasks; this points to the likelihood that tasks associated with a high verbal-associative load and prominent needs for verbal categorization often obscure the underlying capabilities of LHD patients in prosody investigations. Individuals in our RHD group—especially R5 who had suffered a large temporo-parietal lesion—were relatively consistent across tasks in the qualitative misuse of prosodic information for rendering an emotional response, a claim that was best exemplified in their rating performance. These latter findings support a large volume of research that stipulates a mandatory right-hemisphere role in specialized functions for decoding emotional prosody.

As noted earlier, current methods do not allow precise inferences about the functional locus of our RHD patients' receptive difficulties, although these deficits are presumed to affect procedures which undertake early perceptual analyses of prosodic/pitch contours (Meyer et al., 2002; Sidtis, 1980; Van Lancker & Sidtis, 1992) or which evaluate the emotive significance of prosodic cue sequences from the auditory input (Adolphs, 2002; Bowers et al., 1993; Gandour et al., 2003; Pihan, Altenmuller, & Ackermann, 1997). There are growing suggestions that right cortical regions are preferentially involved in *both* the extraction of long-term pitch variations in speech (which are central for differentiating emotions) and subsequent processes which presumably map these features onto acquired knowledge of their emotional-symbolic functions (Gandour et al., 2004; Pell, 1998; Pihan et al., 2000; Zatorre et al., 2002). Regions of the right temporal cortex and anterior insula have been linked to the extraction of complex pitch attributes in prosody, whereas inferior frontal and parietal regions, sometimes greater on the right, have been tied in various ways to executive and evaluative operations that resolve meaning from prosodic expressions (see Adolphs, 2002; Gandour et al., 2004; Wildgruber et al., 2002, for recent descriptions of localization). These descriptions are not inconsistent with our finding that two RHD patients with lesions confined to posterior/parietal regions of the right-hemisphere (R1, R7) were relatively unimpaired in many of our emotional prosody tasks.

Still, it merits emphasizing that there were individuals in both the LHD and RHD group who tended to perform within the control group range for discrimination/identification of prosody but not for prosody rating, and vice versa, implying that breakdowns in emotional prosody processing following hemispheric damage are not entirely uniform and may arise in multiple ways (Sidtis & Van Lancker Sidtis, 2003). Requiring listeners to engage in both categorical *and* graded processing of emotional prosody appears to represent a highly constructive and sensitive approach for conducting future behavioural work in this area. As these comparisons are refined, future data are likely to promote more definitive ideas about the significance of individual findings within the patient groups studied.

The pattern of deficits witnessed in our LHD group, as discussed earlier, was influenced to some degree by verbal-associative requirements of our prosody tasks (Kucharska-Pietura et al., 2003; Tompkins & Flowers, 1985), and differentiated most clearly in the condition which required them to integrate emotional information decoded from prosody *and* meaningful semantic content to generate a response (i.e., the prosody-semantic task). Previous researchers have commented on a critical role for the left hemisphere in combining the products of specialized prosodic operations with those that conduct phonological, syntactic, and semantic analyses of spoken language (Friederici & Alter, 2004; Gandour et al., 2004; Grimshaw et al., 2003). Consistent with these ideas, our findings imply that the entry point and primary locus of our LHD patients' difficulties involved left-hemisphere procedures for engaging in a *comparative analysis* of emotional-evaluative components of prosody (which are facilitated in great measure by right-hemisphere coding mechanisms) with concurrent features of language content. This deficit would affect the conjoint processing of cross-channel speech cues which collectively bias a listeners' impression of the emotive, attitudinal, or social -pragmatic context for an utterance (Geigenberger & Ziegler, 2001; Wunderlich et al., 2003).

The fact that emotional prosody is acquired and understood in human communication as a socialized code for representing affect in the language (speech) code (Scherer, 1988) dictates the need for explicit mechanisms that combine emotion-related knowledge derived from these distinct but co-dependent messages in the auditory signal. Processing at this comparative stage is likely to recruit important contributions of the left hemisphere via collosal relay of certain information from the right hemisphere (Klouda, Robin, Graff-Radford, & Cooper, 1988; Paul et al., 2003; Ross et al., 1997). One can speculate that areas of left inferior frontal gyrus, which are commonly activated in tasks of judging emotional prosody in speech (Buchanan et al., 2000; George et al., 1996; Kotz et al., 2003; Plante et al., 2002; Rama et al., 2001; Wildgruber et al., 2002) and which have been described as mediating "effortful" semantic processing when prosodic and semantic features about emotion conflict (Schirmer, Zysset, Kotz, & von Cramon, 2004), are important for facilitating initial comparisons in the perceived emotive value of prosody in reference to semantic language content.[2] A further possibility, which merits some consideration, is that left-hemisphere mechanisms for integrating emotional prosody with semantic language content are functionally and neuroanatomically proximal to those which *directly* process the linguistic–phonemic attributes of prosody in speech, functions which are now well-established in the left hemisphere (Baum & Pell, 1999; Hsieh et al., 2001).

The hypothesized nature of our LHD patients' deficit does not preclude the possibility that left-hemisphere regions contribute in a partial but still *direct* manner to the resolution of emotional meanings from prosody (Adolphs et al., 2002; Kotz et al., 2003) by facilitating cross-channel comparisons during auditory processing. Rather, it merely emphasizes that left-hemisphere mechanisms are enhanced during emotion processing when emotive attributes of vocal signals are recognized as codes tied to, albeit not *within*, the language system, with mandatory reference to corresponding phonological and semantic structure (Gandour et al., 2004). This hypothesis fits evidence that judging "speech-filtered" or hummed stimuli devoid of segmental information is typically associated with substantially reduced left-hemisphere involvement (Friederici & Alter, 2004; Lalande, Braun, Charlebois, & Whitaker, 1992; Meyer et al., 2002; Mitchell et al., 2003). The very fact that our stimuli were constructed to be "language-like", with appropriate phonological and certain grammatical properties of English, probably explains why LHD patients tested here had troubles in our 'pure prosody' tasks; these stimuli would have invoked automatic mechanisms for comparing activations produced by the prosody as well as the (semantically anomalous) language content (Poldrack et al., 1999; Schirmer et al., 2004). These comparative and integrative procedures may well have rendered this stage of processing more "effortful" for many of our LHD participants.

Additional research based on a larger and more robust sample of LHD and RHD patients will be needed to thoroughly test these claims. The likelihood that subcortical structures such as the basal ganglia supply a mechanism which dynamically modulates inter-hemispheric co-operation at the cortical level (Pell & Leonard, 2003) will also need to be explored thoroughly. This research will help identify brain networks which facilitate a cognitively elaborated response about the emotive value of prosodic information in speech in tandem with various forms of (relatively) left-sided linguistic processing of the same signal (Friederici & Alter, 2004). In turn, this knowledge will advance ideas of how listeners adopt a unitary and contextually appropriate impression of a speaker's emotive condition, their attitudinal stance, and other interpersonal information from speech.

[2] Although detailed lesion information was not available for each of our LHD patients, frontal–temporal or frontal–parietal lesions were present in nearly half of this group, including all individuals who were "impaired" on the prosody-semantic identification task, affirming the importance of left frontal regions to prosodic speech perception.

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