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The Effects of Auditory Distractors on the Auditory and Reading Comprehension of Adults with Unilateral Right Hemisphere Damage

Karen L. Burrell, Craig W. Linebaugh,
and Claudia Cozens-Hoffman

Individuals who sustained damage to the right cerebral hemisphere have presenting symptoms that include a wide range of communication impairments (Myers, 1994). In particular, right hemisphere-damaged (RHD) patients have been reported to experience impaired comprehension of complex linguistic stimuli in both the auditory and visual modalities (Adamovich and Brooks, 1981; Giannotti, Caltagirone, Miceli, and Masullo, 1981; Hier and Kaplan, 1980; Myers, 1979; Swisher and Sarno, 1969).

There is a growing body of evidence indicating that impaired orientation of attention may contribute significantly to impaired auditory and reading comprehension by persons with right hemisphere damage. Posner, Walker, Friedrich, and Rafal (1984, 1987) have asserted that the right parietal lobe controls the orientation of directed attention in visual space. Robin and Rizzo (1989), using tasks based on the reaction time paradigms developed by Posner and colleagues (Posner and Boies, 1971; Posner, Snyder, and Davidson, 1980), examined brain-damaged subjects' orientation to target stimuli presented in left and right hemispace to valid, neutral, and invalid visual cues. They observed that left hemisphere-damaged (LHD) subjects failed to benefit from valid cues, while RHD subjects showed prolonged reaction times (RT) to invalid cues. This suggests that the RHD subjects experienced difficulty reorienting attention following invalid cues. In addition, when compared to normal subjects' performances, LHD subjects showed their greatest prolongation of RTs in the auditory modality, while RHD subjects showed the greatest prolongation of RTs in the visual modality. Further, RHD subjects in this study, whose lesions were confined to the basal ganglia, showed prolonged RTs comparable to those subjects with right parietal lesions. In conjunction, the performances of the LHD and RHD subjects in this study indicate that both the right and left hemispheres and right hemisphere structures beyond the parietal lobe are involved in the orientation of attention.

Recently, defective allocation of attention has been invoked to explain impaired linguistic performance in persons with aphasia (McNeil, Odell, and Tseng, 1991) and dementia (Grady, Grimes, Patronas, Underland, Foster, and Rapoport, 1989). These explanations have employed a limited capacity view of attention (Kahneman, 1973; Kahneman and Triesman, 1984) to account for the diminished performances of brain-damaged individuals. In this approach, "the available pool of attention or the ability to allocate attention effectively" (McNeil et al., 1991, p. 32) may be diminished. Thus, a failure to efficiently allocate sufficient attention to the various processes required to perform a linguistic task would result in degraded performance.

A somewhat alternative view of the role of attention in explaining impaired linguistic performance may be derived from models in which resources are allocated from discrete pools of attention (Navon and Gopher, 1979; Friedman and Polson, 1981; Wickens, 1984). The study of attention orientation in LHD and RHD subjects by Robin and Rizzo (1989) as well as studies of a patient with simultanagnosia (Rizzo and Robin, 1990) and normal young and elderly subjects (Robin and Rizzo, 1992), supports a multiple resource pool approach. In this view of attention allocation, specific resource pools may be diminished or the mechanism of drawing resources from different pools may be impaired. The result would be slowed or inaccurate performance.

A special challenge to the attention allocation mechanisms of persons with brain damage may be the performance of linguistic tasks in the presence of distractors. Basili, Diggs, and Rao (1980) examined the auditory comprehension of non–brain-damaged, LHD, and RHD subjects. These investigators examined their subjects' performances on subtests III, IV, and V of the Token Test (DeRenzi and Vignolo, 1962) in quiet and in the presence of white noise and speech babble. The non–brain-damaged subjects' performances were minimally affected by the distractors. The LHD subjects performed similarly in quiet and white noise, but their performances were reduced in the presence of speech babble. The RHD subjects' performances were somewhat reduced in the presence of white noise and substantially reduced in the presence of speech babble. This effect was most prominent on subtest V.

Biggs (1989) examined the performances of eight aphasic adults on the Boston Naming Test (Kaplan, Goodglass, and Weintraub, 1983) and a word fluency task in quiet and in the presence of white noise, instrumental music, and speech babble. The subjects' performances did not differ significantly across the four conditions.

Brown (1990) examined the performances of eight college students who had sustained a traumatic brain injury on the Revised Token Test (McNeil and Prescott, 1978) in quiet and in the presence of instrumental music, speech babble, and competing voice. Five of the eight subjects had significant auditory comprehension deficits, but no significant differences were found in the subjects' performances across the four conditions.

The present study was undertaken to further investigate the effects of different types of auditory distractors on the language comprehension of persons with RHD. It was hypothesized that the auditory and reading comprehension of RHD subjects would be more adversely affected by the presence of auditory distractors than would the comprehension of non–brain-damaged persons. It was also hypothesized that visual modality comprehension would be more adversely affected than auditory modality comprehension in the RHD subjects. Further, a series of hypotheses regarding the effects of different distractors were examined. Specifically it was hypothesized that subjects' performances would be adversely affected by both intelligible and unintelligible speech distractors, that intelligible speech would more adversely affect comprehension than speech babble, and that multispeaker conversation would have a greater effect on comprehension than would monologue.

METHOD

Subjects

The subjects for this study were eight right hemisphere-damaged (RHD) persons and seven non–brain-damaged (NBD) persons who had undergone a laryngectomy. Persons who had undergone a laryngectomy were used as control subjects in order to compare the RHD subjects' performances with those of persons with a history of a chronic communication disorder and extensive speech rehabilitation. All subjects were right-handed, native English speakers who had at least an eighth grade education and denied any history of substance abuse. All had an average hearing level of at least 35 dB HL for the frequencies 500, 1000 and 2000 Hz. In order to ensure that subjects had adequate baseline auditory and reading comprehension performances for an experimental effect to be observed, all subjects performed with at least 60% accuracy on match-to-sample auditory and reading comprehension pretests using stimuli similar to those used in the experimental tasks. The two groups of subjects were comparable in age (RHD mean age = 59.5 years, SD = 14.6; Control mean age = 65.5 years, SD = 7.9) and education (RHD mean education = 12.0 years, SD = 2.5; Control mean education = 11.4 years, SD = 2.4).

All RHD subjects had right hemisphere lesions secondary to single or multiple cerebrovascular accidents. Radiologists' interpretations of CT scans confirmed that all RHD subjects' lesions were confined to the right cerebral cortex, basal ganglia, or both. Lesion locations for all subjects are provided in Table 1. All RHD subjects had cognitive-linguistic impairments consistent with RH damage and had been receiving speech-language treatment since their most recent vascular event. Information on individual RHD subject's age, education, time post onset of most recent CVA, and performance on the RIC Evaluation of Communication Problems in Right Hemisphere Dysfunction (Burns, Halper, and Mogil 1985) is provided in Table 1. All RHD subjects' symptoms also included some degree of left neglect. Results of line bisection and line cancellation tasks for individual RHD subjects are presented in Table 2.

Procedures

All subjects in the study participated in three different tasks. All tasks were match-to-sample tasks in which the subjects chose one of four stimuli by depressing a switch that was situated next to each item in the response field. Depression of the switch stopped a digital timer that had been activated by the examiner upon presentation of a stimulus. Subjects were instructed to select a response and depress the switch as quickly as possible. The response choice selected by the subject and response latency were recorded for all items in all three tasks; however, response latencies will not be considered here because of their extreme variability.

The first task was a color matching task in which the examiner presented a colored circle, and the subject selected an identical colored circle from the response field. This task was used to familiarize the subjects with the apparatus used in the experiment, to ensure appropriate placement of the response field (i.e., the center of the response field shifted sufficiently to the right of midline) for RHD subjects in order to minimize the effects of left neglect, and to obtain baseline response. All subjects performed this task without error.

The second task was an auditory comprehension task. The stimuli were 20 sets of four sentences. Each sentence was eight or nine words in length and contained the critical elements of agent, action, object, and location. All sentences were of the syntactic form article + subject + is + verbing (+ article) + object + preposition + article + object (e.g., The man is putting boxes into the truck. The woman is writing a letter at the desk.). Which of the four sentences from each set that served as the stimulus was randomly determined for each subject. The response field consisted of four 3" × 5" color photographs, one depicting the stimulus sen-

Table 1. Biographical and Pretest Information of RHD Subjects

Subject	*Age*	*Educ.*[a]	*T.P.O.*[b]	*Infarct*	*Pretest Aud./Read.*[c]	*RICE*[d] *Behavior*	*RICE*[d] *Pragmatics*	*Neglect*[e]	*SLP Dx*[f]
1	73	12	1.5	multiple: occipital frontal parietal	8/9	27 moderate deficits	31	moderate	moderate-to-severe deficits
2	59	13	1.0	multiple: basal ganglia parietal	10/9	29 moderate deficits	42	mild	mild-to-moderate deficits
3	42	13	1.5	frontal	9/10	28 moderate deficits	35	mild	moderate deficits
4	64	9	1.0	multiple: temporal × 3	7/8	43 minimal deficits	54	mild	mild deficits
5	63	10	2.0	multiple: frontal parietal	8/9	28 moderate deficits	34	mild	moderate deficits

(Continued)

Table 1. Biographical and Pretest Information of RHD Subjects (continued)

Subject	Age	Educ.[a]	T.P.O.[b]	Infarct	Pretest Aud./Read.[c]	RICE[d] Behavior	RICE[d] Pragmatics	Neglect[e]	SLP Dx[f]
6	70	9	1.5	multiple: frontal parietal temporal	9/9	26	31	moderate	moderate deficits
						moderate deficits			
7	44	16	1.0	temporal	8/7	31	31	mild	moderate deficits
						moderate deficits			
8	61	14	1.0	basal ganglia	10/8	26	30	moderate	moderate deficits
						moderate deficits			

[a]Number of years of formal education
[b]Number of months post onset of cerebrovascular accident.
[c]Scores from Auditory and Reading Pretests; Maximum score = 10.
[d]Maximum scores on *RICE*: Behavior Subtest = 45; Pragmatics Subtest = 60.
[e]Visual neglect as determined by line bisection and letter cancellation tasks.
[f]Diagnosis of subject's cognitive-linguistic deficits as determined by the subject's primary speech–language pathologist, per results of the subject's most recent evaluation at the time of testing.

Table 2. Measures of Left Neglect in RHD Group

		Line Cancellation Errors[b]	
Subject	*Line Bisection*[a]	*Left/Right*	*SLP Dx*[c]
1	55.0	7/1	moderate
2	25.0	2/0	mild
3	20.0	3/0	mild
4	15.0	0/0	mild
5	15.0	0/0	mild
6	90.0	18/3	moderate
7	20.0	10/2	mild
8	105.0	18/1	moderate

[a]Number of millimeters left of actual midpoint (rounded to nearest 0.5 mm).
[b]Errors of omission (i.e., failure to cross-out a line); with 18 lines on each side.
[c]Diagnosis based on both formalized testing and informal observation of functional tasks by primary Speech–Language Pathologist.

tence, the others differing by one or two critical elements. In this task, the stimulus sentence was presented live voice at 55–65 dB SPL. The examiner's vocal intensity was monitored on-line using a Realistic sound level meter, Model 33-2050.

The third task was a reading comprehension task. The same sentence sets and picture stimuli were used as in the auditory comprehension task. Here too, the stimulus sentence was randomly determined for each subject. In this task the stimulus sentence was presented in upper- and lowercase, 24-point Times print on a 5″ × 7″ card.

Subjects performed the auditory and reading comprehension tasks under four conditions, in quiet and in the presence of three different auditory distractors. In one distractor condition, **Babble,** the distractor consisted of speech babble and background cafeteria noise. No individual speaker or conversation could be determined. The second distractor, **Monologue,** employed a professionally recorded speaker presenting a lecture on the Arthurian legends. The third distractor condition, **Conversation,** used an intense political debate recorded from the television program *Crossfire.*

The distractors were played continuously throughout the comprehension tasks at 55–65 dB SPL on a Fischer tape recorder (Model PH402). The tape recorder had been calibrated using a Type I sound level meter (Bruel and Kjaer, Model 2203).

The auditory and reading comprehension tasks were administered on different days with a minimum of 24 hours and a maximum of 7 days between administrations. The orders of administration for the auditory and reading comprehension tasks and for presentation of the four conditions were counterbalanced across subjects.

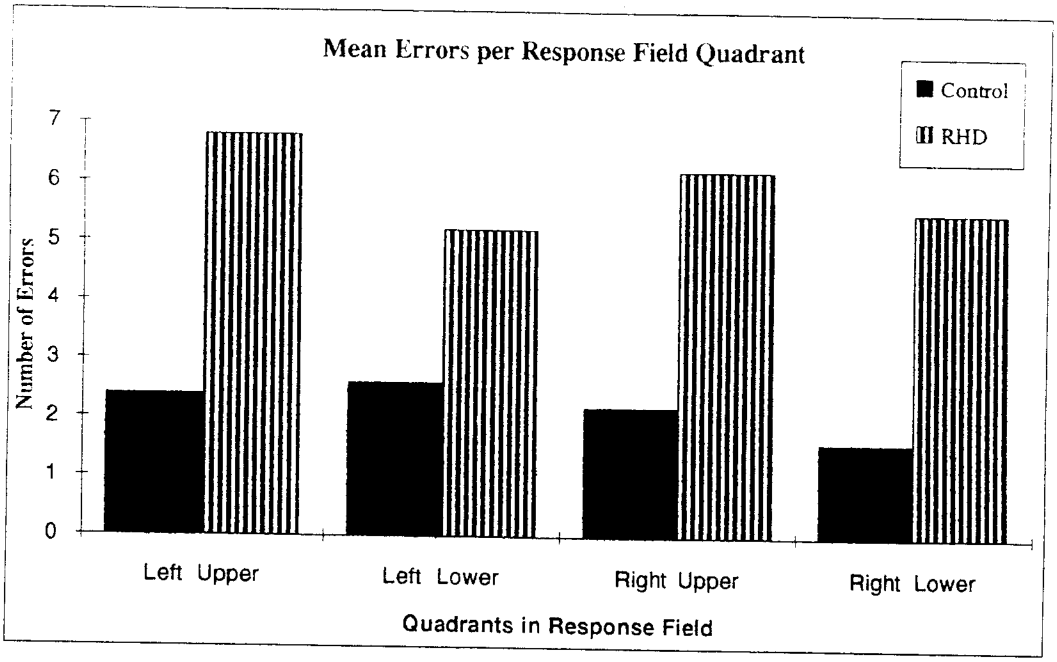

Figure 1. Mean number of errors per response field quadrant across tasks and conditions for the control and RHD subjects.

RESULTS

Mean Errors per Response Field Quadrant

Figure 1 displays the mean number of errors made by both subject groups in each of the quadrants of the response field across both tasks in the four conditions. This analysis shows that error responses were distributed relatively evenly between the right and left halves of the response field, indicating that the presence of left neglect did not contribute substantially to the greater number of errors made by the RHD group.

Performances on Auditory and Reading Comprehension Tasks

The mean numbers of errors made by the control and RHD groups in the auditory and reading comprehension tasks under all four conditions are shown in Table 3. Control subjects made a total of 24 errors (95.7% correct) on the auditory comprehension tasks and 38 errors

Table 3. Mean Number of Errors for Control and RHD Subjects on the Auditory and Reading Comprehension Tasks in the Four Distractor Conditions

	Distractor Condition			
Subject Group	*Quiet*	*Babble*	*Monologue*	*Conversation*
Control				
Auditory	1.00 sd = 0.76	0.71 sd = 0.70	0.71 sd = 0.88	1.00 sd = 0.87
Reading	1.43 sd = 1.03	1.29 sd = 1.20	1.57 sd = 1.18	1.14 sd = 0.99
RHD				
Auditory	2.13 sd = 2.20	2.00 sd = 1.55	2.50 sd = 2.33	3.38 sd = 2.07
Reading	2.63 sd = 2.16	2.75 sd = 2.53	4.13 sd = 1.62	4.38 sd = 2.87

(93.2% correct) on the reading comprehension tasks. RHD subjects made a total of 80 errors (87.5% correct) on the auditory comprehension tasks and 111 errors (82.6% correct) on the reading tasks. All errors consisted of a subject's indicating an incorrect picture in the response field. All subjects' errors were distributed essentially equally across the critical elements in the stimuli.

Table 4 shows the distribution of errors across the four conditions in the auditory and reading comprehension tasks for both subject groups. The RHD subjects' performances on both the auditory and reading comprehension tasks in quiet were comparable to those made by RHD subjects in other studies (Myers, 1979; Adamovich and Brooks, 1981; McNeil and Prescott, 1978) which assessed RHD subjects' auditory or reading comprehension. An exception was subject 7 who made more errors than expected on the reading task.

A three-way analysis of variance using number of errors as the dependent variable, was executed. The analysis tested for differences between subject groups (control vs. RHD), task modality (auditory vs. reading comprehension), and distractor condition (Quiet vs. Babble vs. Monologue vs. Conversation). Alpha level was set at .05.

The group × task modality × distractor condition, the group × modality, and the modality × condition interactions failed to reach statistical significance. The group main effect did reach significance ($F(1,13) = 7.89$; $p < .02$), indicating that the RHD subjects made significantly more errors than

Table 4. Number of Errors (percentage of errors) for Control and RHD Subjects on the Auditory and Reading Comprehension Tasks in the Four Distractor Conditions

		Distractor Condition			
Subject Group		*Quiet*	*Babble*	*Monologue*	*Conversation*
Control					
	Auditory	7 (29.2)	5 (20.8)	5 (20.8)	7 (29.2)
	Reading	10 (26.3)	9 (23.7)	11 (28.9)	8 (21.1)
RHD					
	Auditory	17 (21.3)	16 (20.0)	20 (25.0)	27 (33.7)
	Reading	21 (18.9)	22 (19.8)	33 (29.7)	35 (31.5)

did the control subjects. The task main effect failed to reach significance although the RHD subjects made 31 more errors on the reading than on the auditory comprehension tasks.

The group × condition interaction was significant ($F(3.39) = 2.93$; $p < .05$). Figure 2 displays this interaction. The control subjects made essentially equal numbers of errors across the four conditions on both the auditory and reading comprehension tasks. RHD subjects made essentially equal numbers of errors in the Quiet and Babble conditions, but more errors in the Monologue and Conversation conditions. This effect was more prominent on the reading than on the auditory comprehension tasks.

Examination of the data from the RHD subjects revealed that seven of the eight subjects made more errors on the reading than on the auditory comprehension tasks. Subject 6, whose lesion included portions of the frontal, parietal, and temporal cortices and who had moderately severe left neglect, made 19 errors on auditory stimuli and only one error in reading. However, the subject's response latencies on the reading task were exceptionally long (Mean = 11.45 seconds in Quiet). Regarding individual subject's responses on the auditory comprehension tasks under the various distractor conditions, three subjects (numbers 1, 6, and 8) made more errors in the Monologue and Conversation conditions than in the Quiet and Babble conditions. One additional subject (number 5) made more errors in the Conversation condition than in the other three conditions. On the reading tasks, four subjects (numbers 1, 3, 4, and 8) made more errors in the Monologue and Conversation conditions than in the other two conditions. Two subjects (numbers 2 and 5) made more errors in the Monologue condition than in the other three.

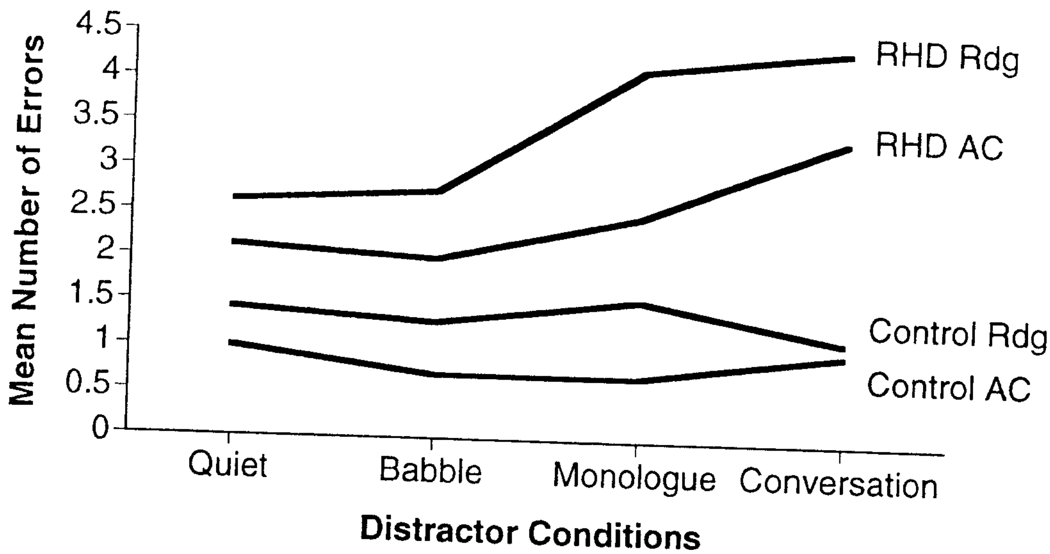

Figure 2. Mean number of errors made by the control and RHD subjects', groups on the auditory (AC) and the reading (RDG) comprehension tasks in the four distractor conditions

DISCUSSION

The results of this study support some, but not all, of our original hypotheses. The auditory and reading comprehension of the non–brain-damaged subjects in this study were essentially unaffected by any of the auditory distractors that were used. This suggests that the comprehension tasks employed were not sufficiently demanding and/or that the distractors that were used were not sufficiently intrusive. In any case, the attention allocation mechanisms of the non–brain-damaged subjects were able to focus sufficient resources for the accurate, efficient completion of the tasks in the presence of the distractors.

Conversely, the RHD subjects' performances were diminished in the presence of some of the distractor conditions relative to their performances in quiet. Both the Monologue and Conversation distractors adversely affected the subjects' comprehension of the stimulus sentences, but the difference between these two conditions was nonsignificant. The speech babble distractor did not significantly diminish the subjects' performances. The RHD subjects' comprehension of the stimulus sentences in the visual modality (reading) was also more adversely affected by the presence of the intelligible distractors (Monologue and Conversation) than was their comprehension in the auditory modality.

Our subjects performed differently than did the RHD subjects of Basili et al. (1980). The performances of their subjects were reduced in the presence of speech babble, whereas the performances of our subjects were not.

Those investigators hypothesized that their subjects' degraded performance in the presence of speech babble may have been related to difficulty separating the target sentences from the competing signal because of acoustic similarities between the two signals or the linguistic nature of the babble. This notion might contribute to an explanation of our subjects' performances in the presence of intelligible distractors, but cannot be reconciled with the lack of an effect in our speech babble condition.

A more viable explanation might lie in differences in the complexity of the experimental tasks used in the two studies. The subjects of Basili and colleagues showed a minimal difference in their performances between the quiet and babble conditions on subtest III, a slight difference on subtest IV, and a more substantial difference on subtest V. Recall that the stimuli on subtest V of the Token Test all include six critical elements and are highly variable in linguistic complexity. Our stimuli included only four critical elements and were consistent in complexity. In addition, responses on subtest V require manipulation of a ten-token response field. Responses on our tasks required pointing to one of four pictures. Hence, comprehension of stimuli and execution of responses on subtest V may require allocation of more attentional resources than did those in our paradigm. As a result, subjects' performances on subtest V would be more susceptible to diminution in the presence of speech babble than would their performances on our tasks.

Our subjects' performances also differ from those of Brown (1990) whose traumatically brain-injured subjects did not perform differently in quiet and in the presence of speech babble and intelligible voice distractors. While no data are available that permit a direct comparison of the two subject groups' respective levels of auditory comprehension, it seems likely that Brown's subjects who were all enrolled in college may have had higher baseline levels of comprehension and thus were less susceptible to the effects of distractors.

Our results suggest that the attention allocation abilities of the RHD subjects were challenged to a greater degree by intelligible than by unintelligible distractors, and that breakdowns in attention allocation were manifested to a greater degree in the visual than in the auditory modality. A detailed analysis of the experimental tasks will facilitate consideration of these results. In the experimental protocol, the distractor was presented prior to the presentation of the first trial and continued throughout the presentation of the 20 trials in each condition. Each trial was initiated by presentation of the pictorial response field with the stimulus sentence being presented after a 5 second interval. Successive trials were initiated 20 seconds after the preceding response. This procedure potentially required repeated serial shifts in attention orientation. Each shift would involve disengagement from nontarget (distractor) stimuli, a shifting of attention to target stimuli, and engagement of attention to the target stimuli (Posner, 1980).

interval between presentation of the response field and that of the target sentence was fixed at 5 seconds, thereby rendering the onset of the sentence highly predictable. Another factor is that the target sentence was presented via live voice, whereas the distractors were presented via audiotape. This may have facilitated subjects' reorienting attention to the target stimulus as well as their separating the target from the auditory background. A fifth factor is that orientation of auditory attention may be mediated by left hemisphere structures that remained intact in the RHD subjects. Robin and Rizzo (1989) reported that damage to left temporal-parietal structures impaired orientation to auditory targets to a greater degree than to visual targets. Conversely, damage to homologous right hemisphere structures resulted in greater impairment in orienting to visual than to auditory targets. Thus, our RHD subjects may have responded more accurately in the auditory condition because their reorientation to the auditory stimulus sentences was executed by intact left hemisphere structures.

The greater degradation of the RHD subjects' performances on the reading than on the auditory comprehension tasks is consistent with previous research on the orientation of visual attention. Presumably, the RHD subjects' disengagement of attention from the auditory distractors was mediated by intact left hemisphere structures. However, the engagement of visual attention to the pictorial response field and subsequent reorientation of attention to the printed stimulus sentence and then back to the response field was likely mediated by right hemisphere structures. Posner et al. (1984, 1987) have suggested that the right parietal lobe is primarily responsible for orienting visual attention. Robin and Rizzo (1989) have reported data that suggest that right hemisphere structures outside the parietal lobe are also involved in orienting visual attention. Our findings are consistent with those of Robin and Rizzo in that subjects whose lesions did not include the parietal lobe (numbers 3, 4, 7, and 8) made substantially more errors on the visual than on the auditory tasks. It appears, therefore, that breakdowns in the reorienting of visual attention may account in large measure for the greater difficulty encountered on the reading than on the auditory comprehension tasks.

The implications of our findings for models of attention orientation are somewhat ambiguous. The differences in our subjects' performances on the auditory and visual tasks supports models in which attention is allocated from different pools. However, the differential effects of intelligible and unintelligible auditory distractors on visual tasks suggests that at some level, attentional resources are allocated by a common mechanism. Additional studies are needed to clarify the factors that influence intramodal and crossmodal attention orientation.

The clinical implications of our findings are more straightforward. RHD subjects' auditory and reading comprehension is adversely affected by the presence of intelligible speech in the auditory background. Patients, their significant others, and rehabilitation professionals need to be aware of this phenomenon. Further, ecologically valid clinical protocols should be developed to assess the degree to which an individual patient's performance is affected by different types of distractors and to guide facilitation of their functioning in natural environments.

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