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APHASIA, DICHOTIC TESTING AND DEFECTIVE HEARING

Ulf Norrsell, MD,[1,3] Solweig Ramsing, Speech Therapist,[1] Ulf Rosenhall, MD[2] and Christian Blomstrand, MD[1]

From the [1]Neurology Division, Department of Clinical Neuroscience [2]Audiology Division, Ear, Nose and Throat Clinic [3]Physiology Division, Department of Physiology and Pharmacology, Göteborg University and Sahlgrens' Hospital, Göteborg, Sweden

ABSTRACT. Cerebral lesions causing aphasia are often found close to auditory areas. The aphasia may therefore sometimes be aggravated by hearing problems, which are concealed by communicative restrictions. Unilateral lesions of the cerebral auditory system influence the functional ear preference disclosed by dichotic tests. For that reason we have examined aphasic patients with recent, initial, unilateral brain infarctions for ear preference with regard to dichotically presented two syllable words. In a consecutive series of 114 patients who could cope with the test, 29 showed signs of an acquired left ear advantage (LEA). All were offered, and 22 accepted a full scale audiological examination including pure tone, speech and phase audiometry. Nine of these patients showed retrocochlear or central hearing disturbances, which added to their communicative predicaments. The LEA of 11 patients lacked audiological rationales and a compensatory shift of cerebral speech-lateralization cannot be excluded.

Key words: aphasia, dichotic listening, audiometry.

When normal people are presented simultaneously with two different sounds of linguistic nature dichotically, i.e. one for each ear, they will often show ear advantage. They will usually be able to recall a greater number of the sounds (often syllables) presented to the right ear compared with the left (2), or so called right ear advantage (REA). The dichotic method for determination of normal or brain damaged persons' ear advantages has become widely used following Kimura's (8, 9, 10) original observations. Kimura had observed two things: She noticed that the relative advantage or proficiency was diminished for an ear contralateral to unilateral temporal lobe damage. This "lesion effect" is attributed to damage of the auditory cortex and has been confirmed subsequently (6, 17, 19). She also noticed a possibly essential correlation between a subject's preference for one ear and the cerebral dominance for speech of the opposite hemisphere. On the basis of two assumptions, that second observation has supplied major reasons for the test's ubiquity. 1: That it provides a non-invasive method for estimating hemispheric dominance. 2: That the not seldom observed left ear advantage (LEA) of aphasic stroke patients can be taken to indicate a compensatory takeover of speech function, from one hemisphere to the other. Nevertheless, these two assumptions have also been disputed (4, 5, 7, 22).

The discussion about the interpretation of aphasics' LEA continues (16) on the basis of partially indirect evidence. However, lesions causing aphasia are often situated close to the cerebral auditory areas, and a "lesion effect" explanation is therefore possible in some individual cases. We have been interested to find out concretely to what extent the recovery of aphasics may be curbed by concurrent hearing disturbances. As a first step, aphasic patients with dichotic LEA were also examined audiologically, and almost half of the group was found to have a complex hearing defect, which may well have aggravated their condition.

MATERIAL AND METHODS

Subjects

The observations were made on 22 persons with LEA, who are listed in Table I. They belonged to the group of patients who over a 4-year period had been directed to the neuropsychology section of the neurology division for assessment of possible aphasia. Dichotic testing was made on all such patients, if feasible, and had been possible for 114 aphasics of whom 29 showed LEA. Audiological testing was not standard procedure under the circumstances, but was explained and offered to the LEA group. The above-mentioned 22 persons were those who were willing and able to accept the offer.

Dichotic testing

The full dichotic test consisted of three parts: a monotic hearing test, followed by a dichotic training test with numbers, followed by the dichotic words test. The hearing test consisted of Swedish everyday, two-syllabled words which were played from a tape recorder through earphones one at a time with 3 s intervals. The first word was presented through both phones at conversation level. The following word was presented at unchanged intensity, but through the left earphone only, and the next word also in the left ear, but with an overall, 10 dB (SPL) intensity attenuation. The subsequent words were also presented in the left ear and attenuated 10 dB at a time until 50 dB (SPL), overall below the starting intensity was reached, and then amplified again in 10 dB steps back to the original level. After a new binaural presentation, the same procedure was repeated for the right ear, and then again for the left ear, and finally a last time for the right ear. The patients were instructed to repeat each word aloud immediately after presentation, and in the end the patient had been presented with 22 words in each ear, and 5 words bilaterally. The lowest intensity which had elicited a correct repetition was considered to be the threshold value.

The dichotic numbers test was made with Swedish numbers >20 and <100 with all multiples of 10 omitted. The numbers were played from a tape recording at 3 s intervals. One ear heard a real number, while the other was presented simultaneously with its constituent phonemes repeated backwards. The real numbers, 16 for each ear, were switched between the ears according to Durup's (3) pseudo-random series. One number was presented binaurally, before and after each group of 8 dichotic stimuli, and the intensity was kept throughout at the maximal level of the preceding hearing test. The patient had been told that he would hear a real number together with interfering noises, and had been instructed to immediately repeat the real number aloud.

The dichotic words test was made with Swedish everyday, two-syllabled nouns. The protocol for the presentation was exactly analogous to the preceding numbers test.

Audiometric testing

All of the patients were evaluated with pure tone, speech, and phase audiometric tests with one exception. The patient GJ's general hearing difficulties made the phase audiometric testing ineffectual. The inclusion criteria for that test were pure tone averages for 0.5, 1 and 2 kHz of 40 dB HL or better, and a pure tone threshold at 0.5 kHZ of 30 dB HL or better for either ear.

The phase audiometric testing has been described elsewhere (18). Briefly, 500 Hz tones were presented in each ear through headphones (TDH-39). The tones were first presented in phase and adjusted to a comfortable loudness level to give a midline impression. The testing was commenced with a phase lag of 90° (500 μs) between the ears. The phase lag was diminished by 1.8° (10 μs) decrements at the beginning, but by 0.9° (5 μs) decrements below 36° (200 μs). The left and the right ear was permitted to lead at random with regard to phase, and between each test the tones were presented without phase lag in order to provide a reference, midline impression. The patients were instructed to indicate the direction of the subjectively experienced deviation from the midline of the test tones, and a testing series was finished after three consecutive 'errors', i.e. mismatches between the responses and the leading tone. The testing series were repeated until reproducible results were obtained, and the shortest 'correctly' reported phase lag was considered to represent a patient's discriminatory capacity.

The control group consisted of 50 apparently healthy persons, 23 females and 27 males (mean age 48.3 y, range 20–69). The same inclusion criterion was used for patients and controls with regard to tone audiometric proficiency. Phase lags exceeding the control group's mean result with two standard deviations were considered to be abnormal.

RESULTS

Those of our aphasic patients who were able to repeat normally presented, two-syllabled words without great difficulties were also asked to perform a more complex task of word repetition. In that case the two-syllabled word was presented to one ear together with a distraction which consisted of the same word spoken backwards, and presented simultaneously (dichotically) to the other ear. More than a quarter of the aphasics who were able to participate in this type of testing found it easier to repeat those words which had been presented to the left ear compared with those presented to the right. In this respect they were different from a group of presumably normal persons of whom less than 10% were able to use their left ears better in this respect.

The scatter diagram in Fig. 1A shows the results of 20 each, normal females and males (median age 38 y, range 22–65) who had been tested with the same test as the aphasics. Three of them used their left ears better, and consequently had a quotient for correctly repeated right ear words vs left ear words (r/l quotient) <1. The lowest r/l quotient of 0.6 belonged to a right-handed person. Four of the persons in Fig. 1A were not right-handed and only one of those had a r/l quotient <1 (0.8). The results of 22 aphasics with r/l quotients <1, and who satisfied our additional criteria of having first instance, acute and recent, left-sided, unilateral brain damage, and who had later undergone audiometry are shown for comparison in Fig 1B.

The 22 patients are listed in Table I, and their r/l quotients are specified. It is obvious from both Fig. 1B and Table I that the aphasics' relatively better use of their left ears was more pronounced than that of normal persons. Only two patients had a r/l quotient >0.6, i.e. higher than the smallest 'normal' quotient. The patient EN who was the only non-right-handed among the patients, according to the criteria of Varney & Benton (21) had a r/l quotient of 0.1.

The results of any test that compares a person's ability to repeat equivalent words which have been

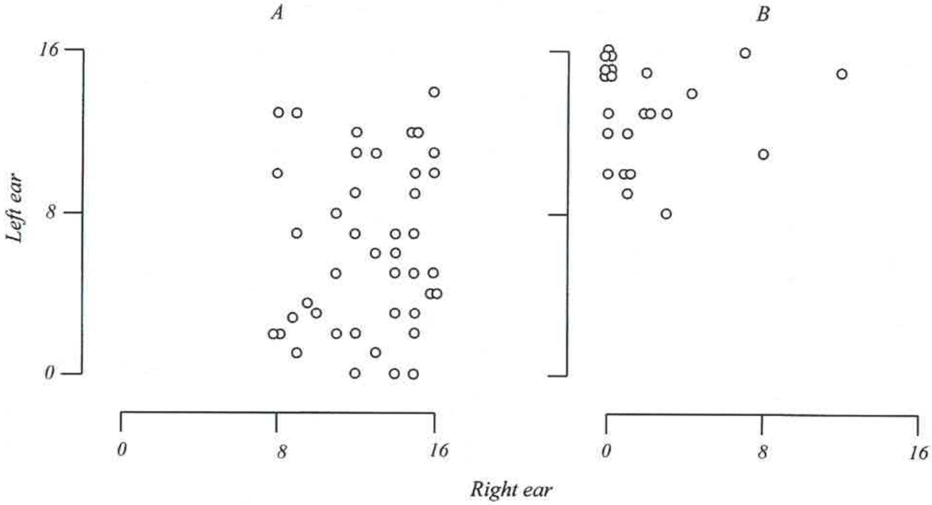

Fig. 1. Number of correctly repeated words, which had been presented to left ear (ordinates) vs. right ear (abscissae). Sixteen common, two-syllable Swedish words were presented dichotically to each ear in combination with a homo-phonemic pseudo-word. (A) 40 normal persons. (B) 22 aphasic patients.

presented to either ear, will by necessity be influenced by any differences of hearing capacity. For that reason our dichotic tests were preceded by a rough hearing test. The median threshold for the 22 aphasics was 30 dB below the standard intensity with a range between 10 dB and 50 dB. The average difference between right minus left ear thresholds was −3.2 dB with a confidence interval (95%) of 3.2. The patients were not able to repeat all of the words which had been rendered at threshold and supra-threshold levels, and perhaps could not be expected to do, due to their aphasia. The average difference, however, between the correctly repeated number of right ear, monotic words minus the corresponding left ear words was −1.7 with a confidence interval (95%) of 2.0.

The audiometric examinations had been made as a consequence of the patients' LEA, and they were divided into three categories on basis of the audiometric results. I: Those without any audiometric explanation for the LEA. II: Those with manifest retrocochlear hearing disturbance. III: Those with hearing problems favouring LEA.

The audiometric examinations had revealed that the above-described rough hearing test had to a certain extent been inadequate. Six of the patients were found to have left/right asymmetries caused by cochlear hearing losses (11). Three of the patients had better hearing with their right ears (AA, AN, BE), and three patients had better hearing with their left ears. The better left ear hearing of the latter group could possibly have explained their <1 r/l quotients, and consequently these patients were grouped as category III in Table I on that basis, and excluded from further consideration with one exception. The patient AB had also presented an additional central hearing predicament which might have influenced his dichotic performance and was placed with category II for that reason. The three patients with better hearing of the right ears ought to have produced r/l quotients >1, if hearing had been a decisive factor in their cases. For that reason, they were classified with category I of Tables I and II, which contains all of the patients who lacked an audiometric explanation for their atypical r/l quotients.

The results of the audiometric examinations, are summarized in Table II. The major result was the finding that nine (41%) of the patients suffered from retrocochlear, or central hearing losses in the form of defective directional hearing (11). These nine patients required greater than normal phase-lags between the ears of varying magnitudes for experiencing reproducible directional shifts. Three of them required phase-lags of 23°–44°, two required phase-lags of 45°–66°, and four required phase-lags $>67°$. The patients were designated category II and had an average result of 55.8° compared to 15.3° for category I, which is shown in Table II. Table II also shows that the patients belonging to category II had got pure tone

Table I. *Twenty-two patients with aphasia after acute, unilateral, left hemisphere damage, who showed left ear advantage (LEA) for a dichotic test, and who have been divided into 3 categories after audiometric results*

Category I, Audiometric explanation for LEA lacking. II, Abnormal phase audiometric results. III, Right ear hearing deficiency. Order of listing after the r/l quotients.

Initials	Age (y)	R/L quotient[1]	Dichotic % correct[2]	Monotic % correct[3]	T-T points[4]	Aphasia type	Aud. ctx dysfunct.[5]
Category I							
C Z	66	0.0	38	50	8	Fluent	Probable
A A	68	0.0	41	na[6]	14	Nonfluent	Unlikely
A N	18	0.0	47	80	12	Nonfluent	Unlikely
G E	40	0.0	50	84	6	Nonfluent	Unlikely
E N	72	0.1	34	88	9	Fluent	Unlikely
T M	75	0.1	41	65	10	Fluent	Unlikely
B K	45	0.1	53	70	12	Nonfluent	Possible
G L	49	0.3	56	90	14	Nonfluent	Unlikely
P H	18	0.4	72	88	16	Fluent anomic	Possible
R St	49	0.7	59	84	13	Fluent	Unlikely
B E	48	0.8	84	100	12	Fluent	Unlikely
Category II							
A B	64	0.0	47	59	5	Fluent	Probable
I-M B	36	0.0	47	85	14	Nonfluent	Probable
L M	73	0.0	47	91	7	Nonfluent	Unlikely
B N	44	0.0	50	91	3	Fluent	Probable
G A	81	0.1	31	53	5	Fluent	Unlikely
M F	63	0.1	34	88	10	Fluent	Possible
I J	58	0.2	47	70	9	Fluent	Possible
L S	58	0.2	50	na[6]	3	Nonfluent	Unlikely
R Sa	61	0.4	34	96	9	Fluent	Unlikely
Category III							
G J	65	0.0	31	50	1	Fluent	Unlikely
L K	61	0.2	47	81	0	Fluent	Probable

[1] Number of correctly repeated right ear words for the dichotic test divided by corresponding left ear words.
[2] Per cent total amount correctly repeated words for dichotic test.
[3] Per cent correctly repeated supra threshold words for hearing test.
[4] The 16 item Token Test results (20).
[5] Possible damage of left auditory cortex.
[6] Not applicable.

thresholds which were about 10 dB HL worse than those of patients belonging to category I.

Table I indicates some general differences between categories I and II, not with regard to age r/l quotient or type of aphasia, but with regard to the dichotic, monotic, and Token Tests. The average results of this test were higher for category I (11.5) than II (7.2). However, the difference was not statistically significant.

The hearing test which initiated the dichotic testing procedure, and the dichotic word test itself both

Table II. *Average results of low frequency (0.5, 1, 2 kHz), and high frequency (3, 4, 6 kHz) pure tone audiometry, speech (monosyllabic words) audiometry, and phase audiometry for categories I and II*

		Low frequency dB HL		High frequency dB HL		Speech per cent correct		Phase degrees	
Category	Ear	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
I, $n = 11$	Right	8.9	7.8	30.0	18.1	93.8	5.5	15.3	3.6
	Left	7.7	7.9	36.2	26.2	92.0	7.0		
II, $n = 9$	Right	19.0	12.6	42.8	30.3	87.6	11.2	55.8	21.4
	Left	16.1	11.8	43.2	28.6	90.4	8.8		

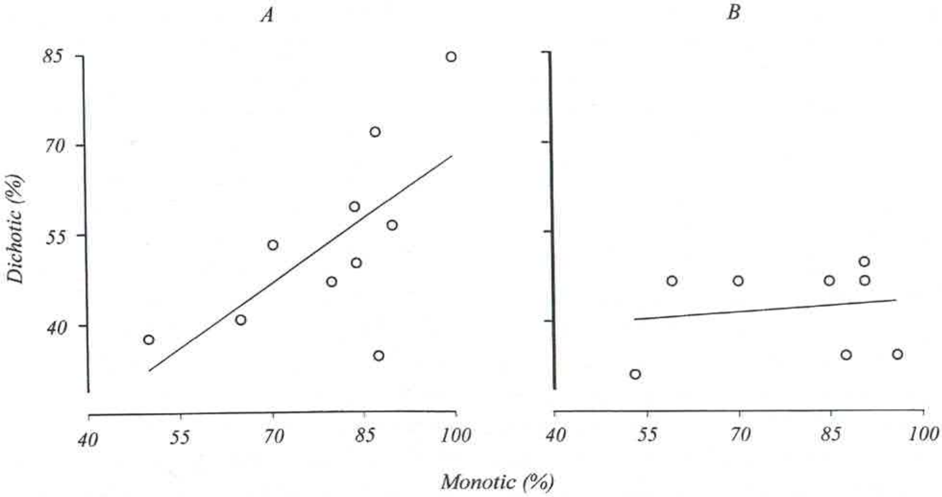

Fig. 2. Per cent correctly repeated, dichotically presented words (ordinates) vs. monotically presented words (abscissae). (A) Ten aphasic patients without central hearing predicaments. Linear regression $y = 0.71x - 3.44$ ($r = 0.66$). (B) Eight aphasic patients with central hearing predicaments. Linear regression $y = 36.60 + 0.07x$ ($r = 0.15$).

consisted of series of common two-syllabled Swedish words which had to be repeated. The two tests could therefore be regarded as repetition tests of different specifications, and were compared in that capacity. Table I lists the per cent correct responses for the whole of the dichotic word test, i.e. with the results for both ears compiled. Furthermore it lists the per cent correct responses for the hearing test, i.e. the results for both ears compiled, and calculated against the total number of words at and above the threshold intensity for the best ear (not applicable for two patients, who have been marked na). The possible co-variations of the results of the two tests are illustrated in Fig. 2.

Fig. 2 shows a tendency for the results of the hearing test and the dichotic test to be positively correlated for category I (Fig. 2A), but not for the patients with defective directional hearing, who constituted category II (Fig. 2B). The regression lines have been entered into the diagrams and the correlation coefficient was significant for category I ($r = 0.66$, $p < 0.05$, two tailed test) but not for category II ($r = 0.15$).

Estimates of lesions

The patients were judged to have suffered either embolic, haemorrhagic or thrombotic strokes with unilateral, left-sided thalamic and/or hemispheric cortical and/or subcortical cerebral damage on the basis of anamneses and combined clinical and neuro-radiographic (computed tomography) observations. There was no correspondence between etiology or size of damage and our audiologically determined categories. The clinical procedures did not permit more than the tentative suggestions with regard to possible functional disturbances of the primary auditory cortex of the left temporal lobes, which have been listed in Table I.

DISCUSSION

Aphasic, stroke patients were explored with a dichotic word test for which 90% of normal persons had shown an REA, and the remaining 10% had shown an LEA, which was close to right/left symmetry. In contrast, approximately a quarter of the patients showed an explicit LEA. These findings conformed to observations of a recent, comprehensive paper by Niccum & Speaks (17). Thus, the relative ear advantage for dichotic tests with stimuli of linguistic character has been widely assumed to indicate lateralization of cerebral speech functions to the contralateral hemisphere. As a consequence, the repeatedly observed shift from REA to LEA in aphasic stroke patients could indicate a possibly recuperative take-over by the right hemisphere, but there are alternative and possibly simpler explanations. Niccum & Speaks (17) have emphasized that the lesions causing shifts of ear advantage often involve the auditory cortex of the left hemisphere, and consequently might indicate changes of hearing competence instead.

We have investigated that possibility insofar as all of our LEA aphasics were offered the choice of an audiometric examination. Forty per cent of those who were able to take advantage of the offer were found to suffer from a central hearing loss. The exact localizations and extent of the patients' left hemisphere lesions were not determined outside our regular clinical procedure; therefore observations regarding possible critical structures were trivial.

It was impossible to rule out whether our patients with central hearing loss also had right hemisphere speech dominance. Nevertheless, unilateral damage of the cerebral auditory cortex causes diminution of the ability to discriminate complex auditory patterns with the contralateral ear (1, 12), and in our patients' cases the right ears. A possible hearing disorder therefore provided a sufficient explanation for their LEA. Like the patients of Blaettner et al. (1), some of our patients also complained of hearing problems of the 'cocktail party' variety. Considering rehabilitation, it appears that auditory examination is motivated for some stroke patients, and that the simple dichotic tests, which are nowadays used in many neuropsychological laboratories, may be used for uncovering the condition.

The dichotic test was preceded by a monotic hearing test for all of the patients. All patients, except for one (BE), differed from normal persons in this test by having failed to repeat all of the words that had been presented above the threshold intensity. The patients' aphasia may explain this inadequacy, and if so, the result of the hearing test could also be used as a relative measure of the ability to repeat words. The dichotic word test may also be used as a measure of the ability to repeat words, albeit of a different character. The patients had been divided into three categories on the basis of their audiometric results. For patients belonging to category I there was no audiometric cause for their LEA. In their case, the results for the two hearing tests were positively correlated. Category II consisted of patients with central hearing loss. These patients showed no such tendency, but repeated the dichotically presented words consistently at a rate corresponding to the poorest repeaters of all categories. The observation may be used to support a suggestion that the LEA of patients with central hearing loss signified a diagnostically distinctive subgroup. It bears remembering in this context that observation of a relatively increased difficulty with dichotic, compared with monotic, words was part of the reason for the development of the Staggered Spondaic Word (SSW) test (12). The SSW is a much used test of central auditory function, but perhaps not a first choice for aphasics.

Category III consisted of two patients who had better left ear hearing due to right sided cochlear hearing losses. This peripheral hearing irregularity may not have been the primary cause of their LEA, but precluded proposals of more elaborate, alternative explanations.

The patients with best speech understanding as measured by the Token Test were found to be clustered to category I, i.e. the patients without any audiometric cause for their LEA. On that basis it might be tempting to suggest their type of LEA to represent a recuperative right hemisphere lateralization of speech functions, which had been provoked by the left hemisphere infarctions. However, the design of the present study permitted neither confirmation nor denial. The hypothesis underlying that prevalent suggestion is controversial (4, 5) and it awaits further work for verification, in addition, work which takes confounding factors into account (13, 14, 15).

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Address for offprints:
Ms Solweig Ramsing
Department of Clinical Neuroscience
Neurology Division
Sahlgren's Hospital
S-413 45 Göteborg
Sweden