CHAPTER

7

The Effect of Focal Cerebral Lesions on Intramodal and Cross-modal Orienting of Attention

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> Everybody knows what attention is. It is the taking possession by the mind, in clear vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from things in order to deal effectively with others, and it is a condition which has a real opposite in the confused, dazed and scatterbrained state.
>
> **William James (1890)**

Current studies in humans and nonhuman primates support James's view and suggest that attention is a distributed neural system that modulates processing efficiency throughout the brain. For example, Treisman, Treisman, and Gelade (1980) and Treisman and Paterson (1984) have provided evidence to suggest that the perception of objects requires the integration of features that are bound by attentional factors. Posner and Boies (1971), Posner, Nissen, and Ogden (1977), Posner (1980), and Posner, Snyder, and Davidson (1980) have used a reaction time (RT) paradigm to examine the allocation of directed attention (orientation of attention) in visual space which it is argued (Posner, Walker, Friedrich, and Rafal, 1984, 1987) is controlled by the right parietal lobe.

Attentional mechanisms should also contribute to the processing of language. Posner, Peterson, Fox, and Raichle (1988) have suggested that "attention for action" interacts with semantic activation by focusing on specific lexical units. Neeley (1977) has shown that attention to one meaning of a word leads to suppression of alternate meanings of the same item. Moreover, the priming of semantic information by the phonological system is probably directly driven by attentional factors.

The relation between abnormal language processing in brain-injured individuals and attentional mechanisms has not been extensively studied. Most clinical studies have concentrated on patients with right-hemispheric lesions, especially in the parietal lobe. These patients typically neglect left hemispace, which suggests a contralateral attentional control mechanism.

Attentional deficits have been demonstrated in patients with left-hemispheric lesions, although the hemispatial defect is subtle. Hillis-Trupe and Caramazza (1987) postulated that some reading errors in patients might be attributed to hemispace contralateral to a lesion, which is not detected by routine clinical examinations including tasks such as line cancellation or line bisection. At another level of processing, attentional deficits for specific language operations may contribute to aphasia independently of hemineglect in patients who have left-hemispheric lesions. McNeil (in press) has suggested that the variability observed in the language behavior of aphasic patients might be accounted for on the basis of "high frequency fluctuations" and that patients with aphasia might reach their "limited capacity" sooner than normal individuals.

The purpose of this preliminary investigation reported here was to examine the orienting of attention in patients with focal cerebral lesions. Our hypotheses were that orienting of attention (1) depends on a distributed bihemispheric network that encompasses several processes located in separate modality specific pools, (2) is predominately organized in relation to contralateral hemispace, and (3) contributes to linguistic performance and cognitive activity at several levels. To test these hypotheses we developed three tasks to measure orienting of attention in vision, in audition, and between these modalities. Our predictions were that the orienting of attention tasks would provide an index of modality-specific attentional impairment in brain-injured subjects, that performance would be more impaired in the hemispace contralateral to the lesion, and that patients with left-hemispheric lesions and aphasia would have defects of attention that could be discriminated from those found in subjects with right-hemispheric lesions on the basis of performance on our tasks.

METHOD

SUBJECTS

We studied orienting of attention in eight cooperative subjects with stable focal ischemic cerebral lesions defined by computerized tomography or magnetic resonance images (Table 7-1). The four patients with left hemispheric lesions had aphasia. The four remaining patients had comparable lesions of the right hemisphere and no aphasia. Performance on the orienting of attention tasks was compared to that of 30 normal subjects.

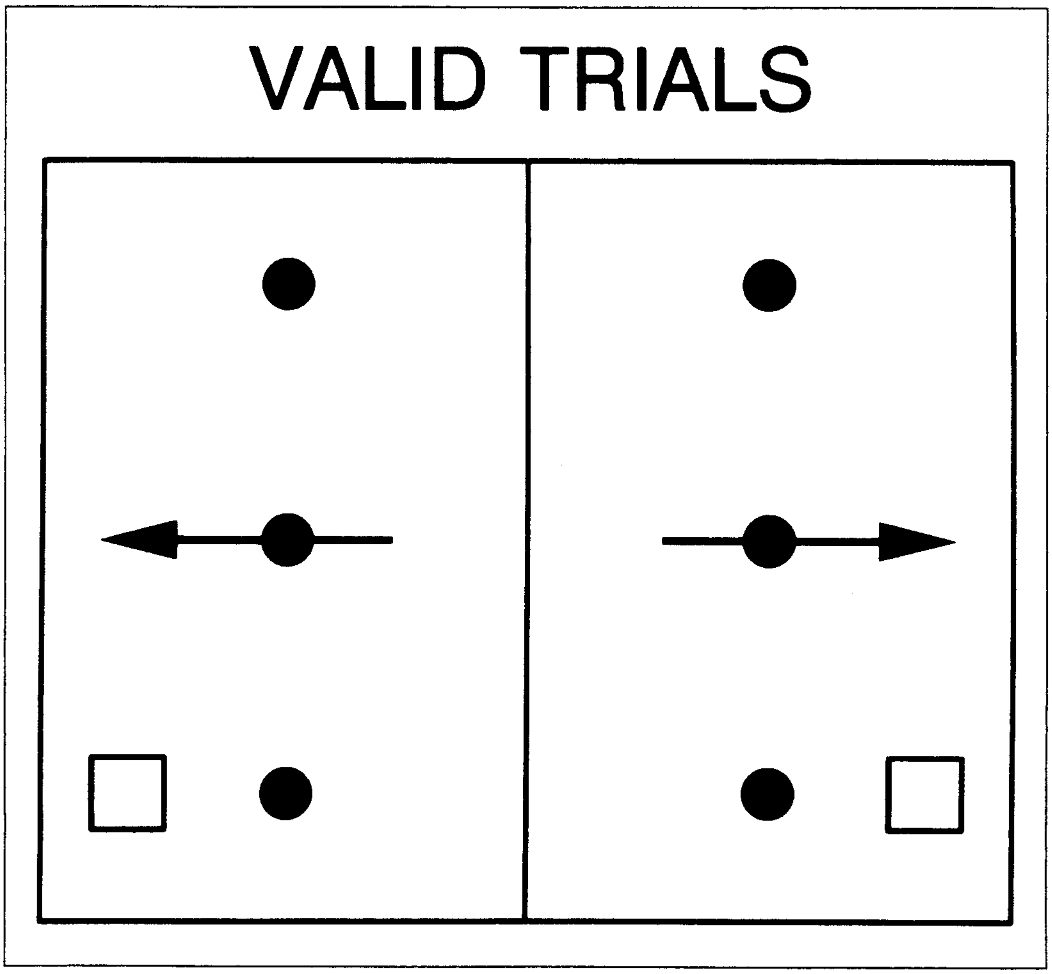
TABLE 7-1. LESION INFORMATION

Patient	*Side of lesion*	*Site of lesion*
1	Left	Posterior temporal–inferior parietal
2	Left	Basal ganglia
3	Left	Posterior temporal
4	Left	Posterior temporal
5	Right	Posterior temporal–parietal
6	Right	Basal ganglia
7	Right	Basal ganglia
8	Right	Temporoparietal

APPARATUS AND PROCEDURES

The orienting tasks were based on "Posner's paradigm," which examines RTs for orienting attention to visual targets only. At the start of each trial, subjects fixated on a dot in the center of a video monitor (Fig. 7-1, *top*). The dot was replaced by a central arrow (Fig. 7-1, *middle*), which cued the location of a subsequent target to the left or right (Fig. 7-1, *bottom*). A random delay of 200 to 600 ms separated the disappearance of the cue and the appearance of the target. This unidirectional cue was valid with a 0.8 probability. Invalid cues (Fig. 7-2), where the target appeared in the opposite direction of the cue, occurred with a 0.2 probability. A bidirectional arrow (Fig. 7-3) served as a neutral cue in which there was an equal probability of subsequent target appearance to either side. Visual targets were light squares subtending approximately one-half degree of visual angle presented at 10 degrees to the left or right of central fixation.

Figure 7-1. Valid trials: The target occurs in the same direction as the unidirectional arrow cue.



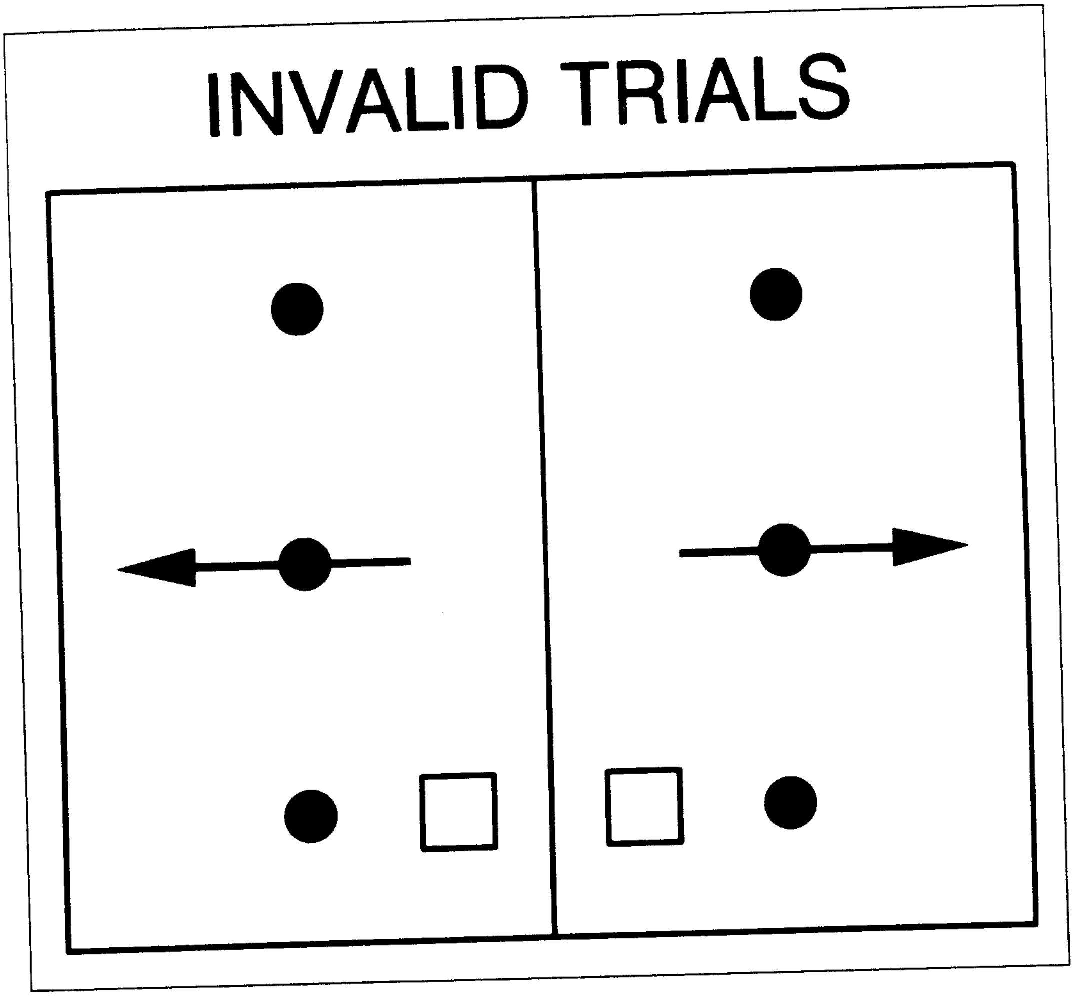


Figure 7-2. Invalid trials: The target occurs in the opposite direction as the unidirectional arrow cue.

Subjects were instructed to react to the target as quickly as possible by pushing a touch switch with their right hand. They were told to use the unidirectional arrow cue to assist them, since it usually predicted target location. At least 100 trials were collected on each subject.

Attention was also tested under conditions that required auditory and cross-modal orienting. For each of these conditions, cuing was the same as for the visual condition. In the auditory-only condition, subjects were required to report the occurrence of 200 Hz square wave pulses presented to the left or right ear through headphones at 70 dB SPL. The cross-modal condition required subjects to report either an auditory or a visual target (i.e., direction was cued but modality was uncertain).

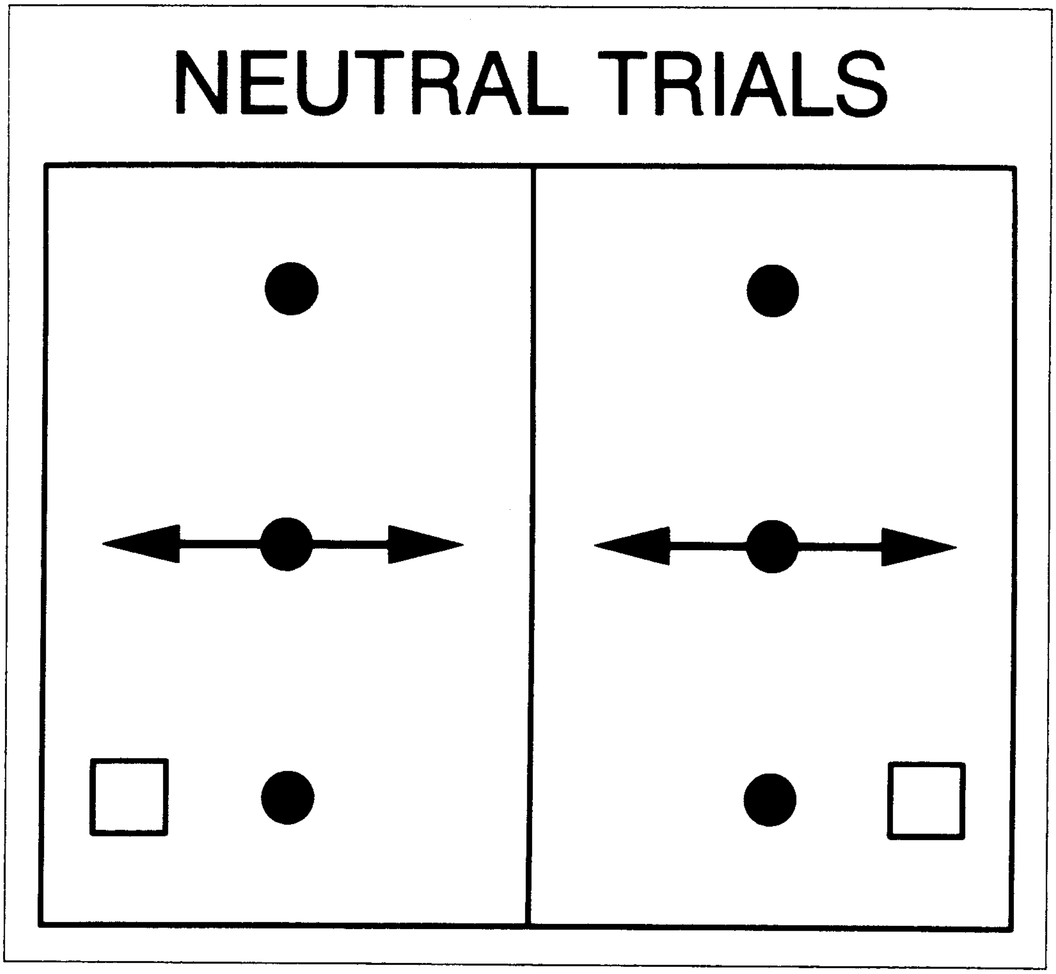


Figure 7-3. Neutral trials: The target occurs either to the left or right following a bidirectional arrow cue.

RESULTS

In normal subjects (Robin and Rizzo, unpublished data), RTs were fastest for valid trials and slowest for invalid trials in all three modal conditions (Fig. 7-4). These results are consistent with Posner's (1980) normative findings that were restricted to vision. Normals had shortest RTs in audition and longest RTs in the cross-modal condition with vision intermediate (Fig. 7-5). The ability to measure orientation of attention in the auditory and cross-modal conditions documented here is important because it enables us to test the extent to which attention can be allocated to specific modalities and between modalities. Finally, normals showed no significant differences in RT between the left and right sides (Fig. 7-6).

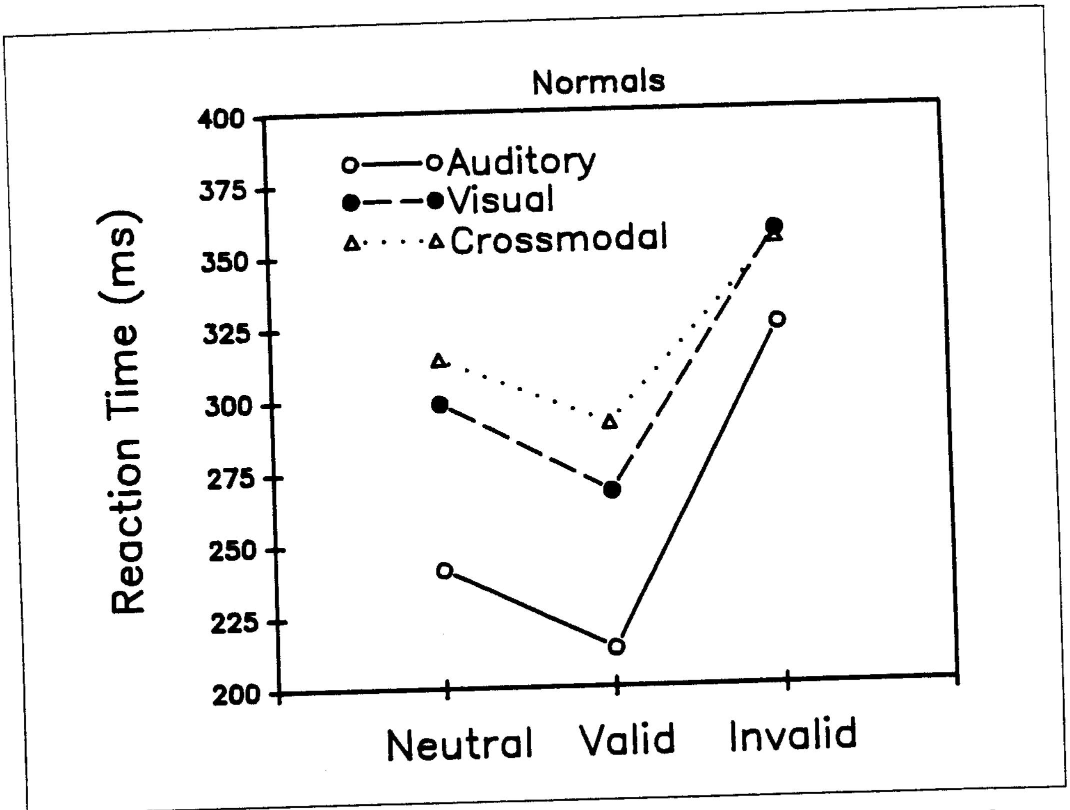


Figure 7-4. Normal control results: reaction times for valid, invalid, and neutral trials for all three experimental conditions.

Performance of brain-injured subjects on orienting attention tasks was quite different (Fig. 7-7). All brain-injured subjects had prolonged RTs compared to normals, regardless of modality. Patients with left-hemispheric lesions and aphasia (Fig. 7-7, *middle*) showed a marked impairment in the ability to orient attention reflected by their inability to benefit from cuing. Resultant RTs in the auditory and visual modalities showed no differences for valid, neutral, and invalid trials. Group data did suggest an apparent advantage for valid cues in the cross-modal condition; however, these data showed a large standard deviation and did not reach statistical significance.

Patients with right-hemispheric lesions (Fig. 7-7, *bottom*) performed quite differently from the left-hemisphere group because they did benefit from cuing in all three conditions, similar to normals. However, compared to normals their RTs were severely prolonged for invalid trials, especially in the visual and cross-modal conditions.

A second analysis of the data examined RT differences in relation to stimulus laterality. A principle finding of this analysis was that RTs for the brain-damaged subjects were significantly longer contralateral to the lesion. Left-hemispheric lesions (Fig. 7-8, *middle*) resulted in longer RTs to

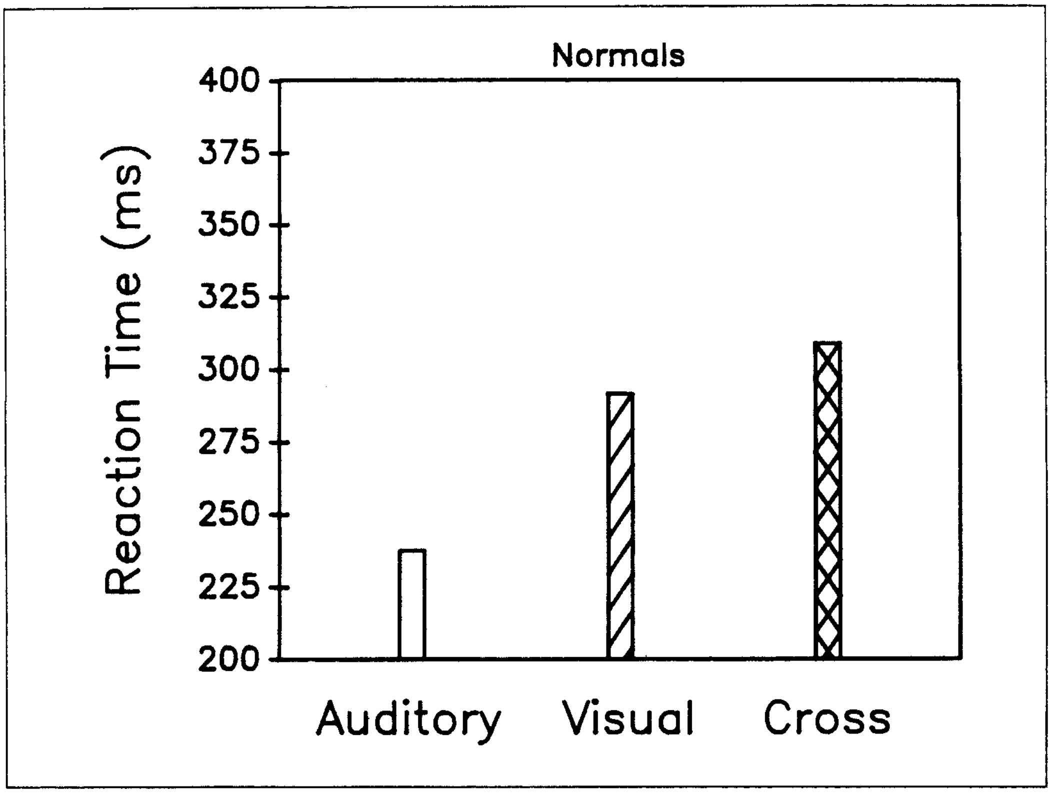


Figure 7-5. Normal control results: reaction times for auditory, visual, and cross-modal conditions.

the right hemispace, and right-hemispheric lesions (Fig. 7-8, *bottom*) resulted in longer RTs to the left. This result obtained even for patients who showed no clinical signs of hemineglect on standard clinical tests such as line bisection or line cancellation.

A final analysis examined differences in RT in audition, in vision, and between modalities collapsed across cuing conditions. Compared to normals (Fig. 7-9, *top*), left-hemisphere injured subjects (Fig. 7-9, *middle*) had the greatest relative impairment of RTs within the auditory modality. By contrast, the patients with right-hemispheric lesions (Fig. 7-9, *bottom*) had the greatest relative impairment of RTs to stimuli in the visual modality.

DISCUSSION

The tasks described in this study did provide a sensitive index of attentional impairment in patients with focal unilateral brain lesions and allowed us to test our a priori predictions. The main findings were that (1) *all* brain-injured subjects had longer RTs than normal, consistent with our hypothesis that attention is a bihemispheric process; (2) *all* patients had

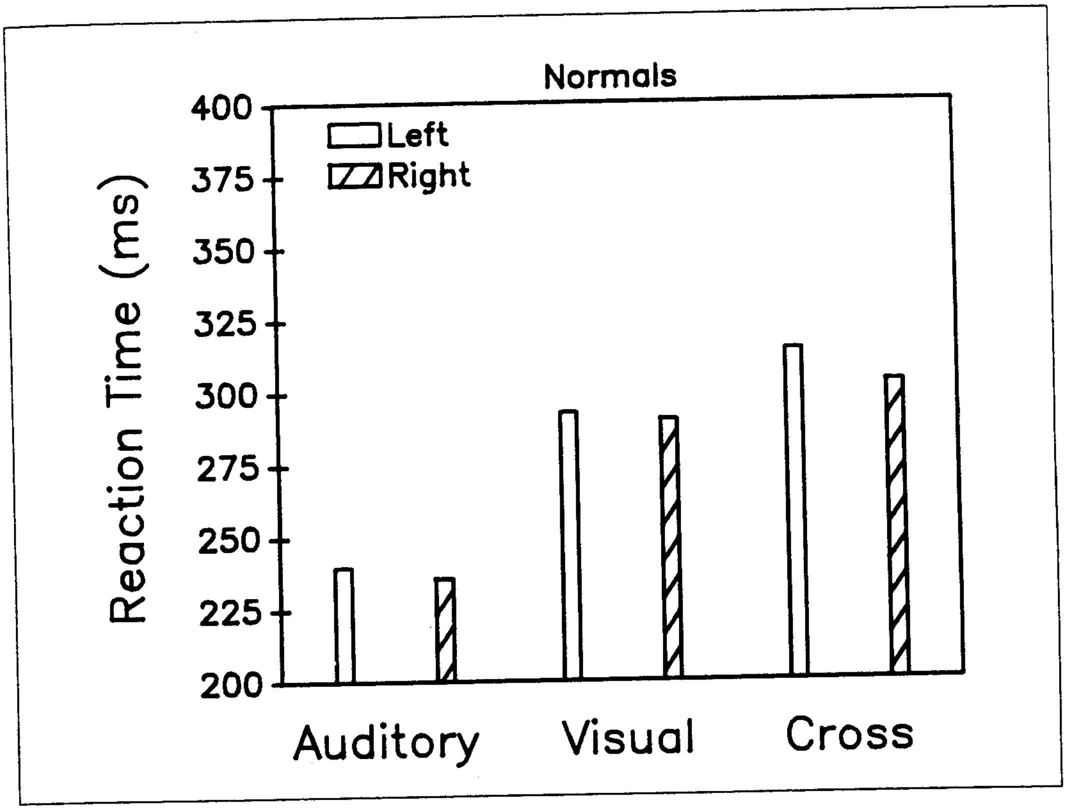


Figure 7-6. Normal control results: reaction times for stimuli presented to the left and right hemispace in all three experimental conditions.

marked impairment of orienting, especially to contralateral hemispace, consistent with our second hypothesis; (3) patients with left-hemispheric lesions had the greatest relative impairment in audition, while patients with right-hemispheric lesions were more impaired in vision, supporting the hypothesis that attention is organized in modality-specific pools; and (4) subjects with left-hemispheric lesions and aphasia did not benefit from valid attentional cues, supporting the hypothesis that attentional defects may contribute to linguistic and cognitive impairments in these patients.

Posner and colleagues (1984, 1987) have argued that neutral operations for visuospatial attention are skewed to the right parietal lobe. Consistent with those findings, our patients with right-hemispheric lesions had abnormally prolonged RTs to invalid cues, and the defect was greatest in the visual modality. Posner emphasized the role of the *parietal* lobe in orientation of attention; however, our data show this ability also depends on structures outside the parietal lobe, since our patients with lesions restricted to the basal ganglia show comparable deficits. Moreover, the attentional deficit is not confined to vision in that our patients also had increased RTs to left hemispace for auditory and cross-modal stimuli.

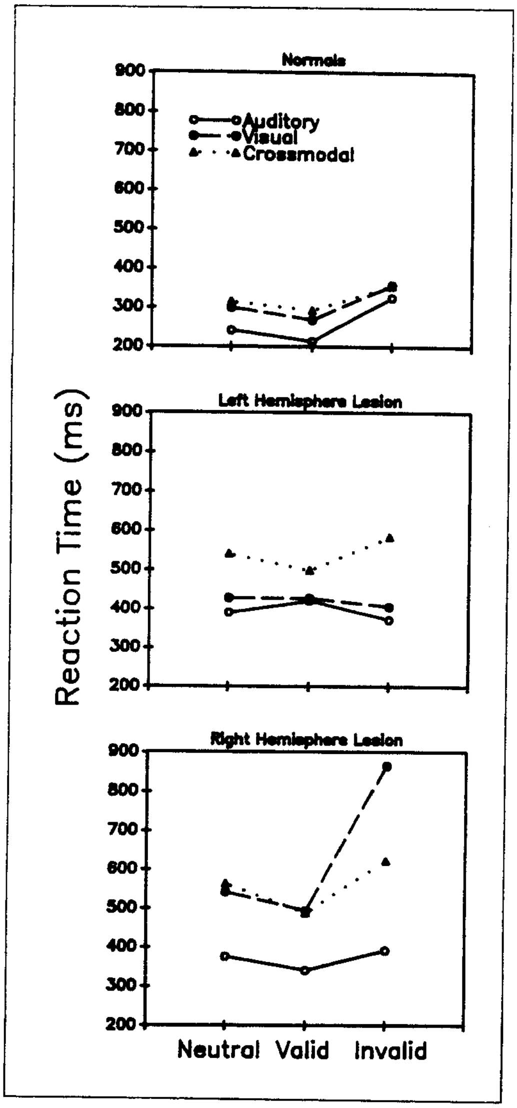


Figure 7-7. A comparison of reaction times for normal subjects (*top*), patients with left-hemispheric lesions (*middle*), and right-hemispheric lesions (*bottom*) for valid, invalid, and neutral trials for all three experimental conditions. Note that the data on normals are the same as that shown in the previous figures, but the scale has been changed to conform to the increased reaction times found in the brain injured subjects.

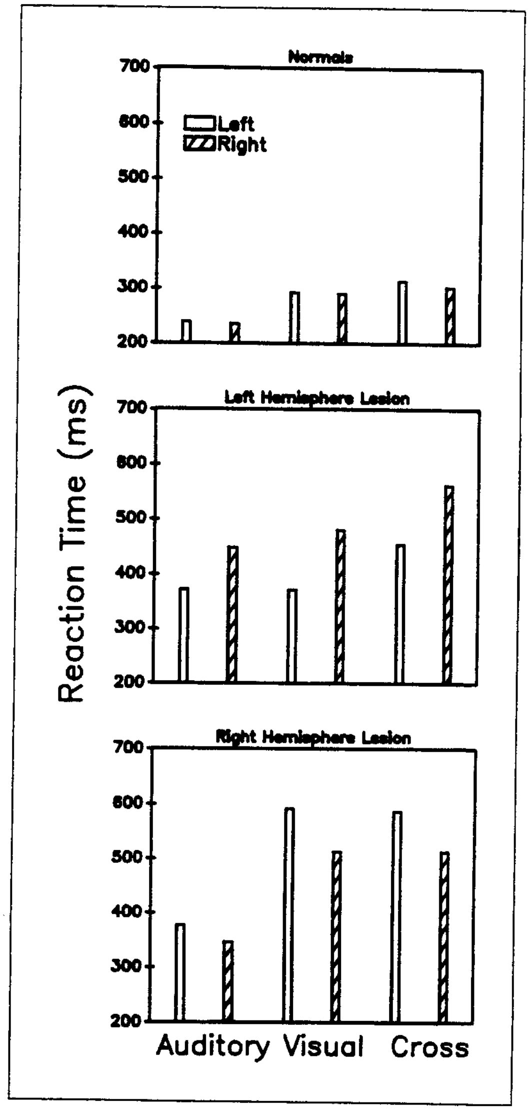


Figure 7-8. A comparison of reaction times for normal subjects (*top*), patients with left-hemispheric lesions (*middle*), and right-hemispheric lesions (*bottom*) for stimuli presented to the left and right hemispace for all three experimental conditions.

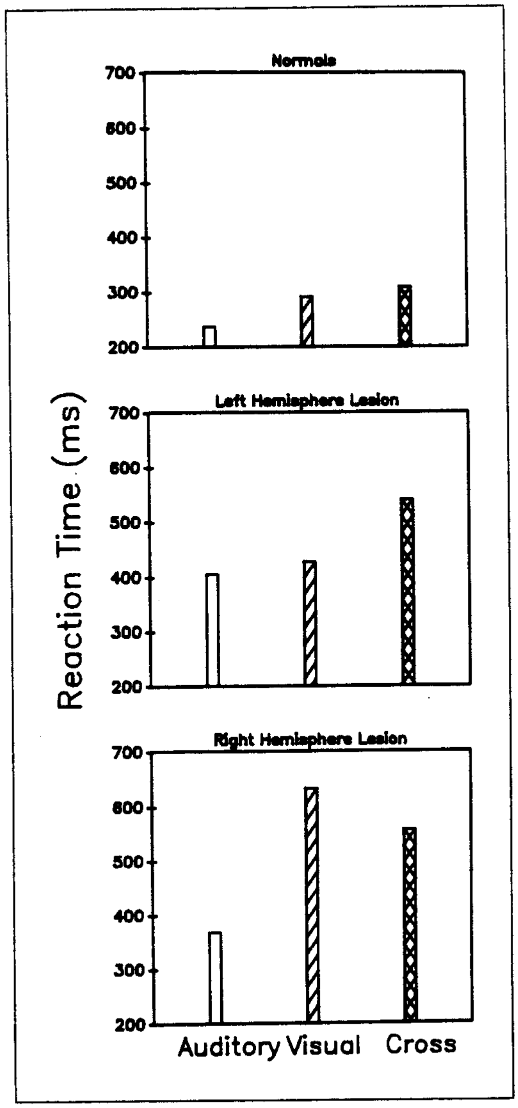


Figure 7–9. A comparison of reaction times for normal subjects (*top*), patients with left-hemispheric lesions (*middle*), and right-hemispheric lesions (*bottom*) for auditory, visual, and cross-modal conditions.

The results of this study also indicate that the ability to orient attention for spatial information is not confined to the right hemisphere. Compared to controls, patients with unilateral lesions restricted to the left hemisphere also had abnormal orienting of attention. In addition, their performance was quite different from the right-hemisphere group because they did not benefit from cuing. Moreover, the left hemisphere may be more involved in allocation of auditory rather than visual-spatial attention because left-hemipshere-damaged patients showed the greatest relative increases in RTs to auditory stimuli.

Abnormal attention may result in an inability to process complex linguistic information by altering the efficiency of phonological, graphemic, syntactic, semantic, and lexical operations. Factors that might contribute to orienting of attention include (1) the detection of the target whether or not it is expected, (2) movement of attention away from a nontarget locus in sensory or cognitive space, (3) release (disengagement) or redistribution of attention as it shifts toward a target site, (4) reengagement of attention at the new position, (5) sustaining of the attentional state in its new conformation, and (6) the response criterion adopted. These underlying factors operate on internal representations serving language and cognition as well as on low-level representations related to geometric properties of physical stimuli. Our brain-injured subjects may have an impairment in one or more of the attentional factors noted above. The orienting tasks used in this study do not allow us to specify precisely which underlying mechanisms lead to impaired RTs at the level of spatial or linguistic processing.

It is apparent that the left and right hemispheres control different aspects of attention related to the factors above. Posner and colleagues (1984, 1987) suggested that patients with right parietal lobe lesions have difficulty disengaging from attention-cued locations. The patients in this study with right-hemispheric lesions outside parietal lobes may also have abnormal disengagement. By contrast, the attentional defect in patients with left-hemispheric lesions and aphasia is probably not related to abnormal disengagement of attention because that deficit is unlikely to explain an increase in RTs for valid rather than for invalid trials.

FUTURE STUDIES

One new paradigm to probe attentional mechanisms examines the sustaining of attention over a complex visual array (Rizzo and Robin, 1988). This task has the possibility of indexing operations not assessed by Posner's paradigm. Subjects view computer-generated "stars" placed randomly over a video display. Up to 1500 stars can be generated on a computer monitor. Subjects are required to respond to each event consisting of the appearance or disappearance of a single star by pushing a computer key. Hits, misses, false alarms, and RTs are recorded. Normal subjects identify events with better than 90-percent accuracy, with a false-alarm rate of less than 5 percent and RTs between 180 and 225 ms.

The implementation of this new attention paradigm has provided preliminary evidence for dissociation of attention processes assessed by different tasks. For example, one interesting brain-injured patient was tested on this paradigm. He identified only 45 percent of the events, had a false-positive rate of 19 percent, and had prolonged RTs. Yet, this patient had a normal performance on the orienting tasks described earlier.

Another paradigm examines RTs to a tone in various backgrounds consisting of speech and/or language stimuli, tonal patterns, chords, or white noise. The background stimuli are designed to occupy the resources of the attention-related stimuli whose operation may be skewed to a given hemisphere or a set of structures that more efficiently process a given type of stimulus (e.g., temporal patterns — left hemisphere, chords — right hemisphere).

ACKNOWLEDGMENTS

The research reported here was supported in part by NIH program project No. PO-NS-19632. We wish to thank Dr. Hanna Damasio for her interpretation of the neuroimaging data. Martin Milder developed the computer software used to implement our paradigms. We also wish to thank Teresa Brobeck and Linda N. Hug for their assistance in data collection and reduction. Finally, Ms. Colleen Thompson is acknowledged for her secretarial support.

REFERENCES

Hillis-Trupe, A. E., and Caramazza, A. (1987). *The graphemic buffer and attentional mechanisms.* Reports of the Cognitive Neurophysiology Laboratory, The Johns Hopkins University, Baltimore MD (Report No. 30)

James, W. (1890). *The principles of psychology.* New York: Holt.

McNeil, M. R. (in press). Aphasia in the adult. In N. Lass (Ed.), *Handbook of speech-language pathology and audiology.* Philadelphia: B.C. Decker.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106,* 226–254.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32,* 3–25.

Posner, M. I., and Boies, J. (1971). Components of attention. *Psychological Review, 78*(5), 391–408.

Posner, M. I., Nissen, M. J., and Ogden, W. C. (1977). Attended and unattended processing modes: The role of set for spatial location. In H. J. Pick (Ed.), *Modes of perception.* Hillsdale, NJ: Erlbaum.

Posner, M. I., Petersen, S. E., Fox, P. T., and Raichle, M. E. (1988). Localization of cognitive operations in the human brain. *Science, 240,* 1627–1631.

Posner, M. I., Snyder, C. R. R., and Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 102*(2), 160–174.

Posner, M. I., Walker, J. A., Friedrich, F. J., and Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *The Journal of Neurosciences,* 4(7), 1863–1874.

Posner, M. I., Walker, J. A., Friedrich, F. A., and Rafal, R. D. (1987). How do the parietal lobes direct covert attention? *Neuropsychologia,* 25(1A), 135–145.

Rizzo, M., and Robin, D. A. (1988, November). *Vanishing targets in simultanagnosia: Failure to sustain visual attention over an array.* Paper presented at the Annual Meeting of the Society for Neuroscience, Toronto, Canada.

Robin, D. A., and Rizzo, M. (in preparation). Orienting attention in vision, audition and between modalities.

Treisman, A. M., and Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12,* 97–136.

Treisman, A., and Paterson, R. (1984). Emergent features, attention, and object perception. *Journal of Experimental Psychology: Human Perception and Performance, 10*(1), 12–31.