

## Auditory Neglect after Right Frontal Lobe and Right Pulvinar Thalamic Lesions

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Auditory unilateral neglect or extinction to simultaneous stimulation is reported in a right-handed male with a lesion in the right frontal lobe and in the right thalamic pulvinar area. The patient was submitted to stereotactic thalamotomy for a post-traumatic intentional ataxia in the left extremities. He was subjected to repeated tests with dichotic listening to consonant-vowel syllables under three different attentional instructions. He was also tested monaurally with the same stimulus materials as used in the dichotic test. The results showed almost complete extinction of the left ear input during dichotic presentations, despite normal hearing when tested with audiometer screening. The left ear extinction effect was independent of instructions to attend to the left or right ear input. However, during monaural presentation, correct left ear reports increased to about 85%. The results are interpreted as showing an auditory attentional neglect caused by the right frontal and pulvinar lesions. © 1991 Academic Press, Inc.

In the present study we report a case of auditory hemispatial neglect after a traffic accident resulting in a diffuse lesion in the right frontal lobe

The present research was financially supported by the Norwegian Council for Research in the Medical Sciences (NAVFRMF), and by Nansenfondet, Oslo, Norway to Knut Wester and Kenneth Hugdahl. Address all reprint requests to Kenneth Hugdahl, Department of Biological and Medical Psychology, Division of Somatic Psychology, University of Bergen, Årstadveien 21, N-5009 Bergen, Norway.

and a restricted lesion in the right pulvinar. The patient was tested with dichotic listening (DL) with consonant-vowel (CV) syllables (Studdert-Kennedy & Shankweiler, 1970) under three different attentional instructions (cf. Bryden, Munhall, & Allard, 1983; Hugdahl & Andersson, 1986). The patient was part of a larger study on dichotic listening comparing right- and left-sided thalamotomy in patients with dyskinesias and tremor. The present patient is, however, presented as a single case-study because of his profound neglect-like behavior following right-sided lesions in the frontal lobe and pulvinar thalamus. We thus hypothesized that he might constitute a rare example of auditory neglect (cf. Heilman & Valenstein, 1972a).

The neglect phenomenon is usually observed after right hemisphere lesions (Heilman & Watson, 1977; Robertson, 1989; Jeannerod, 1987), and patients with hemineglect perform poorly on a variety of behavioral tasks on the side of space contralateral to their lesion (Rapcsak, Verfaillie, Fleet, & Heilman, 1989). Heilman and Valenstein (1972a) proposed an attention-arousal hypothesis to account for unilateral neglect that involves secondary association centers in the inferior parietal lobe. However, unilateral neglect can also be produced after lesions in the frontal lobe and especially in tertiary association areas (Heilman & Valenstein, 1972b).

Although most studies of unilateral neglect are concerned with visual dysfunctions, Heilman and Valenstein (1972a) reported 10 patients with auditory neglect, including frontal locus (see also Silberpfennig, 1941). Thus, although neglect usually accompanies lesions of right parietal areas, a few rare cases of frontal lobe neglect have been reported in the literature.

Heilman and Valenstein (1972a) used monaural and binaural nonverbal auditory stimulation and defined auditory neglect as "if a patient was consistently able to identify unilateral stimuli but consistently missed one side with bilateral simultaneous stimuli, he was considered to have auditory neglect" (p. 33).

Thus, if auditory neglect is related to the same underlying mechanisms as the more familiar visual neglect, then auditory stimuli uniquely presented contralateral to the lesioned side should be ignored or neglected. In addition, specific instructions to attend to and report only items presented to the side contralateral to the lesioned side should have no effect on performance. Finally, if failure to report items presented to the ear contralateral to the lesion under dichotic competition is due to neglect and not to hearing loss, then *monaural* presentations should *not* be neglected.

Dichotic listening takes advantage of the fact that in auditory projections to a given hemisphere, the number of neurons from the contralateral ear is greater than the number of neurons from the ipsilateral ear (Rosenzweig, 1951; Nebes & Nashold, 1980). Kimura (1967) has thus suggested that under conditions where the two ears compete for left hemisphere

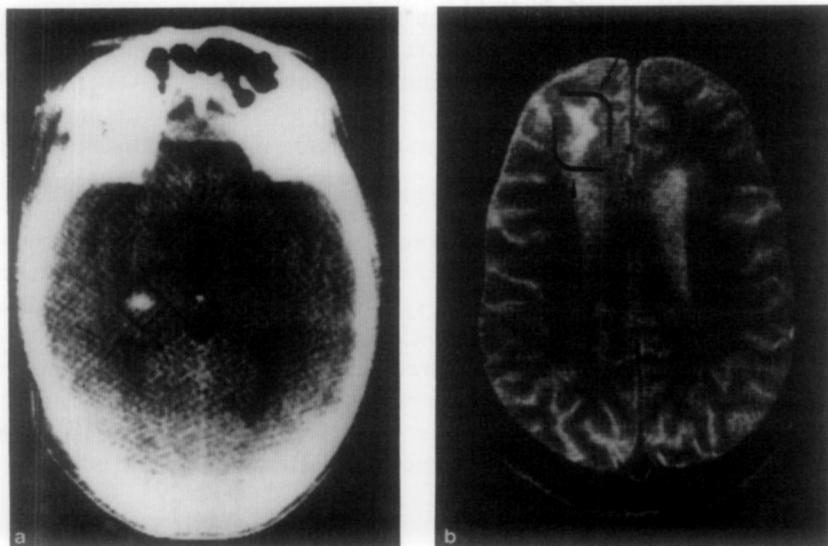


FIG. 1. (a) A horizontal section CT scan revealing a small right-sided thalamic lesion posteriorly in the pulvinar area (encircled). (b) A horizontal section MRI scan revealing a right-sided diffuse frontal lobe lesion (encircled). Note that the right side of the brain is shown to the left and vice versa in both the MRI and CT scans according to standard radiological conventions.

language processing capacity, right ear input blocks input from the left ear. The blocking or occlusion of the ipsilateral pathways may occur at either the subcortical or the cortical level (Kimura, 1967; Zaidel, 1976; see also Hugdahl, 1988, for a review).

#### THE PATIENT

The patient, a 22-year-old male, was severely head-injured in a car accident 4 years earlier. Following the accident, he remained unconscious for 10 days and was treated conservatively, which included respiratory treatment. Cerebral computer tomograms (CTs) showed a small hemorrhage in the right, posterior pulvinar thalamus. CT and magnetic resonance imaging (MRI) scans revealed moderate contusions in the right frontal lobe, involving the supplementary motor areas, as well as signs of a more generalized cerebral atrophy. This is seen in Figs. 1a, 1b. The MRI scan was taken about 6 months before surgery, and the CT scan was taken the same day as the surgery.

After the accident, the patient had a slight/moderate left hemiparesis and a marked intentional ataxia of the left arm and leg. He also experienced impaired vision, particularly in the left visual field.

During the following years, the left hemiparesis improved, whereas the

intentional ataxia grew worse and assumed the character of an uncontrolled and disabling involuntary movement, especially affecting the proximal muscle groups of the upper limb. For this reason he was referred to our (neurosurgical) department for a stereotactic thalamotomy. For details concerning the surgery, see Wester and Hauglie-Hanssen (1990).

### DICHOTIC LISTENING

The dichotic stimulus materials consisted of the six stop-consonants *b*, *d*, *g*, *p*, *t*, and *k* which were paired with the vowel *a* to form six basic CV syllables (*ba*, *ga*, *pa*, etc.). The syllables were paired with each other for all possible combinations, thus yielding 36 dichotic pairs including the homonymic pairs (the homonyms were used as test trials and excluded from statistical analyses). Each pair was randomly recorded three times on the tape. Thus, the total number of trials on the tape was 108. The intertrial interval (ITI) between stimulus presentations varied between 4 and 5 sec.

The dichotic tape was computer generated and each CV syllable had a duration of 320 msec. Maximum onset difference between the channels was 0.5 msec due to computer multiplexer resolution and the sampling frequency (10 KHz).

Each syllable was originally read by a male voice and inputted into the computer. After computer analysis, the syllables were recorded onto a NAGRA IV tape recorder. In order to more easily test the patient in the hospital environment, the NAGRA tape was copied onto a chrome dioxide cassette and played from a SONY WM DD minicassette player with "plug-in-type" earphones. The output of the minicassette player was calibrated and the mean intensity was 84 db SPL measured with a Brüel and Kjaer 2204 sound level meter.

The DL testing was performed the day before surgery, immediately before surgery (inside the operation room), during surgery (electric stimulation), just after surgery (immediately after suturing the wound), and the day after surgery. However, since his DL performance remained essentially the same across tests, data are collapsed across test sessions.

The patient had to answer with the syllable he heard on each trial. His answer was marked on a specially designed scoring sheet. In addition, everything that was said during the testing was taped on another minicassette tape recorder through a small microphone clipped to the patient's shirt. A short pause was inserted after each list of 36 trials to let the patient rest.

In the nonforced recall condition, the patient was instructed to report both of the stimuli as accurately as possible. If he only managed to identify one syllable on a trial, he should report that one. No specific instruction concerning allocation of attention between ears was given.

In the forced-right condition, the patient was told that he would hear

two different stimuli, but that he should only attend to and report what he heard in the right ear, ignoring the left ear input.

In the forced-left condition, the patient was told that he should only attend to and report what he heard in the left ear, ignoring the right ear input. The instruction was otherwise identical to the instruction given in the forced-right condition.

Order of presentation of the instruction was randomized across test occasions.

### MONAURAL TESTING

The monaural tests were for clinical reasons only made pre- and post-operatively. In order to be comparable with the dichotic tests, the monaural tests were performed with the same stimulus materials (i.e., CV syllables) as during the dichotic tests. The monaural tests were performed by removing the left or right earphone, respectively. During the presurgery test, the left earphone was removed first, and then the right one. During the postsurgery test the order was reversed. There were 36 monaural trials for each monaural test. Data were collapsed across sessions, taking the mean of the tests.

## RESULTS

### *Audiometer Screening*

The patient's hearing was tested with a Tegnér audiometer screening apparatus. Since most of the energy in the DL test was between 500 and 4000 Hz, the patient was tested for detection thresholds for tones presented between 500 and 6000 Hz in steps of 1000 Hz (except for between 500 and 1000 Hz). Threshold differences between the ears did not exceed 10 db at any frequency, except for 6000 Hz. Thus, general hearing was considered normal within the critical frequency range.

### *Dichotic Listening—Nonforced Attention*

Mean percentage correct recalls from the left and right ears are seen in Fig. 2. Figure 2 is arranged as follows: To the far left are the results from the nonforced recall condition, then those from the forced-right, forced-left, and monaural input conditions. As can be seen in Fig. 2, there was only about 5% recall at all from the left ear. The right ear correct recall was, however, on the average 86% across tests. The difference in correct recall from the left and right ear was statistically significant when tested with the  $\chi^2$  for the goodness of fit test, assuming equal correct reports from the ears as the null hypothesis ( $\chi^2(1) = 67.16, p < .001$ ).

### *Forced-Right Attention*

During the forced-right attention condition, correct left ear recall was even further reduced compared with that during the nonforced condition.

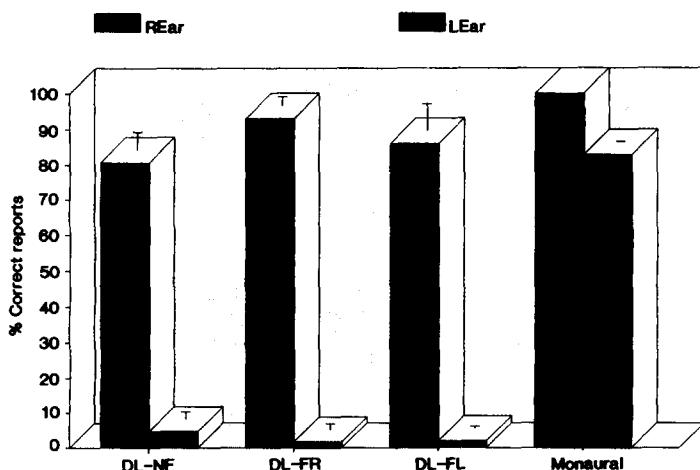


FIG. 2. Mean percentage correct reports from the right and left ear during dichotic and monaural listening. LEar, left ear input; REar, right ear input. Small bars = SD. Note that data are plotted across test sessions.

As can be seen in Fig. 2, average correct left ear reports were approximately 3%. Correct right ear recall was slightly higher than during the nonforced condition, on the average 93% across tests. The difference between correct left and correct right ear recall was statistically significant ( $\chi^2(1) = 84.38, p < .001$ ).

#### Forced-Left Attention

Once again, correct recall from the left ear was close to zero (average 2%), while correct right ear recall was on the average 86% across tests. The difference between left and right ear correct recall was statistically significant when tested with the  $\chi^2$  test ( $\chi^2(1) = 80.18, p < .001$ ).

#### Monaural Testing

Results from the monaural tests are seen in the far right panel of Fig. 2. The results showed on the average 100% correct recall during right ear input and 83% correct recall during left ear input. Thus, correct left ear recall increased from roughly zero during the three dichotic tests to above 80% during the two monaural tests. The difference between right and left ear correct recall was not statistically significant when tested with the  $\chi^2$  test ( $\chi^2(1) = 1.58, \text{n.s.}$ ).

## DISCUSSION

To sum up the main findings:

- (1) Correct left ear recall (input to the contralateral lesioned right hemisphere) was close to zero during all DL test conditions.

(2) Correct right ear recall was high, between 80 and 100% during all DL test situations.

(3) During the monaural presentation mode, correct recall increased to 100% for right ear recall and to about 86% for left ear recall.

(4) Normative group mean data for dichotic listening from normal male adults generally show 60–70% correct right ear recall and 40–50% correct left ear recall (Hugdahl, 1988). Thus, the present patient was clearly *below* the normal range for left ear correct recall, but *within* the normal range or actually slightly *above* for right ear correct recall.

The increase in *left* ear correct recall during the monaural input condition was dramatic compared to that during the dichotic input condition. Thus, there was a remarkable difference between the dichotic and the monaural presentation modes for the left ear which was not seen for the right ear (where the increase during the monaural condition was marginal). The high percentage correct left ear recall during the monaural listening mode together with the fact that there were no significant differences between the ears in threshold performance when tested with audiometer screening (most thresholds were at 10 or 20 db) makes a strong case against an explanation of the patient's DL performance as due to a peripheral hearing loss, or to a perceptual deficit. Instead the explanation should be looked for in terms of attentional neglect or auditory hemispatial extinction (cf. Heilman & Valenstein, 1972a; Mesulam, 1981). Since the patient showed no deficit in primary sensory pathways, as revealed during monaural testing, a plausible interpretation of the DL results is that the neglect reflected an underlying right hemisphere attentional deficit (cf. Posner & Peterson, 1990).

The present results have further demonstrated that auditory neglect is not secondary to a deficit in primary sensory pathways, but probably due to lesions of structures coupling sensorimotor functions and attention. It seems that the pulvinar/reticular areas in the right thalamus play an important role in this respect and that auditory neglect may occur after dissociation of sensorimotor and attentional processes (cf. Velasco, Velasco, Ogarrio, & Olvera, 1986). The dichotic listening performance of the present patient would thus fit the requirements for unilateral neglect to simultaneous stimuli listed by Heilman and Watson (1977).

The failure to report the left ear input under dichotic presentations involves a failure of directing attention, since specific instructions to attend only to the left ear input had no effect on recall. Since the patient had multiple lesions involving different distinct areas in the brain, one should be careful in attributing the behavioral cognitive dysfunction solely to one area rather than the other. However, one may speculate if the effects reported in the present case are more due to the thalamic than to the frontal lesion. Both Heilman and Watson (1977) and Mesulam (1981) have emphasized the possible role of arousal and attention dysfunction

in neglect, involving lesions of parts of the reticular system. Furthermore, Heilman and Valenstein (1972b) have warned against a pure perceptual explanation for neglect, instead arguing for a unilateral arousal defect. This was partly based on the fact that neglect can be produced outside of primary cortical areas. Thus, a lesion in the posterior auditory parts of the thalamus, as in the present case, may also involve lesioning of the thalamic reticular nucleus, with dysfunctional attention and arousal as a consequence (cf. Henderson, Alexander, & Naeser, 1982). We have previously shown (Hugdahl, Wester, & Asbjørnsen, 1990) that stereotactic lesions in the ventrolateral thalamus (close to the thalamic reticular nucleus) affect dichotic listening performance in Parkinson patients.

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