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The Ability to Perceive and Comprehend Intonation in Linguistic and Affective Contexts by Brain-Damaged Adults

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Receptive tasks of linguistic and affective prosody were administered to 9 right-hemisphere-damaged (RHD), 10 left-hemisphere-damaged (LHD), and 10 age-matched control (NC) subjects. Two tasks measured subjects' ability to discriminate utterances based solely on prosodic cues, and six tasks required subjects to identify linguistic or affective intonational meanings. Identification tasks manipulated the degree to which the auditory stimuli were structured linguistically, presenting speech-filtered, nonsensical, and semantically well-formed utterances in different tasks. Neither patient group was impaired relative to normals in discriminating prosodic patterns or recognizing affective tone conveyed suprasegmentally, suggesting that neither the LHD nor the RHD patients displayed a receptive disturbance for emotional prosody. The LHD group, however, was differentially impaired on linguistic rather than emotional tasks and performed significantly worse than the NC group on linguistic tasks even when semantic information biased the target response.

INTRODUCTION

Suprasegmental features, including fundamental frequency, amplitude, and duration, convey both linguistic and paralinguistic aspects of vocal communication. Numerous reports indicate that the comprehension of phrase- or sentence-level prosodic messages may be disturbed subsequent to acquired neurological insult (see Joanette, Goulet, & Hannequin, 1990, Chapter 6, for a review). To further our understanding of how sentence intonation is perceptually decoded, and to identify possible hemispheric differences is processing linguistic and affective signals, experimental studies have compared normal control (NC) subjects to brain-lesioned patients with focal left- (LHD) or right-hemisphere (RHD) infarcts on prosodic tasks.

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Results of these investigations are varied. Weintraub, Mesulam, and Kramer (1981), on tasks of grammatically-based prosody, found that RHD patients were impaired relative to nonneurological control subjects in their ability to use prosody to discriminate, repeat, and produce linguistic contrasts. In studies of affective intonation, right-brain-damaged patients have also demonstrated greater deficits than NC and/or LHD subjects in discriminating (Tompkins & Flowers, 1985; Tucker, Watson, & Heilman, 1977) and identifying (Blonder, Bowers, & Heilman, 1991; Bowers, Coslett, Bauer, Speedie, & Heilman, 1987; Ehlers & Dalby, 1987; Heilman, Scholes, & Watson, 1975; Heilman, Bowers, Speedie, & Coslett, 1984; Tompkins & Flowers, 1985; Tucker et al., 1977) the emotional tone of utterances. Together, these findings provide evidence that the right hemisphere of the brain may be specialized to process sentence-level prosody, particularly its affective components (Ross, 1981; Ross & Mesulam, 1979; Van Lancker, 1980).

Other findings, however, indicate that both left- and right-hemisphere damage can disrupt the processing of linguistic or affective intonation (Cancelliere & Kertesz, 1990; Heilman et al., 1984; Schlanger, Schlanger, & Gerstman, 1976; Seron, Van Der Kaa, Van Der Linden, & Remits, 1982; Van Lancker & Sidtis, 1992). For example, Van Lancker and Sidtis (1992) found no differences between LHD and RHD subjects in the ability to identify various affects from prosodic cues, but found that both brain-damaged groups were impaired relative to a normal control group. In addition, in examining the errors that subjects made in identifying intonation, Van Lancker and Sidtis (1992) suggested that the two patient groups may have been basing their decisions on different acoustic cues, with LHD subjects making greater use of fundamental frequency information and RHD subjects relying more on durational cues. Reliance on neither frequency nor temporal cues alone proved sufficient for the task. Although these findings must be regarded as preliminary, the results highlight the hypothesis that bilaterally distributed mechanisms may underlie our ability to decode intonation (Van Lancker & Sidtis, 1992).

In a study that examined both linguistic and affective intonation simultaneously, Heilman et al. (1984) found that RHD patients made significantly more errors than LHD and NC subjects (who also differed significantly) in identifying the emotional meaning of speech-filtered utterances, whereas the two patient groups were equally impaired relative to the normal group in identifying typical linguistic–prosodic meanings. Additionally, it was revealed that only the LHD subjects' performance was affected by the type of prosody tested; LHD subjects made significantly more errors on the linguistic task than on the emotional task.

Based on these results, the authors hypothesized that affective prosody may be lateralized to the right hemisphere of the brain (RHD subjects were most impaired), whereas grammatically-based intonation may be more bilaterally represented (both patient groups were impaired relative to normals)

(Heilman et al., 1984). Alternatively, they posited that the right hemisphere may dominate *all* processing of sentence-level prosody, and that the left hemisphere may become involved only on tasks that increase the need for linguistic processing (i.e., nonaffective tasks). The authors concede that their data allow the possibility of either interpretation.

The general uncertainty in the literature with respect to each hemisphere's role in prosodic perception may be due, in part, to methodological differences across studies. For example, the performance of LHD, RHD, and nonneurological control subjects has not always been examined on the same tasks, thereby limiting our understanding of each hemisphere's contribution (Heilman et al., 1975; Seron et al., 1982; Tucker et al., 1977; Weintraub et al., 1981). Moreover, investigations vary considerably with respect to the nature of the stimuli presented on prosodic tasks and the extent to which concomitant linguistic (i.e., syntactic/semantic) processing is required of subjects in decoding intonational meaning. Some investigators have presented natural, well-formed utterances which are semantically congruent with the prosodic target (Blonder et al., 1991; Bowers et al., 1987; Heilman et al., 1975; Tompkins & Flowers, 1985), whereas others have attempted to isolate perceptually the intonation contour by means of low-pass filtering sentences of the linguistic content (Bowers et al., 1987; Heilman et al., 1984; Tompkins & Flowers, 1985) or by intoning nonsense utterances (Schlanger et al., 1976; Seron et al., 1982). It is not clear from these studies in what way these different methodological approaches affect subjects' abilities on perceptual tasks of intonation.

In order to attain a more cohesive description of how sentence prosody is decoded by normal and neurologically impaired adults, a number of factors tested previously in perceptual studies of intonation have been incorporated into a single experimental paradigm. Left-hemisphere-damaged aphasic patients, RHD patients without aphasia or neglect, and age-matched control subjects without neurological damage were asked to discriminate and identify both linguistic and affective intonation patterns. In light of evidence that LHD subjects may be more impaired than NC or RHD subjects by the ''increased verbal-associative demands'' of prosodic tasks (Tompkins & Flowers, 1985), the degree to which linguistic (i.e., phonetic, syntactic, semantic) cues were available in the auditory signal was manipulated across tasks in order to characterize the effects of different levels of linguistic structure on subjects' comprehension of each type of intonation.

Based on past findings, it was hypothesized that RHD patients would be impaired in processing both linguistic and affective prosody, except on tasks in which semantic information cued the prosodic target (Bowers et al., 1987). In contrast, it was anticipated that the LHD group would be differentially affected by tasks that imposed a greater need to process linguistic information (Heilman et al., 1984; Van Lancker, 1980). In addition to accuracy measures, response latencies were computed in an attempt to provide an even

TABLE 1
Clinical and Demographic Characteristics of LHD and RHD Subject Groups

Subject	Sex	Age	Postonset (months)	Major neurologic signs
L1	M	43	48	Mild/moderate nonfluent aphasia
L2	F	43	41	Moderate/severe nonfluent aphasia, hemiparesis
L3	F	58	43	Moderate/severe nonfluent aphasia, hemiparesis
L4	F	77	18	Verbal apraxia, hemiparesis
L5	F	71	28	Fluent (anomic) aphasia, hemiparesis
L6	M	56	27	Mild nonfluent aphasia, hemiparesis
L7	M	79	5	Nonfluent aphasia, hemiparesis
L8	F	74	81	Moderate nonfluent aphasia, hemiparesis
L9	F	78	8	Mild aphasia, hemiparesis
L10	M	57	11	Moderate apraxia, hemiparesis
R1	F	82	33	Hemiparesis
R2	F	50	14	L. homonymous hemianopsia
R3	F	51	23	Hemiparesis
R4	M	70	8	Hemiplegia
R5	M	71	8	Hemiparesis
R6	F	68	11	Hemiparesis
R7	F	56	11	Hemiparesis
R8	M	65	20	L. homonymous hemianopsia
R9	M	69	6	Hemiplegia

more sensitive evaluation of subjects' prosodic abilities in the different task-processing conditions.

METHOD

Subjects

Ten patients with cerebral infarctions confined to the left hemisphere ($X = 63.6$ years), 9 patients with cerebral infarctions confined to the right hemisphere ($X = 64.7$ years), and 10 control subjects with no prior history of neurological damage ($X = 64.7$ years) participated in all parts of the experiment. All subjects were right-handed, native speakers of Canadian English, and groups were closely balanced for gender.

Clinical and demographic information about the LHD and RHD patient groups is summarized in Table 1. Unilateral brain lesion occurred as a result of a single cerebrovascular accident, as determined from patients' medical records. The presence and location of lesions were documented by CT scan in all but two cases, in which contralateral hemiparesis served as the diagnostic confirmation of left- or right-hemisphere-damage. Patients were tested at least 3 months postonset of stroke (mean time postonset: LHD group, 31 months; RHD, 15 months). All LHD patients were aphasic (9 nonfluent, 1 anomic), whereas no RHD subjects evidenced signs of aphasic deficit. No accompanying visual neglect was present in these patients at the time of testing, as assessed by the Bells Test (Gauthier, Dehaut, & Joanette, 1989). No participant in the study was known to have been previously diagnosed with psychiatric or neurological disease.

The hearing of all subjects was assessed with a puretone air conduction screening of both ears at 500, 1000, and 2000 Hz using a Maico (MA-19) portable audiometer. Acceptable hearing levels for inclusion in the study were set at 30 dB HL at each frequency for the better ear.

Stimuli

Three distinct but related sets of auditory stimuli were presented to subjects over eight separate tasks. Each stimulus set varied the extent to which the auditory signal was linguistically structured, while controlling for the availability of prosodic cues in each condition.

Semantically well-formed stimuli. Initial stimuli comprised 60 simple English sentences of eight to nine syllables each. When naturally produced and intoned, half of the sentences indicated the linguistic ''modality'' of emotionally neutral utterances, either declarative, interrogative, or imperative (e.g., *They set the table for dinner—DECLARATIVE*), and half conveyed the affective tone of the speaker, either angry, sad, or happy (e.g., *You're late again for our meeting—ANGRY*).

For linguistic stimuli, the syntactic structures most typical of a statement, question, or command provided additional cues to the prosodic target (e.g., declarative sentences followed the highly routinized English pattern of subject–verb–object). In the affective prosody condition, the verbal content of sentences was *semantically* laden to indicate the emotion expressed through intonation (e.g., the word *pleased* was used in a sentence with a *HAPPY* intonation). It was hypothesized that the presence of congruent linguistic and prosodic structure in the well-formed stimuli would have a facilitory effect on subjects' ability to identify intonational meanings.

Nonsense stimuli. An additional 10 sentences of equal syllable length provided subjects a speech-like auditory precept with appropriate phonetic and prosodic structure for English, but one that was uninterpretable. Normal sentences were rendered nonsensical by substituting real lexical items with easily pronounceable, phonetically plausible alternatives (e.g., *The doctor examined the patient* was replaced with *Suh feckter egzullin tuh boshent*). Care was taken that nonsense ''words'' did not closely resemble true lexical items.

Nonsense word-strings were produced in affective and propositional contexts by mimicking the natural intonation of the well-formed stimuli (see Preparation of Stimuli for further detail). In all, six distinct versions of each nonsense utterance were produced, one indicating each sentence/affect type. Nonsense stimuli created distinct processing demands from semantically well-formed stimuli in that *only* suprasegmental information contributed to the identification of the target meaning, despite the availability of linguistic information in the signal.

Speech-filtered stimuli. Sixty (60) additional stimuli were prepared by low-pass filtering well-formed utterances at 500 Hz to remove all intelligible linguistic (i.e., phonetic/lexical/semantic) content, while preserving the melodic line of the utterances. The perception of speech-filtered stimuli was assumed to involve the least amount of linguistic processing, restricting the available cues to the suprasegmental message.

Preparation of stimuli. A female speaker with a background in radio broadcasting recorded the well-formed and nonsense utterances during one afternoon. Well-formed sentences were recorded with the goal of sounding both natural and spontaneous in their delivery, without undue exaggeration. Nonsense and well-formed sentences were arbitrarily paired and then recorded successively, paying close attention to replicating the natural intonation of the well-formed production. The recording session took place in a soundproof chamber using a high-quality Sony portable cassette recorder and Sony ECM-909 directional microphone. The reader was subsequently paid for her efforts.

Stimulus tapes were digitized and randomized using the BLISS speech analysis system (Mertus, 1989). Well-formed and nonsense stimuli were sampled at a rate of 20 kHz using a 9-kHz low-pass filter. Speech-filtered stimuli were formulated using the original recordings for the well-formed stimuli, sampled at a rate of 20 kHz, but using a low-pass filter set at 0.5 kHz.

Rating potential stimuli. To ensure that prospective stimuli conveyed the desired affective or linguistic target meaning, a group of 10 graduate students naive to the purpose of the study were presented each set of stimuli in random order (for a total of 180 audiofiles). It was noted in a small number of cases ($n = 13$) when a particular stimulus was not identified at least 70% of the time. However, ''problematic'' stimuli were not removed from experimental tasks because they were designed to match the prosodic patterns of stimuli in other tasks; rather, these sentences were marked for further examination. Overall accuracy of subjects across experimental tasks was high (94%).

Experimental Tasks

Eight experimental tasks were presented to test subjects' perceptual abilities in two distinct prosodic domains, and at four presumably different levels of task complexity within each prosodic domain.

Discrimination tasks. Two same/different discrimination tasks using speech-filtered stimuli tested subjects' ability to differentiate intonation contours on the basis of the underlying prosodic features. Stimuli were randomly paired, separated by a 500 ms interval, and presented over 45 trials for each discrimination task; three repetitions of each of the 30 speech-filtered stimuli, therefore, formed the 45 pairings. An equal number of trials represented identical ($n = 18$) and conflicting ($n = 18$) prosodic patterns. An additional nine (9) conflicting trials were further defined, as they conflicted ''within-category'' (e.g., two different intonation patterns with the same target *HAPPY*) rather than between categories (e.g., a *HAPPY* intonation paired with an *ANGRY* intonation). It was anticipated that more subtle deficits in discriminating prosodic patterns, if present, would become evident in the case of within-category conflicting trials.

Identification tasks. Six identification tasks were created, one for each set of auditory stimuli (speech-filtered, nonsense, well-formed) in the linguistic and affective contexts. Each task included 30 trials presented one at a time with a 6 s interstimulus interval. Subjects identified from a closed set of alternatives whether a statement, question, or command had been produced (linguistic context), or whether the speaker's emotional tone was happy, sad, or angry (affective context).

Procedure

Subjects were asked to take part in an experiment of how meaning is conveyed through the tone of voice. Testing took place individually in a quiet room, often in the subject's home. Stimuli were randomized and presented by computer binaurally over headphones (Sony MDR-V3) at a comfortable listening level. Responses were indicated by pushing one of three buttons on a response board, each labeled with both a written word (*STATEMENT, QUESTION, COMMAND; ANGRY, SAD, HAPPY*) and a graphic representation (punctuation mark (. ? !) or facial expression) arranged vertically. Five practice trials preceded each task, acquainting subjects with the nature of the task and orienting them to the positioning of target buttons. Subjects were asked to respond as quickly as possible, since both accuracy and response times (measured from stimulus onset) were recorded.

Completion of all experimental tasks required two sessions per subject. A hearing screening and the two discrimination tasks were always conducted in the first session, followed by the six identification tasks. Discrimination and identification tasks were presented on different days with at least one full day between sessions to avoid any biasing effects of immediate repetition of the stimuli. The ordering of linguistic and affective tasks was counterbalanced within each group, half of the subjects receiving the affective tasks first, and the other half the linguistic tasks.

The three identification tasks were also varied in the order that they were presented to

TABLE 2
Mean Accuracy (Percentage Correct) and Response Times (in ms), by Group, on Linguistic and Affective Discrimination Tasks

	Accuracy		Response time	
Group	Linguistic	Affective	Linguistic	Affective
NC	96.2 ± 4.1	96.4 ± 4.8	382 ± 262	320 ± 455
LHD	86.4 ± 15.5	89.6 ± 9.5	632 ± 490	812 ± 546
RHD	86.2 ± 20.0	80.7 ± 24.7	723 ± 411	646 ± 490

subjects, although well-formed stimuli were always presented after speech-filtered stimuli, again as a precautionary measure to prevent biasing effects. On tasks that used speech-filtered and nonsense stimuli, subjects were informed that the sentences they were about to hear would not sound like ordinary speech (that they might sound like ''someone talking through a wall'' or ''a foreign language,'' respectively), and that they should attend to the speaker's tone of voice in order to make their response.

RESULTS

Accuracy scores, converted to mean percentage correct, and response times, in milliseconds, are reported below.[1] Since stimulus durations varied somewhat from task to task, the response time data were adjusted before analysis to allow direct comparisons across conditions. This was achieved by subtracting the mean stimulus duration for each task from each subject's score; only the adjusted RTs are reported below. The data for discrimination tasks, which tapped lower-level processes of auditory perception, were examined independently from those of identification tasks, which required higher-order knowledge of the typical linguistic or affective ''label'' conveyed by each prosodic pattern. In all cases, post hoc analyses were performed using Tukey's method ($p < .05$).

Discrimination

Separate 3 × 2 mixed design analyses of variance (ANOVAs), with a between-subjects factor of GROUP (NC, LHD, RHD), and a within-subjects factor of CONTEXT (linguistic, affective) were used to examine subjects' accuracy and response times on discrimination tasks.

i. Accuracy. Table 2 provides the mean accuracy scores and standard deviations for each subject group on the linguistic and affective tasks. As may be seen, all groups performed relatively well in both prosodic contexts, sur-

[1] Four ''problematic'' stimuli that did not appear to convey the intended target during pretesting proved unreliable during experimental testing; this determination was based on the accuracy of the NC group, which was markedly lower for these four stimuli (two *COMMAND*, two *HAPPY*) than for remaining stimuli on the task from which the stimulus was taken. However, as these prosodic patterns were not misidentified on corresponding tasks (e.g., a pattern reliably conveyed a command on the nonsense and semantically well-formed tasks, but not on the filtered task), the four utterances were included in the analyses.

TABLE 3
Mean Accuracy (Percentage Correct), by Group, on Trials Differing ''Within-Category'' (n=9) on Linguistic and Affective Discrimination Tasks

	Accuracy	
Group	Linguistic	Affective
NC	86.7 ± 19.5	93.3 ± 10.7
LHD	63.3 ± 34.8	76.7 ± 22.5
RHD	71.6 ± 30.5	70.0 ± 30.4

passing 80% correct in all conditions. The results of the ANOVA of accuracy scores revealed no significant main effects or interactions, indicating that all three groups could discriminate differences in prosodic patterns at a comparable level, and that the underlying ''type'' of intonation was not a factor in subjects' abilities to make these judgments.

A small number of experimental trials in each discrimination task differed ''within-category'' (i.e., two different stimuli both signifying the same target, e.g., *QUESTION* or *ANGRY*); each group's accuracy on this subset of the stimuli is presented in Table 3. Within-category conflicting trials were constructed to test the extent to which brain-damaged patients could discriminate more subtle acoustic differences in prosodic patterns; as shown in the table, group performances were well above chance (50%) in all cases.

A 3 × 2 mixed design ANOVA performed on this subset of the data revealed no significant effects, suggesting that all groups were capable of discriminating even these very subtle differences in the filtered stimuli. However, due to the small number of items (n = 9) and the variability in the data (4 LHD and 2 RHD patients performed at or below chance level), it is possible that our analyses were not sensitive enough to detect group differences in making these fine discriminations.

ii. Latency. Mean group response times on the two discrimination tasks are provided in Table 2. An ANOVA of response times on the discrimination tasks revealed a significant interaction of group and prosodic context [$F(2, 26) = 3.94$, $p < .05$]. Post hoc comparisons indicated that LHD and RHD subjects, who did not differ, took significantly longer than normal subjects to make same/different judgments about prosodic patterns, on both the linguistic and affective tasks.

Identification

Subjects' accuracy and response times were assessed for identification tasks using separate 3 × 2 × 3 mixed design ANOVAs. The between-subjects variable was GROUP (NC, LHD, RHD), while the repeated measures were CONTEXT (linguistic, affective) and TASK (filtered, nonsense, well-formed).

i. Accuracy. Table 4 summarizes the accuracy and standard deviations (percentage correct) of the three experimental groups on each of the six identification tasks. Overall, NC subjects (87%) made fewer errors in identifying the linguistic and affective labels of intonation contours than did LHD (67%) or RHD (71%) subjects. Subjects were generally better able to identify intonation contours conveying emotional (81%) rather than linguistic (69%) content, and their performance improved when semantic information was congruent with the prosodic meaning (92%) rather than when nonsense (67%) or speech-filtered (66%) stimuli carried the suprasegmental message. Six LHD subjects and two RHD subjects performed at chance level on at least one of the linguistic tasks, whereas only two patients (1 LHD, 1 RHD) performed at chance level on an affective task.

The results of an ANOVA yielded significant main effects for group [$F(2, 26) = 8.30$, $p = .002$, by subjects; $F(2, 348) = 110.40$, $p < .001$, by items], prosodic context [$F(1, 26) = 44.18$, $p < .001$, by subjects; $F(1, 174) = 33.72$, $p < .001$, by items], and task level [$F(2, 52) = 131.05$, $p < .001$, by subjects; $F(2, 174) = 65.51$, $p < .001$, by items]. A significant interaction of group and prosodic context was also revealed [$F(2, 26) = 12.99$, $p < .001$, by subjects; $F(2, 348) = 28.51$, $p < .001$, by items], as displayed in Fig. 1.

Post hoc analyses of the group × prosodic context interaction demonstrated that on the linguistic prosody tasks, NC subjects (86%) performed significantly better than LHD (55%) and RHD (66%) patients, who did not differ. On the affective prosody tasks, the ability of NC (88%), LHD (79%), and RHD (76%) subjects to recognize the three emotional tones did not differ from one another. Further, within groups, only the LHD group differed in its ability to identify intonation contours across contexts, proving significantly less accurate in the linguistic context (55%) than in the affective context (79%).

A group by task interaction (displayed in Fig. 2) also emerged [$F(4, 52) = 3.19$, $p < .05$, by subjects; $F(4, 348) = 5.57$, $p < .001$, by items]. Post hoc comparisons revealed that on the filtered tasks, LHD patients (57%) did not differ from RHD patients (62%), and both brain-damaged groups were significantly less accurate than normals (78%). On the nonsense tasks, LHD (58%) and RHD (60%) groups again did not differ, and both patient groups were significantly impaired when compared to NC subjects (83%). On the semantically biasing (well-formed) tasks, the LHD group (85%) performed significantly worse than normal subjects (99.7%). The performance of the RHD group (91%), however, did not differ from that of LHD or NC subjects.

Finally, in comparing the three task levels of identification, the performance of all subjects significantly improved when appropriate semantic content was present (well-formed stimuli) as opposed to absent (nonsense and

TABLE 4
Mean Accuracy (Percentage Correct) on Linguistic and Affective Identification Tasks Using Filtered (FIL), Nonsense (NON), and Semantically Well-Formed (SEM) Stimuli, by Group

Group	Linguistic tasks			Affective tasks		
	FIL	NON	SEM	FIL	NON	SEM
NC	78.3 ± 6.7	80.7 ± 10.3	99.0 ± 1.6	77.7 ± 7.5	86.0 ± 10.1	100.0 ± 0
LHD	47.0 ± 13.7	46.0 ± 13.4	71.3 ± 25.5	67.7 ± 21.4	70.0 ± 16.9	98.0 ± 3.2
RHD	57.0 ± 24.9	52.0 ± 16.5	88.7 ± 21.6	67.4 ± 15.4	67.0 ± 24.4	93.7 ± 11.6

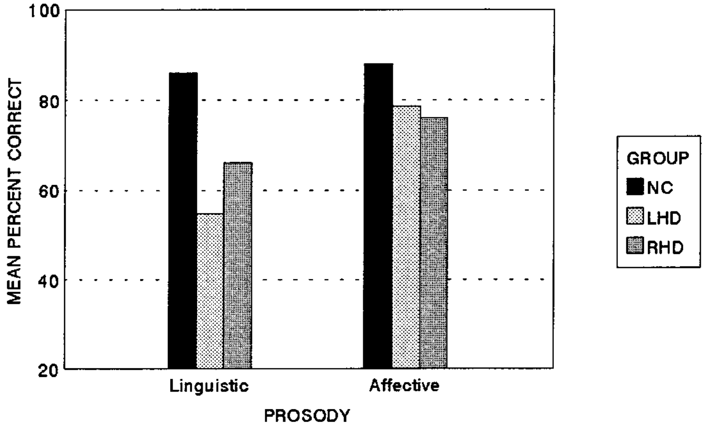

FIG. 1. Mean percentage correct (overall) on linguistic and affective identification tasks by group.

filtered stimuli). Accuracy scores did not differ for any group on the filtered and nonsense tasks.

ii. Latency. Table 5 summarizes the response time data and variability for each group on identification tasks. It may be seen that NC subjects, in general, were quicker to respond in both contexts than either patient group. Latencies in the emotional condition (925 ms) were shorter than in the linguistic context (1303 ms), overall, and tended to be shorter on the task presenting well-formed stimuli (714 ms) than on those using filtered (1369 ms) or nonsense (1260 ms) stimuli. Four LHD subjects and one RHD subject were

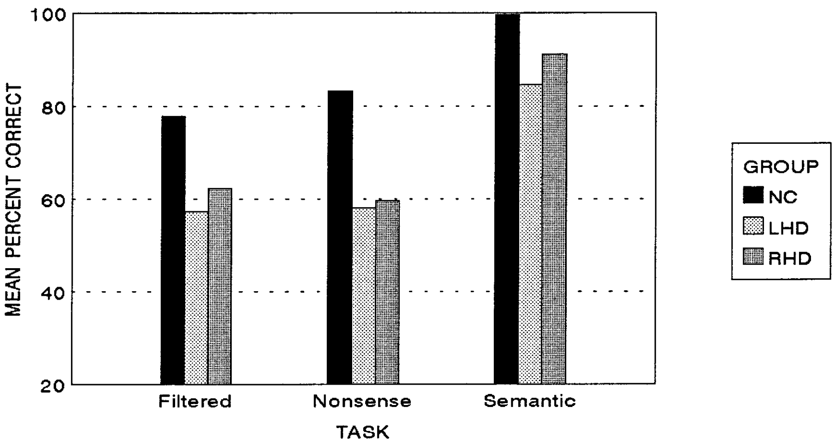

FIG. 2. Mean percentage correct on tasks using speech-filtered, nonsense, and semantically well-formed stimuli by group.

TABLE 5

Mean Response Times (in ms) on Linguistic and Affective Identification Tasks Using Filtered (FIL), Nonsense (NON), and Semantically Well-Formed (SEM) Stimuli, by Group

Group	Linguistic tasks			Affective tasks		
	FIL	NON	SEM	FIL	NON	SEM
NC	1385 ± 419	1084 ± 414	305 ± 253	825 ± 403	698 ± 260	192 ± 432
LHD	1716 ± 811	1879 ± 1274	1409 ± 846	1286 ± 660	1273 ± 876	692 ± 389
RHD	1585 ± 857	1394 ± 710	971 ± 527	1417 ± 869	1229 ± 802	713 ± 637

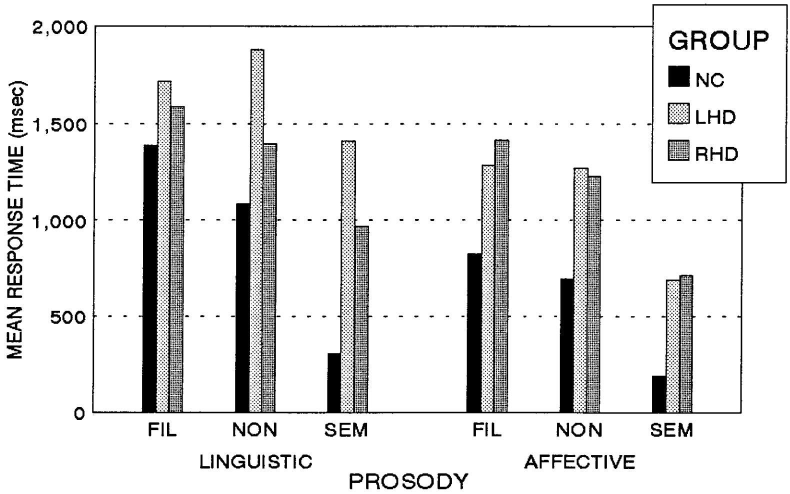

FIG. 3. Mean response times on linguistic and affective tasks using filtered (FIL), nonsense (NON), and semantically well-formed (SEM) stimuli by group.

substantially delayed on all tasks (both linguistic and affective) when compared to other subjects, and one subject with right-hemisphere damage consistently responded slower on affective rather than linguistic tasks.

A group × prosodic context × task level ANOVA revealed significant main effects of prosodic context [$F(1, 26) = 23.18, p < .001$] and task level [$F(2, 52) = 31.39, p < .001$] and a marginally significant main effect of group [$F(2, 26) = 3.26, p = .055$]. In addition, a significant group × context × task interaction emerged [$F(4, 52) = 2.68, p < .05$]; this interaction is displayed in Fig. 3.

Post hoc tests revealed that normal control subjects were significantly slower to respond to linguistic stimuli than emotional stimuli *only for speech-filtered sentences.* The LHD patients responded significantly slower in the linguistic context than the emotional context *for all three tasks,* whereas the performance of RHD subjects *did not differ between affective* and *linguistic contexts* for any of the three tasks.

Further analysis of this interaction revealed that on linguistic tasks, NC subjects were significantly faster on the semantically well-formed task than the filtered or nonsense tasks, which did not differ from one another. The LHD subjects responded significantly faster on the semantic task than on the nonsense task, but latencies for the filtered task did not differ from either the semantic or nonsense tasks; RHD subjects were significantly faster on the semantic task than on the filtered task, but latencies on the nonsense task did not differ from either the semantic or the filtered tasks. For affective stimuli, all three groups responded significantly faster on the semantically

TABLE 6

Stimulus–Response Matrices, by Group, for Statement, Question, and Command Target Intonations (in Percentage), Collapsed across Task Level

Target	Response		
	S	Q	C
NC Group			
Statement	81	2	17
Question	2	95	3
Command	20	1	79
LHD Group			
Statement	63	19	18
Question	30	55	15
Command	36	18	46
RHD Group			
Statement	70	15	15
Question	16	74	10
Command	31	15	54

well-formed task than on either the nonsense or filtered tasks, which did not significantly differ for any group.

iii. Target category effects. It was also of interest whether experimental subjects could identify particular target categories used in linguistic and affective tasks more effectively than others. The stimulus response matrices for the three linguistic targets (statement, question, command) are provided for the NC, LHD, and RHD groups in Table 6, collapsed across task levels. The table demonstrates the superior ability of the control group, relative to the LHD and RHD groups, in identifying sentence types from the intonation and additionally reveals that correct identification of commands (60%) tended to be lower, overall, than for statements (71%) or questions (75%).

Looking strictly at error responses for the linguistic targets, a notable difference is observed in how experimental groups performed when the target response was a statement or command (see Table 6); namely, the control subjects almost invariably tended to confuse statements for commands, and vice versa (88% of all errors for declarative targets were commands, 94% of all errors for command targets were declaratives); in contrast, LHD and RHD subjects did not appear to have a definite response bias for these targets.

Table 7 provides the stimulus–response matrices, by group, for each emotional target (angry, sad, happy), averaged across the three identification tasks. Overall group performance did not differ significantly (as reported above), and correct identifications of sad intonation (90%) were greater overall than for angry (77%) or happy (76%) intonation.

To test suggestions in the literature that the cerebral hemispheres are dif-

TABLE 7
Stimulus–Response Matrices, by Group, for Angry, Sad, and Happy Target Intonations (in Percentage), Collapsed across Task Level

	Response		
Target	A	S	H
NC Group			
Angry	88	2	10
Sad	1	99	0
Happy	12	11	77
LHD Group			
Angry	72	6	22
Sad	9	85	6
Happy	7	14	79
RHD Group			
Angry	70	10	20
Sad	11	87	2
Happy	13	15	72

ferentially specialized to process positive or negative affects (Ahern & Schwartz, 1979; Sackeim, Putz, Vingiano, Coleman, & McElhiney, 1988), the substitution errors of each subject group were examined for the three emotions. It may be seen that these substitutions follow a generally similar trend and did not systematically tend toward either positive (happy) or negative (angry, sad) affects for any particular group. Cursory examination of these data, therefore, do not confirm reports that the left or right hemisphere of the brain may be specialized to process paralinguistic information of a positive or negative quality.

DISCUSSION

The present study set out to investigate the manner in which focal left and right vascular brain lesions disturb the perceptual decoding of both linguistic and affective suprasegmental information.

On tasks of same/different discrimination of speech-filtered utterances, LHD and RHD patients were significantly slower than normals on both linguistic and affective tasks. Their *accuracy,* however, did not differ from that of control subjects, even when a limited subset of trials with more subtle acoustic differences was examined. These findings indicate that the brain-damaged patients were able to differentiate patterns based on the underlying prosodic features. The present research does not point to a low-level perceptual deficit following unilateral right-brain-damage, as previously demonstrated (Blonder et al., 1991; Tompkins & Flowers, 1985; Tucker et al., 1977; Weintraub et al., 1981). However, given the variability in our data on discrimination tasks (particularly evident for the RHD group), further testing is warranted.

On identification tasks, when compared to normal subjects, brain-damaged subjects were significantly impaired in their overall ability to recognize intonational meanings. It should be noted, however, that the left- and right-hemisphere-damaged groups each identified approximately 70% of the intended linguistic and affective targets across tasks (chance level, 33%) and therefore retained a general capacity to decode the prosodic content of speech. This ''general capacity,'' however, varied for the subject groups depending on the type of stimuli being presented.

In categorizing declarative, interrogative, and imperative intonation contours (nonaffective tasks), LHD and RHD patients made significantly more errors than control subjects overall, providing further evidence that grammatically-based prosody may be disrupted following left (Heilman et al., 1984) and right (Blonder et al., 1991; Heilman et al., 1984; Weintraub et al., 1981) hemisphere lesions. Moreover, in our examination of the errors made on linguistic tasks, a marked difference in the *type* of errors made by the normal and patient groups was revealed; that is, LHD and RHD patients did not appear to recognize the perceptual similarities between statements and commands which both have terminally falling contours. It follows, therefore, that LHD and RHD patients may exhibit both quantitative and qualitative differences from normals in the ability to process linguistic intonation.

It is important to remark that the LHD group's mean accuracy on linguistic tasks was substantially (although not significantly) lower than that of the RHD group. Not only did LHD aphasic patients perform relatively poorly on linguistic tasks that required a decision to be based on the intonation alone (those employing nonsense and speech-filtered stimuli), but they made significantly more incorrect responses than normals even when the semantic content was fully intelligible and strongly suggestive of the target intonation. The RHD group did not significantly differ from normals in judging the prosody when congruent semantic information could be utilized (i.e., on the semantically well-formed task). Different factors, therefore, may have contributed to the relatively poor comprehension of LHD and RHD patients on tasks of propositional intonation (Heilman et al., 1984). The increased linguistic demands of the semantically well-formed task, in which syntactic/semantic cues (invoking left hemisphere processing) in addition to prosodic cues were available, may have posed a specific challenge to the LHD subjects; processing these multiple linguistic cues simultaneously may have increased the cognitive demands of the task beyond their capacity (Tompkins & Flowers, 1985).

On tasks of comprehending emotional prosody, the abilities of the left- and right-hemisphere-damaged groups were not shown to differ from those of an age-matched control group; this observation was reflected in both overall accuracy scores (collapsed across the three affective tasks) and at each of the three individual task levels examined. These findings are somewhat contrary to expectations, since previous studies have demonstrated that RHD patients (Blonder et al., 1991; Bowers et al., 1987; Heilman et al., 1975; Heilman et al., 1984; Ross, 1981; Schlanger et al., 1976; Tompkins & Flowers, 1985; Tucker et al., 1977; Van Lancker & Sidtis, 1992) and LHD aphasic patients (Heilman et al., 1984; Schlanger et al., 1976; Seron et al., 1982; Van Lancker & Sidtis, 1992) may be impaired in the comprehension of emotional prosody.

Important clinical differences in the patient samples used in studies of emotional prosody (particularly for RHD subjects) may account for the discrepancy between the present and past findings. Heilman et al. (1975) attributed their RHD patients' emotional comprehension deficits to ''right hemisphere dysfunction and neglect,'' as did Tucker et al. (1977). Both studies, in which RHD patients performed at chance level, isolated their subjects' lesions to parietal or temporoparietal regions, and their patients presented with a unilateral neglect or inattention of the left hemispace. Other investigations have similarly tested RHD groups in which a large proportion of the patients had parietal or temporoparietal lesions and a lasting neglect behaviour (Blonder et al., 1991; Ehlers & Dalby, 1987; Heilman et al., 1984; Tompkins & Flowers, 1985). In those investigations, significant deficits of affective processing following right hemisphere insult were observed, although performance of the groups was still above chance level.

Although the majority of our RHD patients also had parietal lesions, they did not demonstrate visual neglect at the time of testing. In other studies in which the RHD subjects were free from neglect (Schlanger et al., 1976; Van Lancker & Sidtis, 1992), data have revealed the patients to be less severely impaired than a comparison group of LHD subjects (with both brain-damaged groups impaired relative to normals). Focal right-hemisphere insult accompanied by other severe neurological signs (such as neglect), therefore, may result in an inferior ability to assess and comprehend the emotional aspects of speech; however, in the event of less severe neurologic deficits as in the present group, RHD patients may largely retain these skills.

Alternatively, it may be the case that our RHD subjects' primary damage was less extensive than in previous studies in which an emotional–prosodic defect was observed. Since large lesions are thought to be necessary for a lasting neglect behavior (Brown, 1983), the coincidence of neglect and emotional prosodic deficits reported previously may simply reflect the more severely compromised neurologic state of their RHD subjects.

Another goal of the present investigation was to explore how varying the amount of linguistic structure in the auditory signal would affect subjects' ability to identify affective and nonaffective prosodic cues. For all three groups, filtering sentences of the phonetic and semantic content resulted in significantly more identification errors than when intelligible stimuli were presented (Bowers et al., 1987). Nonsense utterances, which have also been used to restrict perception to *prosodic* rather than verbal information (Blumstein & Cooper, 1974; Schlanger et al., 1976; Seron et al., 1982), similarly yielded poorer performance than well-formed stimuli for all groups. The presentation of nonsense stimuli, however, did not affect the performance of the three subjects groups relative to tasks using filtered speech.

Appropriate semantic structure (and not phonetic/phonological cues, as provided by nonsense stimuli), therefore, proved useful for all subjects in recognizing the propositional or affective significance of prosodic patterns, but was particularly beneficial for the LHD and RHD subjects. Although a normal adult speaker may use both prosodic and semantic features in assessing an utterance, and may make relatively effective use of only one set of cues when required, it would appear that brain-damaged patients are more dependent on the redundancy provided by both segmental and suprasegmental structure in order to process accurately linguistic and affective meanings.

Of considerable interest in this investigation was the comparison of LHD, RHD, and NC subjects' abilities across propositional and affective prosodic domains. Such studies are rare in the perceptual literature on intonation, where the focus has often been restricted to the abilities of a particular subset of these three groups (Heilman et al., 1975; Ross, 1981; Tucker et al., 1977; Weintraub et al., 1981) or to the perception of one particular type of intonation (Bowers et al., 1987; Blonder et al., 1991; Heilman et al., 1975; Ross, 1981; Schlanger et al., 1976; Seron et al., 1982; Tompkins & Flowers, 1985; Tucker et al., 1977).

In our attempt to evaluate more comprehensively subjects' receptive prosodic abilities, we found evidence at three different task-processing levels that LHD subjects' comprehension of suprasegmental features is affected by the communicative function of those cues in speech. Control subjects and RHD patients each demonstrated similar abilities on corresponding linguistic and affective tasks (reflected in both their accuracy and response times), whereas LHD aphasic subjects *always* responded slower and with less precision on the linguistic tasks. The present results, therefore, suggest a pattern that is qualitatively identical for each group to one reported in a related study of linguistic and affective prosody (Heilman et al., 1984); this finding further emphasizes the probability that LHD patients are susceptible to the linguistic load of stimuli in processing suprasegmental cues (Van Lancker, 1980).

Despite the evidence that linguistic intonation presents substantially more difficulties for the LHD aphasic patients than emotional intonation, the RHD patients in the current investigation, as discussed, were also impaired in identifying sentence-type contrasts. As significant right-hemisphere involvement in processing linguistic–prosodic stimuli has been noted in the past (Bradvik, Dravins, Holtas, Rosen, Ryding, & Ingvar, 1991; Heilman et al., 1984; Weintraub et al., 1981), our data are interpreted as evidence that the grammatical aspects of sentence prosody may be processed bilaterally (Heilman et al., 1984).

It is less clear in the current paradigm in what way the emotional aspects of suprasegmental features are decoded, since neither neurological group we tested presented with deficits on affective tasks. However, examination of the accuracy data in the affective condition reveals that the RHD group performed poorer on all four emotional tasks (discrimination and identification) relative to the NC and LHD groups. There are some indications, therefore, to support the hypothesis that emotional prosody is lateralized primarily to the right hemisphere for processing (Blonder et al., 1991; Bowers et al., 1987; Ehlers & Dalby, 1987; Heilman et al., 1975; Heilman et al., 1984; Ross, 1981; Tompkins & Flowers, 1985; Tucker et al., 1977).

Yet it is also plausible that affective prosody, like propositional prosody, is subserved by mechanisms distributed in both cerebral hemispheres and is not strongly lateralized in perception (Cancelliere & Kertesz, 1990; Schlanger et al., 1976; Seron et al., 1982; Van Lancker & Sidtis, 1992). Possibly, as suggested recently, bilaterally represented mechanisms may be required to process and decode different acoustic properties of emotional speech (Van Lancker & Sidtis, 1992).

In summary, substantive evidence that the comprehension of grammatical intonational meanings may be disturbed by focal left or right hemispheric lesions has been provided. Somewhat unexpectedly, the present results also demonstrated that the comprehension of affective tones in these patients may be largely spared. Detailed, objective measures of the severity and extent of patients' neurologic damage (and relevant accompanying signs) in future investigations may help to address the inconsistent findings in the literature. In addition, it will be important to determine whether the prosodic disturbances of brain-damaged patients on experimental tasks would be present in a natural, contextually enriched speech environment or to what degree these defects may be compensated for by increased awareness and integration of visual, gestural, or other cues in communication.

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