We should like to thank the nursing staff of the recovery and theatre suites at Wycombe General Hospital, and Miss J. Spearpoint and Mrs. A. Andrews for secretarial help.

References

- Bernhoff, A., Eklund, B., and Kaijser, L. (1972). *British Journal of Anaesthesia*, 44, 2.
 Boulton, T. B., and Rushman, G. B. (1971). Epontol Symposium, Scheveningen (12 June). *British Medical Journal*, 1969, 4, 319.
 Fletcher, C. F., Earnest, D. L., Shuford, W. F., and Wenger, N. K. (1968). *Archives of Internal Medicine*, 122, 483.

- Johns, G. (1970). *British Journal of Anaesthesia*, 42, 74.
 Johnstone, M., and Barron, P. T. (1968). *Anaesthesia*, 23, 180.
 Lavidar, D. G. (1970). *British Journal of Anaesthesia*, 42, 652.
 Lee, J. A. (1958). *Synopsis of Anaesthesia*, chapt. 9, p. 227. Bristol, John Wright.
 Lord, P. H. (1968). *Proceedings of the Royal Society of Medicine*, 61, 935.
 Lord, P. H. (1969). *British Journal of Surgery*, 56, 747.
 MacIntyre, I. M. C., and Balfour, T. W. (1972). *Lancet*, 1, 1094.
 Mann, P. E., et al. (1971). *Anaesthesia*, 26, 3.
 Millar, R. A., Gilbert, R. G. B., and Brindle, G. F. (1958). *Anaesthesia*, 13, 164.
 Wirth, W., and Hoffmeister, F. (1965). In *Die intravenöse Kurznarkose mit dem neuen Phenoxyessigsäurederivat Propanidid (Epontol)*, ed. K. Horatz, R. Frey, and M. Zindler, p. 17. Heidelberg, Springer.
 Wirth, W., and Hoffmeister, F. (1968). *Folha Médica*, 57, 179.

PRELIMINARY COMMUNICATION

Auditory Perception

J. A. M. MARTIN, DOROTHY MARTIN

British Medical Journal, 1973, 2, 459-461

Summary

Auditory perceptual tasks involving the discrimination of fine differences in frequency, duration, or rhythmic pattern were given to a group of sixth form schoolboys. The results indicate that there is a wide range of auditory skills for different individuals, even within a relatively homogeneous group. There are also differences in a person's ability to carry out distinct tasks; there does not necessarily appear to be any correlation between his ability for each task.

The findings support observations arising out of consideration of hearing problems in children and adults that pure tone threshold audiometry and its derivatives give an inadequate definition of hearing disorder and a limited understanding of the nature of hearing.

Introduction

Hearing is measured clinically by pure tone audiometry, a procedure which determines the threshold of sensation for a number of frequencies between 125 Hz and 8 kHz. Consequently, deafness tends to be equated with hearing loss, and defined in terms of the physical features of frequency and intensity. The theoretical background derives largely from Fourier's mathematical analysis of irregular wave forms. He showed that these could be resolved into a number of constituent sine waves, the acoustical equivalent of which is pure tones. Pure tone threshold audiometry with its various refinements is now a highly developed tool which has gained universal acceptance in the estimation of hearing loss and for the diagnostic siting of the lesion in the middle ear, cochlea, or auditory nerve.

The constraints of the test procedure disguise limitations in our ability to investigate hearing function, and Littler (1960) was impelled to ask why such importance was attached to pure tone analysis. From a number of objections which might be levelled at the technique, the most important is that it gives no

measure of the patient's ability to distinguish between sounds. It is possible for the clinician to answer the question "How much sound is heard?", but not "How are sounds being heard?"

The investigation of hearing in young children produces a number of problems which would otherwise be unsuspected if they could be coerced into the formal situation required by pure tone audiometry. This may be exemplified by certain children who are slow in learning to talk. Their difficulty seems to consist not so much of an alteration of auditory threshold but of an impaired ability to sort out, or make sense of, acoustical events. Consideration of a number of developmental and abnormal responses leads one to suggest that there are factors on the sensory side, in addition to simple hearing loss, which must be studied if there is to be an adequate explanation of the differing patterns of hearing behaviour (Martin, 1971).

Neurological disorder in the adult affirms the possibility that a person may have difficulty in recognizing meaningful sounds yet have no hearing loss. In such patients Bay (1964) questions the value of pure tone threshold audiometry and concludes that there is no *non-verbal* (our italics) test which is sufficiently sensitive to show disorders of auditory perception.

Levels of Hearing

There is sufficient evidence to justify reappraisal of presentday concepts of hearing and of deafness, and of the methods adopted to investigate them. Hearing may be regarded as an activity taking place at three levels of organization.

(1) The transformation of acoustic energy occurring in the air about our ears into activity within the auditory nerves, with intermediate transformations occurring in the middle ear and cochlea. This is the primary sensory process, investigation of which has given rise to an impressive amount of experimental work and to a number of theories of hearing. Pure tone audiometry measures dysfunction only at this level.

(2) The ability to discriminate between sounds. Sounds entering the auditory space in which we are immersed are never steady state pure tones, but are acoustically complex, having form, structure, and movement. They start and stop, abruptly or gradually, and last for a greater or lesser period of time. They may be rapidly repetitive, they may be periodic or random, their frequency characteristics and loudness levels may alter. They may come from one direction or another or move through space, they may be many or few. We can sort out this multiplicity of acoustical events arising from activity in the world around. A theory of hearing needs not only to explain the activity of the end organ, but how the central nervous system processes the sensory input flowing into it from the auditory nerves. There is no reason to suppose that this processing is confined to the area labelled "auditory cortex." The remarkable complexity of the auditory pathways in the brain stem, mid-brain, and thalamic

Royal National Throat, Nose, and Ear Hospital, London W.C.1

J. A. M. MARTIN, F.R.C.S., D.L.O., Director, Nuffield Hearing and Speech Centre

DOROTHY MARTIN, S.R.N., Research Assistant

region lend strong circumstantial support to the contrary. There is a little quantitative information on processing at this level, but there is virtually no method by which disturbance of such sensory organization can be investigated.

(3) The ability to identify and recognize the sounds heard. This covers a wide spectrum of function ranging from the ability to specify an object or activity which has caused a particular sound to the ability to attach meaning to the highly abstract groups of sounds we call sentences. It is possible to measure word recognition, but speech audiometry introduces its own problems. A word is very much more than a string of acoustical events, and this form of audiometry is not simply measuring auditory function but is trespassing in the domain of language.

Method

A number of tests were constructed involving differing aspects of auditory perception, so that the nature of the discrimination process might be investigated experimentally at a behavioural level.

Change of Frequency.—A complex tone was built up on a speech synthesizer with its basic form resembling the acoustical structure of a vowel and having a fundamental and two formant frequencies. The characteristics of the sound were kept constant with the exception of the fundamental frequency, which was altered by an amount of 1 Hz, 2 Hz, 4 Hz, or 10 Hz from 200 Hz. Test tapes were made so that the subject listened to one sound and after a brief interval compared it with a second. The task was to decide if the sounds of the pair were the same or different. Identical pairs and pairs differing by the intervals stated were assembled in random order, each pair occurring 10 times in the test. The method is a modified version of the AX procedure used by Harris (1952) to determine difference limens for pure tones, and was adopted as being the simplest and most sensitive testing procedure.

Duration.—A considerable amount of experimental work (Lehiste, 1970) has been carried out to determine the ability of the subject to identify differences in the duration of pure tones. In the present investigation a series of durations ranging from 10 msec to 200 msec was used, in ratios varying from 1:1.2 to 1:2.3 when the relative durations of the pair of sounds are compared. The sound and the overall test procedure were constructed in the way described for the frequency discrimination test.

Rhythmic Pattern.—The recognition of patterns occurring in speech is attracting a lot of interest—discussed, for example, by Corcoran (1971). Despite this, little is known of the ability of individuals to recognize or discriminate between rhythmic patterns. It seemed appropriate to start by turning to the well-recognized patterns of rhythm used in music. An expert percussion player recorded a stressed four-beat rhythm. The accent occurred on the first beat and the rhythms differed by adding an off-beat placed after the first, second, or third beats. It was necessary to run a series of tests to find the appropriate level of difficulty. The final test tape was made with one bar each of two different rhythms in the first sound sequence of the pair, and this was compared with a second sequence which might or might not repeat the overall pattern. There were 20 such pairs in the test, and the response required was "same" or "different."

TEST GROUP

The tests were administered to a group of 25 schoolboys, ranging in age from 15 to 18 years, comprising one complete class of a sixth form. Fourteen subjects listened to every test, all being present on each occasion, and it is the results of these that are reported. The sounds were played back in free field at the group's chosen level, some 30-40 db above the ambient noise.

A brief explanation and practice ensured that the task was fully understood. The apparatus used included a Nagra tape recorder, Leak amplifier, and paired Wharfedale loudspeakers.

Results

WHOLE GROUP

The detailed results for the tests involving ability to detect fine differences in tone of a complex sound are given in table I. The mean total score of correct responses is 22.36, or 55.9%.

TABLE I—Perception of Tonal Differences. Accuracy of Response for 10 Discriminations

Subject No.	Age	Detection of Difference of:				Total Score (out of 40)	Percentage Accuracy
		1 Hz	2 Hz	4 Hz	10 Hz		
1	17	2	1	6	10	19	47.5
2	15	2	2	9	10	23	57.5
3	16	2	4	6	10	22	55
4	16	6	7	10	10	33	82.5
5	16	7	8	10	10	35	87.5
6	16	1	1	5	10	17	42.5
7	17	1	1	6	10	18	45
8	16	7	5	10	10	32	80
9	16	0	0	0	10	10	25
10	16	5	3	3	6	17	42.5
11	18	0	1	5	10	16	40
12	16	2	6	5	10	23	57.5
13	17	2	4	9	10	25	62.5
14	15	1	3	9	10	23	57.5

In all experiments of this type the score of each subject is expected to deviate from his "true" score, and the average deviation can be calculated statistically. If it is assumed that all the subjects were of average ability—that is, with true scores of 55.9%—the expected deviation for this test would be $\pm 7.8\%$ but the actual deviation is $\pm 17.7\%$. The greater range of observed over expected deviation indicates that the test is demonstrating personal differences in the ability of the subject to carry out this auditory task over and above the range of chance, normal variation.

Results are summarized in table II for the three auditory discrimination tasks described above. The results for each task are consistent in showing that the actual range of ability is greater than one would predict.

TABLE II—Overall Ability of 14 Subjects to Perform Three Auditory Perceptual Tasks. (Results Expressed as Percentages)

Perceptual Task		Average Score	Deviation	
			Expected	Observed
Frequency		55.9	± 7.8	± 17.7
Temporal duration		51.3	± 9.5	± 17.3
Rhythmic pattern		69.0	± 14.5	± 25.3

INDIVIDUAL RESULTS

With the characteristics of the group established, it is possible to determine how each subject rates in comparison with his peers. This was achieved by calculating a deviation ratio for each subject for each task. His score was subtracted from the mean score and divided by the expected deviation for that task as listed in table II. The results are given in table III.

The further the absolute value of the deviation ratio is removed from zero the greater the certainty that a subject's performance is genuinely above or below average. Purely by chance up to one-third of individual scores might show a ratio greater than ± 1 . From table III it can be seen that most ratios lie outside an expected deviation ratio of this value. Hence there is a real factor involved, and we propose that it is perceptual in

TABLE III—Deviation from Average of Each Subject's Ability for Three Auditory Perceptual Tasks

Subject No.	Deviation Ratio for:		
	Frequency	Duration	Rhythm
1	-1.1	+0.5	+1.7
2	+0.2	+1.8	+0.8
3	-0.1	+1.1	+0.4
4	+3.3	-2.6	-0.4
5	+3.9	-2.2	+1.3
6	-1.7	+1.7	+0.6
7	-1.4	-1.1	+0.1
8	+3.0	+1.9	+0.7
9	-3.9	+0.7	+1.7
10	-1.7	+0.3	-1.8
11	-2.0	-3.4	-4.7
12	+0.2	+1.2	0
13	+0.8	-1.5	-1.7
14	+0.2	+1.6	+1.3

nature (at least in part). A more detailed series of investigations is necessary to determine this conclusively, and is in hand.

Every subject had his hearing assessed by pure tone audiometry. All were within normal limits with the exception of subject No. 4, who had a bilateral loss of 35 db in the low frequencies during the period spanned by the tests.

Conclusions

The data reported here suggest two conclusions:

Given any one auditory perceptual task, there is a wide range of ability to perform the task within a group of normal healthy young people. Intuitively one feels that this is not an unreasonable finding. Individuals clearly vary in their musical talent and are said to have no sense of rhythm or to be tone deaf. Tone deafness is well recognized by the layman, though there is no medical evidence presently available to support the existence of such a phenomenon.

The second conclusion is more surprising.

Given any one individual, there may be wide variation in his ability to perform differing auditory perceptual tasks. Reference to table III and the graph confirms this. For example, subjects 4, 5, and 8 have a high level of ability to determine the tonal difference between closely similar sounds, but subjects 4 and 5 rate significantly below average in their ability to detect differences in duration of sound intervals, while subject 8 is above average. The ability to detect differences of rhythmic pattern is not so clear cut and is probably an expression of certain shortcomings in the construction of the test, of which

Discrimination profiles for three auditory tasks.

we are well aware. Nevertheless, the results as a whole show that there is no correlation between these various auditory skills. It was to explore this possibility that three widely differing types of task were used. It is possible to construct a large number of tests involving different acoustical events and features, and it may prove that the tasks reported here have less significance than others now under investigation or yet to be studied.

We are extremely grateful to the teaching staff and boys of Sevenoaks School, who have taken part in this project and who have been generous in their co-operation; to Professor D. Fry and Dr. A. Fourcin, of University College, London, Department of Phonetics, for help and the use of apparatus; and to Dr. D. Kemp for his advice on the mathematical presentation of the data.

We are indebted to the Department of Health and Social Security for the financial support of this work.

References

- Bay, E. (1964). In *Disorders of Language*, ed. A. V. S. de Reuck and M. O'Connor, p. 125. London, Churchill.
- Corcoran, D. W. J. (1971). *Pattern Recognition*, p. 114. London, Penguin.
- Harris, J. D. (1952). *Journal of the Acoustical Society of America*, 24, 750.
- Lehiste, I. (1970). *Suprasegmentals*, p. 11. Cambridge, Mass., Massachusetts Institute of Technology.
- Littler, T. S. (1960). In *Modern Educational Treatment of Deafness*, ed. A. Ewing, p. 5. Manchester, University Press.
- Martin, J. A. M. (1971). *Proceedings of the Royal Society of Medicine*, 64, 571.

MEDICAL MEMORANDA

Long-term Oesophageal Obstruction by a Foreign Body

R. H. JOHNSON

British Medical Journal, 1973, 2, 461-462

A case of long-term obstruction of the oesophagus by a morula stone (a fruit similar to a plum) in a child is presented. The child had vomited after meals for several months and was grossly malnourished.

The sites of arrest of foreign bodies in the oesophagus are discussed.

Princess Marina Hospital, Gaborone, Botswana
R. H. JOHNSON, F.R.C.S., Surgeon

Case Report

A 4-year-old Motswana boy presented with a history of several months' vomiting which occurred shortly after taking food. There was no other relevant history and no history of ingestion of a foreign body.

On examination, the child was thin and apathetic and weighed 18½ lb. (8.5 kg). No abnormality was found on physical examination other than severe malnutrition. Observation in the ward showed the vomiting to be regurgitation rather than true vomiting. Barium swallow examination showed a non-opaque filling defect in the lower oesophagus.

At oesophagoscopy, a hard mass was found at 25 cm which could not be extracted through the oesophagoscope with any of the instruments available. As the object was just above the cardiac orifice of the stomach a laparotomy to enable removal of the object through a gastrostomy was done and a morula stone 3 cm × 5 cm was delivered easily into the stomach from the oesophagus. The gastrostomy was closed in two layers with catgut around a gastrostomy tube which was brought out through a separate stab incision.

The child made a slow postoperative recovery complicated by