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REPORTS

OF THE

CAMBRIDGE ANTHROPOLOGICAL EXPEDITION

TO

TORRES STRAITS.

VOLUME II.

PHYSIOLOGY AND PSYCHOLOGY.

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PART II.

II. HEARING.

By CHARLES S. MYERS.

My experimental work on the natives of the Torres Straits was limited to the Murray Islanders[1]. As regards Hearing, it comprised an investigation of (i) their auditory acuity, (ii) their upper tone-limit, and (iii) the smallest tone-difference which they could appreciate. The pursuits and habits of the people were not such as would be expected to develop any one of these faculties in a high degree. The children attended school daily, the adults tilled the ground or left the island to dive for pearl-shell. Hence they were not engaged in occupations requiring exceedingly acute hearing; they were not particularly accustomed to hear very high tones; nor were they in the least practised in detecting minute differences of pitch. The musical ability and taste of the islanders, which will later receive separate treatment, are referred to in this volume only so far as they may be supposed to have influenced the faculty under examination.

1. PATHOLOGICAL CONDITION OF THE EARS.

I have here grouped together the pathological affections of the middle and inner ear, which were found to modify the acuity of hearing.

During a stay of over four months in Murray Island only one case of otorrhœa came under our treatment. Seeing how intractable purulent discharges from the middle ear are apt to become in the young, one may, I think, reasonably infer that for the past several years the disease had not been common in the island. Usually the adults were somewhat reticent in speaking of bygone ear-trouble. Altogether I heard only of four natives who had formerly had otorrhœa.

I cannot remember any islander in whom the presence of adenoid growths in the throat might have been suspected.

The island was free from all exanthematous epidemics during our visit. Many years ago there had been outbreaks of measles, which may partly account for the very defective hearing observed among several adult islanders.

But a more important cause of partial deafness lay in their practice of diving after pearl-shell. Until the recent legislation enacted by the Queensland Government, natives

[1] Throughout it had the advantage of Dr Rivers' ready assistance and encouragement.

were induced to dive, without dress or helmet, into such deep water that deaths were of frequent occurrence. At the time of our visit, the hospital at Thursday Island contained several cases of paralysis, which had arisen from diving in excessively deep water.

The effect of deep diving upon many islanders was to cause a noticeable amount of immediate hæmorrhage from one or both ears. "Ear he burst; red stuff come out," was a common reply to my enquiry as to what happened when first they dived. A subsequent purulent discharge occurred in two islanders, Zarob (L. E.) and Jimmy Dei (R. E.[1]). Bleeding from the mouth or nose only or from both was noticed by Komaberi, Zarob, Jimmy Dei and Oroto, from the ears only by Madsa and Groggy, from the ears and from the mouth or nose or from all three by Dubwai, Canoe, Wanu, and Smoke. The following islanders did not observe any hæmorrhage after diving—Wasalgi, Poï, Babelu, Billy Kuris, Alo, Tibi, Billy Gasu.

Politzer[2], quoting the observations of Brigade-Surgeon Chimani, states that in thirty-four of thirty-eight cases of ruptured tympanic membrane produced by boxes on the ear "perfect recovery without any functional disturbance resulted: in four cases no complete cure was effected. . . . . The bleeding was in no case so considerable as to be perceived by the patient." On the other hand, of the six cases of Chimani, in which the membrane had been ruptured owing to falls upon the head, "the bleeding was in three cases so considerable that the patients had their attention drawn to the injury of the ear by the blood flowing from it. In two cases, in spite of the perforation being healed, a considerable hardness of hearing, and in one case a labyrinthine affection, remained."

I examined with the aural speculum several of the islanders whose ears had been injured by sea-diving. In no case had the diving been recent, and in no case could I with certainty detect a rupture of or a cicatrix in the tympanic membrane. Such alterations in texture and transparency of the membrane as I met with will be noted in Table XIX. beside the estimations of auditory acuity.

My observations thus confirm Politzer's statement[3] that the membrana tympani usually regains its normal appearance within a few weeks after rupture. But they seem in direct contradiction to his view that "in most cases disturbances of hearing caused by traumatic ruptures disappear completely." There can be no doubt that in the majority of the islanders diving had caused a considerable amount of deafness. It may be that the sudden rise of pressure within the tympanic cavity produced an effect internally upon the labyrinth as well as externally upon the tympanic membrane; unfortunately I have no evidence indicative of labyrinthine lesion or disease in these cases. Of eighteen men who to my knowledge had dived, the hearing in nine was defective in one ear, in two in both ears, not only in regard to general acuity, but also in regard to the upper limit of pitch.

[1] I use L. E., R. E. and B. E. throughout for the left, right and both ears.
[2] Politzer's *Diseases of the Ear* (Eng. trans.), London, 1894, pp. 249, 250.
[3] *Ibid.* p. 246.

2. AUDITORY ACUITY.

It is scarcely necessary to point out that the stories, which travellers relate about the remarkable capacity possessed by primitive people for distinguishing faint sounds amid familiar surroundings, cannot be accepted as evidence of an unusually acute hearing. Little or nothing concerning auditory acuity can be safely inferred from such a description as that of László Magyar[1], who, travelling among the Kimbunda tribes of South Africa, noted that "they are able to distinguish very accurately sounds which are heard from a great distance, and at once recognize their nature and direction"; nor from such an observation as P. Paulitschke's[2], who found the Somali hunters to have a very delicate sense of hearing, the slightest noise awakening their attention, its direction being recognized with certainty.

Reports of this kind might be cited again and again[3]. They merely show how the savage will take an interest in, and make an inference from a sound, which may be meaningless to, and perhaps neglected by the European ear. We need but imagine such an individual transported to the streets of a busy city, to obtain a complete reversal of the phenomena, the primitive man heedlessly passing various noises which would be full of significance to his more civilized companion.

Nor, indeed, are travellers unanimous in crediting savages with an unusually keen sense of hearing. Sir G. S. Robertson[4], for instance, states—"as the result of very many observations of an unscientific kind, I could never discover that the Káfirs displayed any superiority to other races in .... certainty of hearing." Francis Galton[5] also remarks—"my own experience, so far as it goes, of Hottentots, Damaras, and some other wild races, went to show that their sense-discrimination was not superior to that of white men..." Georg Schweinfurth[6] similarly failed to find any marked superiority of hearing-power among the many tribes of Central Africa which he has visited[7].

It is exceedingly rare to meet with opinions that have been formed after subjecting the ear to a definite test which could be repeated on other ears. I know only of the experiments of two travellers. N. W. Giltschenko[8] observes that "the distance at which an Osset hears the tick of a watch is not greater than with other people. In the open, on the other hand, both on the plain and on the hills, the Osset perceives definite

[1] *Reisen in Sud-Afrika in den Jahren* 1849—1857 (deutsche Uebersetz.), Pest u. Leipzig, 1860, S. 343.

[2] *Ethnographie Nordost-afrikas*, Berlin, 1896, Bd. II. S. 3.

[3] Cf. the remarks of Carl Lumholtz, *Bull. de la Soc. d'Anth. de Paris*, Tome XI. 3me Série, 1888, p. 650, of G. L. Bink, *ibid.* p. 388, and of Godel, *ibid.* Tome III. 4me Sér. 1892, p. 161. Also cf. *From my Verandah in New Guinea*, H. H. Romilly, C.M.G., London, 1889, p. 55; *In the Forbidden Land*, H. Savage Landor, London, 1898, Vol. I. p. 25.

[4] *The Káfirs of the Hindu Kush*, London, 1896, p. 174.

[5] *Inquiries into Human Faculty and its Development*, London, 1883, p. 32.

[6] In a private letter kindly sent me by Dr Schweinfurth.

[7] The experiences of my friend Mr Stanley Gardiner, who has kindly communicated them to me, are not without interest in this connexion. An American clock hung from the roof of his bungalow in the Maldive Islands. The natives, who had never seen the like before, would approach to a distance of two yards from the clock before they took notice of its ticks. Then they spent some time before they could rightly localize the sound. On the shore he found he could frequently pass behind a native, without attracting the attention of the latter, who might have been expected invariably to distinguish between the Englishman's booted tread and that of the bare foot on the sand.

[8] *Biolog. Centralbl.* Bd. XI. 1891, S. 304—318.

sounds, understands spoken words, etc., at a quite extraordinary distance." M. Hyades[1] in his study of the Fuegians says that their "hearing has the same acuity and range as that of the majority of Europeans (experiments with the watch, tuning-fork, etc.)," but gives no details of the facts upon which he bases this opinion.

METHODS OF TESTING AUDITORY ACUITY.

Auditory stimuli are divisible into three classes, viz., simple tones, compound tones and noises. Although little is known as to the psychical relation of these three kinds of stimuli to one another, it is certain that in cases where the sensibility to one kind is noticeably diminished, the sensibility to one or both of the other kinds may be scarcely impaired. Hence it is essential that the class of sound which has been used to test the auditory acuity of any race or individual should be clearly stated.

In estimating the acuity of a sense-organ, it is naturally desirable that the experimental conditions should be reduced to the simplest possible. A noise, obviously, is far too complex and unsafe a stimulus. Nor is the voice more suitable, as it varies greatly in distinctness, volume and quality, not only for different individuals, but also for the same individual, however careful he be, at different times. Moreover, some words are audible at a greater distance than others, according to the relative number, arrangement and nature of the contained vowels and consonants.

The watch has been the most usual instrument for testing auditory acuity. But, in the first place, the results obtained by one observer are incomparable with those obtained by others, owing to the different degrees of loudness of the ticks of different watches. And secondly, it is highly desirable that the sounds chosen should be under greater control than are the ticks of a watch. The data, obtained by gradually removing a ticking watch from the ear until it can no longer be heard, are in every respect as fallacious as those which would result, were the test-types, commonly used in the estimation of visual acuity, to be slowly withdrawn from the observer, until he could no longer recognize a letter of given size[2].

My first experiments among the Murray Islanders were carried on with an ordinary watch. But I quickly recognized the difficulty felt by the natives in accurately fixing the point where, as the watch was removed from the ear, its ticks could no longer be heard. This drawback disappears with the use of a stop-watch, or of an entirely different instrument, in the manner presently to be described.

I had the lenses removed from an ordinary telescope and the tube fitted to stand vertically on a suitable support. The top of the tube was provided with a funnel-shaped aperture, which would just admit of the introduction of a small pith-ball. Near the base within the tube was placed an obliquely inclined disc of felt, on to which the pith-ball fell, there rebounding to escape by a window cut in the side of the tube, and falling noiselessly on a piece of velvet. The velocity of the fall of the ball, and hence the intensity of the sound produced by its impact against the felt-disc, could be varied at will by altering the height of the telescopic tube.

[1] *Mission Scientifique du Cap Horn*, Tome VII., Paris, 1891, p. 209.

[2] The same objection holds good for the method of allowing a tuning-fork to 'ring off' until the subject no longer hears it.

The objections which attend the use of a watch are likewise remedied in Politzer's Hörmesser. It consists essentially of a hollow horizontally-fixed steel cylinder, 28 mm. in length, 4·5 mm. in thickness, emitting the tone *c*, when struck by a small percussion-hammer, which is allowed to fall on it from a small and constant height.

The acuity of hearing, probably more than that of most other senses, varies considerably from hour to hour and from day to day, according to the physiological condition of the observer. For this reason it seems hardly worth while here to follow the example of those otologists who attempt to express auditory acuity in the form of a fraction, whereof the denominator denotes the distance at which the sound should be heard by an ear of average hearing-power, the numerator giving the distance at which it is actually heard by the ear under examination.

A far greater disturbing influence, however, consists in the distraction resulting from various adventitious noises. Through the lack of a suitable room in Murray Island, I was forced to conduct my experiments in the open air. Here the constant rustle of the palm-leaves and the beating of the surf on the sea-shore compelled me to lay aside my telescopic apparatus and Politzer's Hörnesser in favour of a stop-watch.

I used a Runne's clock, which could be made to tick five times a second, and could be easily stopped or set going at will. The loudness of the ticks was found to be much diminished, and to vary noticeably when the clock had 'run down.' The clock was hence always fully wound up before being used for testing. The disturbing noises, to which I have just alluded, varied so obviously from day to day, that it was impossible to compare the results obtained from islanders on one day with those obtained from others on the next. The estimations of auditory acuity must have proved meaningless unless I had tested some fixed person or persons simultaneously with the natives. Dr Rivers kindly came to my assistance. Either he or I was tested along with the islanders; one of us holding the clock, the other standing with his back to the subject under investigation, at the same distance from the clock, and indicating by gesture whether he heard the ticks. The clock was started after irregular periods of silence and was allowed to sound for about three seconds. The threshold was determined, partly by the number of incorrect answers when at a given distance the subject failed to detect the ticks, and partly by the number of illusions when at that distance he imagined that he heard ticks during periods of actual silence. In this way I was able roughly to estimate the relative auditory acuity of thirty-five islanders, compared with that of Dr Rivers or myself, towards the same stimulus under the same conditions of distraction.

It was not to be expected that the natives would evince as much interest in determinations of their auditory acuity as they took in many others of our psychological experiments. Some of the islanders were no doubt conscious of their partial deafness, and, feeling that they were not doing well, did not give their utmost attention to the experiment. In these few instances greater attention would have produced better results. On the whole, however, we were confident that the people were doing their best, and that the appended Tables, XIX. and XX., give a very fair measure of their power of hearing.

The figures, ranged in the two columns under R. E. and L. E., express the distance in metres at which the threshold is reached for hearing the given stimulus. They were obtained after the following method, which I adopted as the most reliable after the trial of various others.

TABLE XIX.

Murray Island Boys, tested by Runne's Clock.

Date	Name	Age	R. E.	L. E.	Standard-observer	Remarks
Aug. 2	Jimmy Dauar...	10	3·00	4·00	worse than C. S. M.	
Aug. 3	Dela..............	10	2·50	2·75	same as C. S. M.	
July 19	Aki	10½	2·75	2·75	{C. S. M. L. E. = 5·00 m. {W. H. R. R. L. E. = 1·75 m.	
Aug. 3	"	"	0·50	1·50	much worse than C. S. M.	
July 19	Tom (Maboali)	11	2·75	3·00	{C. S. M. L. E. = 5·00 m. {W. H. R. R. L. E. = 1·75 m.	
Aug. 3	" " ...	"	3·00	2·50	{R. E. slightly worse than} C. S. M. {L. E. same as}	
Aug. 1	Marau............	11	3·50	4·50	same as C. S. M.	
July 17	William (Tat)...	11½	0·75	0·75	C. S. M. L. E. = 6·00 m.	
?	Sailor	11½	4·00	4·00	worse than C. S. M.	
Aug. 3	Tom (Tanu) ...	11½	2·75	3·00	not quite equal to C. S. M.	
"	Sagigi	11½	1·50	1·25	{R. E. slightly worse than} C. S. M. {L. E. same as}	
July 17	Poï (Pasi)	13	4·50	5·00	} C. S. M. L. E. = 6·00 m.	
"	James	13	2·00	2·00	}	
"	Apori	14	3·00	3·00	}	

Murray Island Girls, tested by Runne's Clock.

Date	Name	Age	R. E.	L. E.	Standard-observer	Remarks
July 15	Maima	11	2·00	2·25	} W. H. R. R. L. E. = 2·25 m.	
"	Gigai	11½	1·75	2·00	}	
"	Seba	12	2·00	3·00	}	
Aug. 3	Nei	13	3·00	?	} W. H. R. R. B. E. = 1·00 m.	
"	Maletta	13½	1·00	3·00	}	nothing abnormal noticed otoscopically.
"	Sidoï	14	1·50	1·50	W. H. R. R. B. E. = 0·75 m.	otorrhœa formerly.
"	Mary	14	2·75	?	not quite equal to C. S. M.	

Murray Island Men, tested by Runne's Clock.

Date	Name	Age	R. E.	L. E.	Standard-observer	Remarks
Aug. 2	Charlie (Pasi)...	16	1·50	1·50	....	has never dived.
"	Berò	17	5·00	2·00	....	
July 20	Tepem...........	18	4·25	4·25	{C. S. M. B. E. = 5·00 m.	
"	Josiah	18	0·05	2·75	{W. H. R. R. B. E. = 0·60 m.	
Aug. 1	Zarob	20	—	—	....	dived æt. 14. White discharge followed.
May 27	Gaunl	30	—	—	....	has dived. L.E. opaque tympanic membrane. Hörmesser 1 m.
July 15	Jimmy Rice ...	30–35	6·50	3·30	W. H. R. R. L. E. = 2·25 m.	
July 20	Babelu...........	30–35	2·25	2·75	{C. S. M. B. E. = 5·00 m.	has dived: no discharge.
"	Boa	35–40	0·75	0·80	{W. H. R. R. B. E. = 0·60 m.	
July 19	Charlie Boro ...	35	1·00	1·00	{C. S. M. L. E. = 5·00 m. {W. H. R. R. R. E. = 1·75 m.	
"	Komaberi	50	1·75	2·00	....	has dived 6–10 fathoms: blood from nose and mouth.
Aug. 2	Tibi	45–50	0·85	2·20	....	has dived 1–2 fathoms: no discharge.
Aug. 1	Alo	50	—	—	....	has dived 7–8 fathoms: no discharge. Watch, R. E. 18 ins., L. E. 9 inches.
Aug. 2	Kriba	50	4·00	—	....	has dived. Opaque tympanic membranes.
Aug. 1	Canoe	50	2·00	2·00	....	has dived: blood from nose and ears.
July 20	Enoka...........	55–60	1·00	1·00	{C. S. M. B. E. = 5·00 m. {W. H. R. R. B. E. = 0·60 m.	

The distance from the subject to the Runne's clock (or Hörmesser) was marked along the ground or floor in half-metres. One ear of the individual was stopped with cotton-wool, the other being directed towards the source of sound. The subject indicated, preferably by a movement of the hand, when he heard the stimulus employed. The instrument was first held at a distance well within his limit, and was then withdrawn from that point, at first metre by metre, later half-metre by half-metre, until the limit of hearing was passed. The instrument was then brought nearer until the sound became once more audible. At every point in the neighbourhood of the threshold five trials of the sound were made. Where more than one out of five successively given sounds were missed, the threshold must be considered as having been reached or passed.

It will almost invariably be found that the sound can be heard one or two (or even more) half-metres further when the watch is being withdrawn from the subject, than when the watch is made to approach towards him. The distance midway between the point where the audible sound just becomes inaudible, and the point where the inaudible sound just becomes audible to the subject, may be taken as indicating the acuity of his hearing.

In the column headed 'standard observer' will be found the estimations simultaneously determined for one or other of three members of the expedition, Dr Rivers (W. H. R. R.), Mr Seligmann (C. G. S.), or myself (C. S. M.).

ESTIMATIONS OF AUDITORY ACUITY IN MABUIAG.

Dr Rivers found sufficient quiet in this island, which I did not visit, to enable him to make several observations with the Hörmesser. They were conducted at night in the old disused church near the sea-shore. At first the noise of the surf and trees was very disturbing, but later the wind dropped so that he "was able to make very satisfactory observations in almost complete silence." When kindly communicating to me the results

TABLE XX.

Mabuiag Men tested by Hörmesser (by W. H. R. Rivers).

Date	Name	Age	R. E.	L. E.	Standard-observer	Remarks
Sept. 23	Urma	30–35	1·50	7·00	C. G. S. B. E. = 9 m.	weather rather windy.
"	Josiah	17	8·00	8·00	C. G. S. B. E. = 10 m.	
"	Min	20	2·50	1·50	much worse than C. G. S.	
"	Gigib	20–25	4·00	3·50	......	
Sept. 28	Tom	30–35	5·00+	4·00+	C. G. S. {R. E. = 8 m. L. E. = 9 m.}	more windy and variable: hence probably the difference in the two ears.
Sept. 30	Waria	35	7·00+	13·00+	C. G. S. B. E. = 16+m.	no wind: almost complete silence.
"	Baira	30–35	6·00	3·00+	much worse than C. G. S.	
"	Waiat	20	2·00	6·00		
"	Peter	35	8·00	5·00		
"	Wame	35	0·75	2·00	W. H. R. R. B. E. = $2\frac{1}{2}$ m.	
"	Monday	20	1·50	0·50		
Oct. 2	Alis	20	6·00+	3·00+	C. G. S. B. E. = 18+m.	no wind.
	William (of Murray I.)	20–25	0·75	0·75		

of his experiments for publication beside my own, he reminded me of a fact which I had also noticed, that with Runne's clock the natives had illusory sensations of stimuli during actual silence far more frequently than when tested with the Hörmesser. There can be no doubt that under suitable conditions, the latter is by far the preferable instrument. But a stop-watch should never be omitted as a last resource, the ordinary watch being, as I have explained, almost useless for determining auditory acuity.

Dr Rivers also sends me the following note. "On one evening I made a few observations to compare the results with Politzer's Hörmesser and Runne's clock. It was far more difficult to obtain definite results with the latter, but it was clear that its sound could only be heard at a much smaller distance than that of the Hörmesser; thus on the evening on which Mr Seligmann heard the sound of the Hörmesser at 7 metres, he only heard Runne's clock at 2 metres eight times in ten, and failed to hear it altogether at 3 metres."

Conclusions.

Of twelve Murray Island boys only five could hear as far or nearly as far as I could, the remaining seven being clearly inferior in auditory acuity. Of five Murray Island adults with whom I compared myself, all save one had remarkably low auditory acuity. The hearing of three Murray Island girls was about the same as that of Dr Rivers, while the hearing of three others was distinctly better. Dr Rivers, however, was certainly suffering from partial deafness when these estimations were made.

Not one of the ten young Mabuiag adults with whom Mr Seligmann later compared himself, could hear as far as he could. Two others could not hear as far as Dr Rivers, whose auditory acuity even by this time had not much improved.

The question arises, Can the above three standards of acuity of hearing be accepted as typical of Europeans generally? If we attempted to reply by testing ourselves among a series of Englishmen at the present time[1], our answers would be necessarily based on the supposition that our auditory acuity in the Torres Straits and in England was the same. In Murray Island certainly our general health was more or less 'below par.' Dr Rivers, as I have just said, knows that he had temporarily subnormal hearing, and I have reason to believe that my own hearing was slightly affected in Murray Island.

In the case of the Torres Straits children the hearing was not very different in the two ears. A great number of adults, on the other hand, proved to be distinctly deafer in one ear than in the other. The remarkably low acuity of the general adult hearing must hence be attributed to pathological conditions. Yet, as the children show a similar, although less marked, deficiency, one is forced to conclude that the general auditory acuity of the islanders in the Torres Straits is inferior to that of Europeans.

[1] Since our return, Mr Seligmann and I have been tested along with a few English adults. The results are probably numerous enough to indicate that our hearing, although not phenomenally acute, is slightly better than that of the average person.

3. THE UPPER LIMIT OF HEARING.

The Galton-whistle which I used was made by Hawksley of Oxford Street, London. The patterns of foreign makers differ considerably from Galton's original design. Its bore was 1 millimetre in diameter. Its length could be varied by sliding in or out the solid rod which closely fitted the tube of the whistle. The exposed end of this movable rod was fitted with a milled head, beneath which rested a graduated ivory scale giving the corresponding length of the whistle in millimetres at any position of the milled head. My own hearing is sufficiently acute to hear the notes produced by the whistle-tube when only 2·25 mm. in length. I therefore asked Mr Hawksley to make me a similar instrument, but of a still smaller bore, for use in the Torres Straits. The instrument was made, but as no audible note could be produced from it I had to confine myself to the use of the wider and more usual whistle. I attached a small india-rubber bulb to its mouth-piece, and after a little practice could so compress it as to give successive blasts of sufficiently unvarying force.

The amount of force with which the whistle is blown determines not only the intensity, but also the pitch of the tone emitted. I have elsewhere[1] published a series of experiments made by me with the Hawksley pattern of Galton-whistle, expressly in order to determine the changes in pitch produced by changes in the force of the air-blast employed. With long pipe-lengths a rise of air-pressure does not necessarily produce a tone of higher pitch; on the contrary a lower tone is under certain conditions emitted. Thus a pipe-length of five millimetres produces a tone of 12,784 vibrations per second, when an air-pressure equal to thirty-two millimetres of water is used; a tone of 9,464 vibr. per sec. when the air-pressure is raised to fifty millimetres; and a tone of 13,704 vibr. per sec. when it reaches four hundred millimetres. As a general rule, however, a greater wind-blast of course produces a higher pitched note.

The force of air employed by compression of the rubber-bulb attached to a Galton-whistle is not easily calculable. In the above-mentioned experiments, in which various wind-pressures were employed, air was driven through the whistle before the force of tap-water, which could accurately be controlled at will. There are reasons for believing that compression of the rubber-bulb generates a momentary pressure of at least 400 mm. of water. But before and after this maximum pressure is reached the whistle is responding to lower air-pressures. Consequently, the pitch of the whistle-tone at any given length varies in height while it is being blown, and, "in order to estimate the pitch of the highest audible tone, either the wind-pressure must be taken into account at the moment both of the physiological and of the physical determination, or the lowest obtainable tone emitted by the whistle with a given pipe-length (at relatively low wind-pressures) must be assumed to be the tone actually heard by the subject at that pipe-length[2]." Near his upper limit of hearing everyone hears a tone just when air is being admitted to the whistle, and often just after it has been shut off. These are moments when the pressure is low and tones of lower vibration-frequency are emitted. The

[1] *Journ. of Physiol.* Vol. XXVIII. 1902, pp. 417 ff.   [2] *Ibid.*

inability to hear a tone during the middle-period of blowing the whistle is no doubt also largely due to the masking effects of the noise of the blast.

The Galton-whistle was originally graduated by its inventor according to the formula $n = \frac{v}{4l}$, where n is the vibration-frequency, v the velocity of sound in air, l the whistle pipe-length. It has, however, been proved beyond doubt that this theoretical formula will not hold in practice even for such a minute bore of tube as that with which English Galton-whistles are made. I find the following to be the vibration-frequency (v) of the tones emitted by wind-pressures (p) from pipe-length (l) of the Hawksley pattern of Galton-whistle. The determinations were objectively made by the methods of sensitive flames and of Kundt's tubes.

l	p	v		
5 mm.	32 mm. water	12,784	vibrations	per second
"	50 " "	9,464	"	"
"	400 " "	13,704	"	"
4 mm.	40 " "	15,159	"	"
"	70 " "	9,360	"	"
"	92 " "	11,896	"	"
3 mm.	40 " "	18,419	"	"
"	130 " "	19,033	"	"
"	? (blown with rubber-ball)	24,812	"	"
2·5 mm.	58 mm. water	19,466	"	"
"	800 " "	22,540	"	"
2·25 mm.	68 " "	20,639	"	"
"	800 " "	22,840	"	"
2·125 mm.	72 " "	23,466	"	"
2 mm.	68 " "	25,190	"	"
"	? (blown very powerfully with rubber-ball)	27,629	"	"
1·75 mm.	84 mm. water	25,955	"	"
"	136 " "	28,082	"	"
"	? (blown very powerfully with rubber-ball)	30,050	"	"

The results of my experiments with the Galton-whistle in the Torres Straits and elsewhere are expressed in pipe-lengths, not in vibration-frequencies. Their value rests on the supposition that after considerable practice with the instrument I am able again and again to produce the same force of blast. I have no doubt as to the general reliability of the figures given. Time after time I have tested my own limit, and that of various friends, and have obtained results sufficiently consistent to warrant confidence in the supposition.

Procedure.

My first aim was to make the subject appreciate the difference between the tone of the whistle-note and the noise of the wind-puff which unfortunately is almost always audible with it. A whistle-note was called *komelag*, a noise of wind is *wag* in the Miriam language. I began thus. Pulling out the solid tube so as to use the greater part of the whistle-tube, I blew a clear, weak, relatively low-pitched note. "That *komelag*," I explained, "no *wag*." I blew the same note with a stronger blast. "That *komelag* and small-fellow *wag*," I said, as the note was now accompanied by a perceptible noise of wind. Then sliding the inner rod 'well home,' I produced a loud noise of wind without a whistle-tone, and exclaimed, "That no *komelag*, that plenty *wag*." Of the fifty-one islanders, whose upper limit of hearing I investigated, only one (Smoke) could not in this way be made to understand the difference between *komelag* and *wag*; and he failed, I have little doubt, from lack rather of interest than of intelligence.

When I had fully assured myself that this difference had become quite clear to the subject, I began the determination of the upper limit of his hearing. His two ears were separately investigated. He sat at a distance of one metre from the whistle, which was held directly opposite to his external auditory meatus. The ear which was not being tested was plugged with cotton-wool; I cannot hope thereby to have altogether excluded binaural hearing, but the procedure was sufficiently effectual to indicate in many adults a difference of sensibility to high tones between the two ears. Five or six determinations for each ear were made in the following way. Starting from above the threshold, I gradually shortened the whistle-length and determined the point where the just audible whistle-note was lost in the noise of the wind-puff. Then, starting from below the threshold, I gradually lengthened the whistle, and determined the point where a sound of the highest audible pitch just emerged from the noise of the wind-puff.

The following is a record of a single experiment. The signs ← and →, indicate that the figures following them (expressing the whistle-length in millimetres) were arrived at by shortening and lengthening the whistle, respectively.

May 27, a.m. Madsa, æt. 18. (He dived a few years ago: "first time red stuff come out of both ears: now he all right." Auditory acuity normal, as tested by watch.)

R. E.	← 2·75,	→ 2·50,	← 2·75,	→ 2·50,	→ 2·50,	← 2·50	av. 2·58.
L. E.	← 2·50,	→ 2·50,	← 2·50,	← 2·50,	→ 3·00,	→ 2·50	

It is interesting to compare the above data with others obtained from him at a later sitting. There can be no doubt that the upper limit of hearing, like auditory acuity, varies slightly from day to day in the same individual. The limit of improvement by practice is, in my opinion, very quickly reached at the first sitting.

June 6, p.m. Madsa (v. supra).

R. E.	← 3·00,	→ 2·62,	← 2·62,	→ 2·62,	← 2·75,	→ 3·00	av. 2·93.
L. E.	← 3·00,	← 3·25,	→ 3·00,	← 3·25,	→ 3·00,	→ 3·00	

EXPERIMENTAL DATA[1].

The following table gives the results obtained from investigations among the boys and girls of Murray Island and of Aberdeenshire in the manner just described. In no case were the two series of data given by each ear sensibly different; therefore only the average limit for the two ears combined need be here recorded.

[1] The data and hence their interpretation will be found to be somewhat different from those published by me earlier in a brief abstract (*Archives of Otology*, Vol. XXXI. 1902, pp. 284 ff.). These differences are mainly due to the fact that I have here 'ruled out' more rigidly the results obtained from partially deaf individuals.

TABLE XXI.

Children	Number	Ages	Whistle-length in millimetres, producing highest audible tone	Av.	M. V.
In Murray Island...	2	5–9	2·06, 2·40	2·23	—
"	15	10–15	2·00, 2·00, 2·12, 2·33, 2·16, 2·33, 2·08, 2·06, 1·90, 2·00, 2·00, 1·90, 1·90, 2·19, 2·05	2·07	0·11
In Aberdeenshire...	4	5–9	1·80, 1·90, 2·08, 2·10	1·97	—
"	18	10–15	2·45, 2·15, 1·92, 1·75, 1·80, 1·90, 1·85, 1·87, 2·20, 2·17, 2·21, 2·02, 2·00, 1·64, 2·00, 1·95, 1·90, 1·95	1·99	0·15

From these data it appears that there is only a small difference in the limit of the highest audible tone between the children of Murray Island and of Aberdeenshire, and that this small difference is in favour of the latter.

Comparison is more difficult between the male adults of the two races. Most of the Murray Islanders had in times past dived for pearl-shell and bêche-de-mer; a few of them had dived more recently, probably in shallower water (see page 142). I have thought it best to divide into seven classes the adult islanders examined. Class A comprises men who had not noticed any ill effects in the ear from diving. Those in whom diving had caused a hæmorrhagic or purulent discharge from one ear are grouped in Class B, a discharge from both ears in Class C, hæmorrhage from the mouth and nose only in Class D. I have placed in Class E those whose hearing in one or both ears was defective from some other cause. The men who had never dived are in Class F. Those about whom I have no information are in Class G. Where the upper limit of hearing differs in the two ears, the results given by each ear are recorded, the results for the right preceding those for the left ear.

It is commonly stated that in affections of the middle ear the appreciation of high tones is unchanged. T. J. Harris[1], after testing over 1,600 cases with the Hartmann-series of tuning-forks, agreed with Politzer[2] that while in diseases of the middle ear the upper limit of hearing is as a rule scarcely altered, in diseases of the inner ear the upper limit is more affected than the lower limit of hearing. With greater caution H. A. Alderton[3] had previously concluded that the upper limit was disturbed to a greater degree in internal than in middle ear-disease, and that in combined disease of the middle and internal ear the most marked changes occurred in that limit. Bezold[4], on the other hand, has urged the extreme view that high tones are conducted to the internal ear independently of the ossicles of the middle ear, so slightly impaired did he find the audibility of such tones in cases of destruction or of anchylosis of the ossicles. As I have already said, I made no attempt to diagnose affections of the internal from those of the middle

[1] *Archives of Otology*, Vol. xxvi. 1897, pp. 1—25.
[2] *Arch. f. Ohrenhlk.* Bd. vi. 1871, S. 43.
[3] *Archives of Otology*, Vol. xxv. 1896, pp. 45 ff.
[4] *Ueber d. funktionelle Prüfung d. menschl. Gehörorg.*, Wiesbaden, 1897, S. 121.

ear among the divers of Murray Island. It is possible, as I have suggested, that the great and sudden changes of air-pressure in the middle ear arising from deep diving may in certain cases have affected the labyrinth as well as the tympanic membrane.

TABLE XXII.

Age	Murray Island			Aberdeenshire
	Name	Class	Whistle-length	Whistle-length
16–19	Zarau	G	2·25	—
	Charlie (Pasi)	F	2·05	—
	Berò	E	3·22, 2·75	—
	Madsa	C	2·75	—
20–29	Zarob	B	3·50, ?	2·27
	Tapau	G	2·00	2·27
	Dubwai	C	2·86	2·11
	Poi	A	4·00, 3·08	—
	Komaberi, jun.	G	3·50	—
	Jimmy Wailu	G	2·87	—
	Loko	B	3·80, 3·18	—
30–39	Dick Tui	E	4·09, 3·52	2·90
	Gaunl	B	3·65, 6·07	2·86
	Babelu	D	3·25, 2·94	2·60, 3·00
	Mabo	F	3·10	2·35
	Oroto	D	3·51	2·42
	Jimmy Rice	G	2·60	—

Age	Murray Island			Aberdeenshire
	Name	Class	Whistle-length	Whistle-length
30–39	Billy Kuris	A	2·84	—
	Groggy	B	6·23, 5·40	—
40–49	Gi	E	4·44, 5·50	2·82
	Pasi	G	2·73	7·00, 3·25
	Wasalgi	A	3·31	2·38
	Smoke	B	?	3·28
	Jimmy Dei	B	4·80, 3·52	4·22, 5·27
	Tibi	A	3·62, 2·96	—
	Azò	A	4·25	—
50–59	Kriba	C	7·12, ?	3·44
	Canoe	C	5·25	4·06
	Alo	A	3·94, 5·75	4·12, 5·27
	Komaberi	D	3·13	—
	Wanu	C	4·39	—
	Wali	E	4·00, 6·00	—
	Lui	G	5·87	—
over 60	Mamus	G	6·16	4·00, 3·47

If the Murray Island and Aberdeenshire adults be compared, irrespectively of any aural lesion or disease produced by diving or other causes, the following results are obtained. (Two men, Groggy and Kriba, have been omitted.)

TABLE XXIII.

Age	Murray Island	Aberdeenshire
16–19	2·25	—
20–29	3·00	2·22
30–39	3·17	2·63
40–49	3·53	3·19
over 50	4·68	3·77

The following table gives the average whistle-length in millimetres, at which the highest tone could just be heard by those adults of Murray Island and Scotland who, so far as I could judge, had normal hearing in one or both ears.

TABLE XXIV.

Age	Murray Island	Aberdeenshire
16–19	2·15	—
20–29	2·58	2·22
30–39	2·84	2·63
40–49	3·00	2·93
over 50	3·86	3·77

CONCLUSIONS.

The results given by the Murray Islanders are very nearly identical with those given by the people of Aberdeenshire (Tables XXI. and XXIV.). Possibly the small existing differences in favour of the latter would have been absent, had it been possible to take observations on a greater number of subjects. The children of both communities hear a higher tone than the adults, the upper limit of hearing becoming gradually lower with increase of years[1].

[1] Cf. Zwaardemaker, *Arch. f. Ohrenhlk.* Bd. xxxii. 1891, S. 53 ff.; *Ztsch. f. Psych.* Bd. vii. 1894, S. 11 ff.

4. THE SMALLEST PERCEPTIBLE TONE-DIFFERENCE.

The determination of the least perceptible difference of pitch among a primitive people has not hitherto been attempted. Recent experiments in this direction upon Europeans have been usually confined to select classes of observers, and have had some other end in view than the mere determination of least perceptible differences. In most cases they have been performed upon trained observers[1], to investigate tone-memory, to discover the smallest appreciable deviation from untempered intervals, to find out how far the Weber-Fechner law holds good for judgments of tone-differences in various regions of the tone-range, or the like. Occasionally they have been performed less precisely with the pianoforte upon exceedingly unmusical people[2], their aim then being to determine what proportion of errors such observers would make for relatively gross differences of pitch. The only investigations, so far as I know, which resemble my own in having been conducted on an entirely unselected group of subjects, are such as were made by J. Allen Gilbert[3] upon school-children. Unfortunately our respective methods of tone-production and general procedure are so different that a comparison of our results is altogether impossible[4].

The influence of experience and of musical ability upon the smallest perceptible tone-difference is, of course, enormous. W. Preyer[5], for instance, remarked that even with little practice a difference of eight vibrations per second became appreciable between tones of the once-accented octave ($c' = 256$ vibr. per sec.), produced by his metal tongues; while he found that a highly practised observer could detect a difference of about 0·3 vibr. per sec., a limit which Luft[6] and his colleague, v. Tchisch, using tuning-forks, later reduced to 0·232 and 0·229 vibr. per sec. for the same tone-region.

I was compelled to devote a considerable part of my time in Murray Island to seeking a suitable method of experiment, as I found that the procedure adopted by earlier workers either was described by them in insufficient detail or was too complex or too unreliable, for me straightway to begin work with my tuning-forks on the Torres Straits islanders. Neither the method of right and wrong cases nor the method of the just perceptible difference as used in experimental psychology proved to be in and by

[1] Cf. H. K. Wolfe, in *Wundt's Philosophische Studien*, Leipzig, Bd. III. 1887, S. 534 ff.; E. Luft, *ibid.* Bd. IV. 1888, S. 511 ff.; I. Schischmánnow, *ibid.* Bd. V. 1889, S. 558 ff.; C. Lorenz, *ibid.* Bd. VI. 1890, S. 26 ff.; M. Meyer, *Ztsch. f. Psych.* Bd. XVI. 1898, S. 352 ff.; Angel and Harwood, *Amer. Journ. of Psych.*, Vol. XI. 1899, pp. 67 ff., Vol. XII. 1900, pp. 58 ff.; etc.

[2] Cf. C. Stumpf, *Tonpsychologie*, Leipzig, 1883, Bd. I. S. 313 ff.

[3] *Studies from the Yale Psych. Laboratory*, Vol. II. 1891, pp. 40 ff. A comparison of the results obtained by the use of gradually changing (continuous) and of interrupted (discrete) pitch-differences has been attempted by L. W. Stern, *Ztsch. f. Psych.* Bd. XXI. 1899, S. 371 ff.

[4] Other methods, all more or less unsatisfactory, are described by Percy Hughes, *Psych. Rev.* Vol. IX. 1902, pp. 603—609.

[5] *Physiolog. Abhandlungen, Ueber d. Grenzen d. Tonwahrnehmung*, Jena, 1876, S. 26—37, where a bibliography of the earlier work will be found.

[6] *Loc. cit.* S. 532. Joachim and another violinist could even appreciate an interval of "about the $\frac{1}{120}$th part of a semitone" in the same tone-region, according to G. Engel, *Aesthetik d. Tonkunst*, Berlin, 1884, S. 294—295.

itself free from objection. Finally I adopted a modified form of the latter, a method which is to a certain extent a combination of both methods, which works sufficiently simply and reliably for me to recommend it to future workers in this field. I have described it in detail below.

In order to obtain comparative data, I found it necessary to repeat with the same tuning-forks and with the same procedure a similar series of experiments upon an unselected group of Europeans. For this purpose I visited a small village of Aberdeenshire, where in the course of several weeks I examined the hearing of twelve Scots children and twenty-one adults.

The general education of the Murray Island children was not very different from that of British school-children. They had been taught European airs in class-time, and sang them with remarkably correct intonation. Consequently the results obtained in my experiments on the children of Murray Island and of Aberdeenshire allow of very close comparison. The adults, however, stand on a different footing. The island school-children were more used to singing European than Papuan airs; the adult islanders, on the other hand, confined themselves almost entirely to the latter, their knowledge of European music being generally limited to church-hymns. Many of the Aberdeenshire adults examined belonged to a highly educated class. Six of them played a musical instrument, and of these three had had the valuable previous experience of tuning the violin, and one the violoncello. The musical, unmusical, and doubtfully musical subjects are grouped separately; but I ought to add that at most only one or two could be termed 'highly musical.' Several of the Murray Islanders examined passed as composers of various native songs. The drum was the only instrument by which their songs were ever accompanied.

PROCEDURE.

I used two forks of the same pitch, $c' = 256$ vibrations per second. An arm of one of the forks (called hereafter the *variable* fork) carried a sliding metal bar which could be firmly clamped at any desired position. The arm of this fork being graduated to scale, its pitch could be made to vary at will by definitely great or small amounts from that of the other or *fixed* fork.

After my return to England, I estimated the vibration-number of the tones of the variable fork by directly counting the beats produced by sounding it with a fork of known and nearly equal pitch[1]. The fixed fork was assumed to give a tone of exactly 256 vibr. per sec. The beat-counting was done on several cool summer days. Repeating it in warmer weather, I obtained results which were not sensibly different. I have therefore assumed that any alterations in pitch, due to changes in temperature during these determinations and during the experiments described later, affected the fixed and variable forks equally and hence produced no appreciable change in the size of their interval. In order to estimate the larger intervals, a third fork of intermediate pitch, the relation

[1] My thanks are due to Mr J. F. Cameron, of Gonville and Caius College, for help from the mathematical side and to Mr G. T. Bennett, of Emmanuel College, from whose considerable experience in beat-counting I obtained much assistance.

of which to the fixed fork had been previously determined, was introduced and sounded with the variable fork. Finally the largest intervals were determined by weighting the third fork with wax.

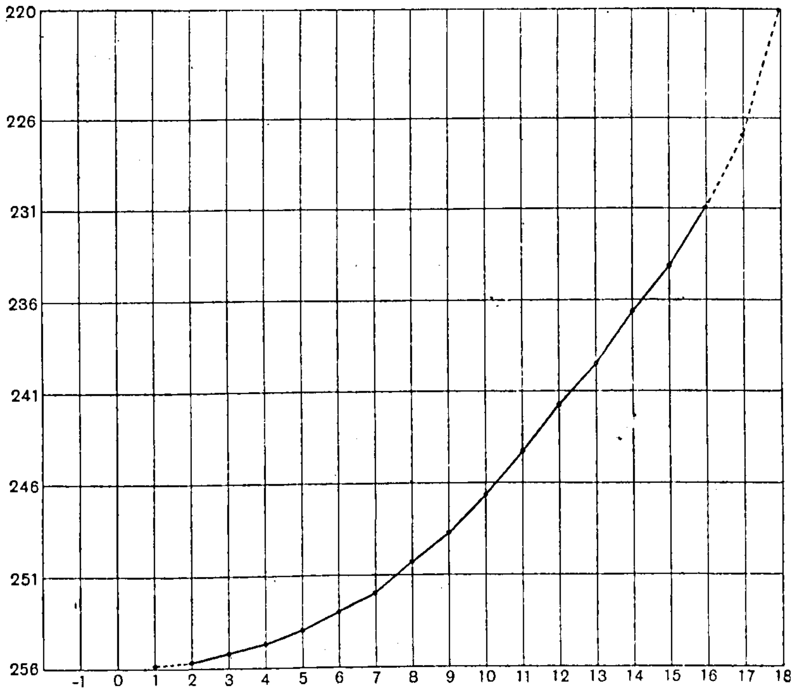

FIG. 11.

From a mathematical study of these results (Fig. 11), there can be no doubt that they are to a sufficient approximation correct. At the lowest and at the two highest of the eighteen positions of the clamp, the vibration-frequencies were theoretically calculated from the form of the curve obtained by determining the vibration-frequencies at the sixteen remaining positions. Estimated in this way, the pitch of the various tones, which were presented to the individual under investigation, is here given: fractions of vibration-numbers are disregarded, except in the case of tones differing by less than five vibrations per second from the pitch of the fixed fork.

256·00 (= fixed fork), 255·86, 255·67, 255·20, 254·75, 254·00, 253·01, 252·00,
250, 249, 247, 244, 242, 240, 237, 234, 231, 227, 220.

In my preliminary experiments on the Murray Islanders I mounted the forks on resonance-chambers and played them with a violin-bow. I found however that far better results were obtained by dispensing with the resonance-chambers and striking instead of bowing the forks. For it was important to produce sounds which were time after time of approximately constant intensity, so that inequalities in loudness might not mislead the subject's judgment of a difference of pitch[1]. A little practice enabled me

[1] Cf. Stumpf, *Tonpsychologie*, Bd. I. S. 237.

to overcome this difficulty satisfactorily. Moreover, I took care invariably to listen myself to the forks before applying them to his ear, rejecting sounds which for any reason appeared undesirable. The experiments were conducted in a small secluded room, tolerably free from external noise. The subject always sat with his back towards me. In one or two suspicious cases his eyes were kept closed; but it is quite certain that the islanders invariably disregarded the movements of my hands, depending for their judgment solely on the nature of the sounds which were presented to them. Sometimes the fixed, sometimes the variable fork was sounded first; the influence of the order of presentation of the forks will be discussed later. The forks were allowed to sound only with very moderate intensity, whereby the possible influence of accompanying overtones was reduced to a minimum. The two forks were successively held about 15 centimetres from the ear, each sounding there for about two seconds. The interval between the withdrawal of the first and the presentation of the second fork was likewise about two seconds, during which the second fork was being thrown into vibration[1]. The subject was asked, immediately after the second sound had been withdrawn, which of the two he considered the higher, and occasionally (see next page) whether he thought they were of the same pitch. His answers were given thus:—"first one high," or "second one high," or "both all same," according as a judgment of difference or of identity had been formed. Save in a few early experiments and in one or two suspicious cases alluded to hereafter, the same sound was never given twice consecutively; there was always therefore a difference (*i.e.* a musical interval), and when the subject returned the answer "both all same," he failed to detect it.

After numerous trials of various methods, I found that the experiments were best conducted in the following manner. Having assured myself that the subject thoroughly understood what was required of him, I began by presenting an interval so large that he could not fail to appreciate it. Next, I rapidly and roughly arrived at an interval which was too small for his correct appreciation. I worked then gradually towards the discrimination-threshold from a point at a little distance above it. Having reached and passed below the threshold, I gradually increased the interval between the forks again, until once more I arrived at the point of just perceptible difference. At each position of the clamp I applied the two forks at least five times (unless the pitch-difference in question was clearly well above or below the threshold), and I was not satisfied that the subject had correctly appreciated the interval unless he gave at least four of five successive answers correctly at the corresponding position of the clamp. To determine the effect of practice, many of the adults and nearly all of the children were examined during the following six weeks on two or three (in two cases on four) different occasions. Here the method of procedure was usually modified. I began the experiment by presenting an interval distinctly smaller than that which the previous experiments had shown to be (for him) the least perceptible. From that point I gradually increased the interval until I had passed above the threshold. Once again I diminished the interval until I had finally determined a new threshold.

[1] Angel and Harwood (*loc. cit.* pp. 67 ff.) found that there was little or no falling off in accuracy of judgment with increase of time-intervals within certain limits.

Twenty-three male adults and twelve boys were investigated in Murray Island. With two exceptions, I had no difficulty in making them realize the distinction between a high and a low tone. It was as a rule sufficient to produce several times on the forks two quickly following sounds more than a tone apart. A few subjects, mostly adults, were very slow in comprehending even this difference; but with them in the end I succeeded, by repeatedly singing a very high and a very low note, asking them which was the higher. There can be no doubt that in these experiments their judgment of pitch-differences was being exercised for the first time. The two adults, who after repeated attempts proved useless for my experiments, were Smoke, and Harry, the elder Mamus. The latter, possibly from lack of will, seemed quite unable to understand what was required of him. The former could generally appreciate a difference of pitch in sounds not less than three tones apart, but was even then uncertain in the lower tone-regions; he resembles many "pitch-deaf" people in Europe.

Each sitting lasted from twenty to thirty minutes. It was broken off earlier whenever signs of fatigue were manifested; these could readily be detected. Considering how monotonous and wearisome the islanders must have found the work of judging between so many successive pairs of sounds, they bestowed upon it a remarkable degree of attention. Of all our physiological and psychological experiments, this estimation of the least perceptible pitch-difference was certainly the most distasteful to them. I endeavoured in many cases to increase their interest towards the close of the sitting, by telling them if their judgments were right or wrong after I had, without so doing, arrived at an approximate determination of the threshold. I have carefully noted in the tables the cases in which the threshold was changed by this procedure.

Judgments of identity ("both all same") were treated as wrong judgments. They were not often given, owing doubtless to the form which my question took. I always asked, "Which one you think high?" save when the subject was clearly hesitating. Then I encouraged him with the remark, "Perhaps you think him all same?" It is, however, possible that the answers "first one high," when the second fork was really the higher, and *vice versa*, were occasionally due to accidental inequalities of tone-intensity. Yet such inequalities must have affected right and wrong judgments equally often.

I cannot confirm the experience of Preyer[1], Wolfe[2] and others who, employing the vibrations of metal tongues, could observe indefinable differences between two nearly unisonant tones, while they were still unable to judge which of the two was the higher or the lower. I find myself here in agreement with Max Meyer[3], and, although disbelieving in his *à priori* argument, am inclined to attribute the phenomenon, as he has done, to difference of quality (*i.e.* to the presence of unequal numbers and intensities of overtones) in the tones produced. König[4] and others held that tuning-forks can produce sounds absolutely free from overtones. Later work[5], however, makes it more than doubtful if any source of sound can be devised that does not simultaneously generate at least the first overtone. During the many thousand occasions on which I listened to the above tuning-forks, I have repeatedly but always unsuccessfully endeavoured to detect a difference

[1] *loc. cit.* S. 34.
[2] *loc. cit.* S. 542.
[3] *loc. cit.* S. 359—360.
[4] *Annalen d. Physik und Chemie*, Bd. CLVII. 1876, S. 177.
[5] Cf. Stumpf, *ibid.* N. F. Bd. LVII. 1896, S. 660.

of quality between the tones produced by them. I have also vainly asked my musical subjects (none of whom, however, was probably as 'highly musical' as I am), if they could detect any such difference. There can, of course, be no doubt that, *ceteris paribus*, a clamped and an unclamped fork of identical pitch do not produce the same overtones with equal intensity. But, as I took care to sound the forks only with moderate loudness, I cannot believe that this was a disturbing factor. Even in the case of the Aberdeenshire adult P., during his third sitting, I could still further lower the clamp[1] so as to produce a no longer appreciable tone-difference; whereas, if his judgments had depended on differences of quality instead of on differences of pitch between the tones, he would still have been able to make a constant distinction between the forks.

It is surprising how distinct is the demarcation of the threshold by the use of the above-described method. Three examples, taken almost at random from my note-book, will show with what clearness the point of just perceptible difference is usually indicated.

R indicates a right answer, W a wrong answer, S a judgment of identity. The vibration-number of the fixed fork was 256, as already mentioned; that of the variable is given, each time it was changed. *hl*, *lh* indicate the order of application of the forks, according as the higher preceded or followed the lower fork. The letter A shows the point where I began to tell the subject if his judgments were right or wrong.

Jimmy Dauar. June 30th, a.m. First sitting. Least perceptible difference, 14 vibr. per sec.

237, *hl* R, *hl* R, *lh* R, *lh* R, *lh* R; 247, *lh* W, *hl* W, *lh* W, *hl* W, *lh* W; 240, *lh* W, *hl* R, *hl* R, *hl* R, *lh* R; 242, *hl* R, *lh* R, *hl* R, *hl* R, *lh* W; 244, *lh* W, *hl* W, *hl* R, *hl* R, *hl* W; A, 244, *lh* W, *hl* W, *hl* R, *hl* W; 242, *hl* W, *lh* R, *hl* R, *lh* R, *lh* R, *lh* R; 244, *lh* R, *hl* W, *hl* W, *lh* W.

Capsize. July 17th, a.m. First sitting. Least perceptible difference, 14 vibr. per sec.

234, *hl* R, *hl* R, *lh* R, *lh* R, *hl* R; 247, *hl* W, *lh* R, *lh* S, *hl* W, *lh* S; 237, *hl* R, *lh* R, *lh* R, *hl* R, *lh* R; 240, *lh* R, *hl* R, *lh* R, *lh* R, *lh* R; 242, *lh* R, *hl* R, *hl* W, *hl* R, *hl* W; *lh* R, *lh* R, *hl* W, *lh* R, *hl* R; 244, *hl* W, *lh* R, *hl* W, *lh* W, *hl* W; *lh* W, *hl* W, *lh* W, *hl* R, *hl* W; A, *lh* R, *hl* W, *lh* W, *lh* R, *lh* R; 242, *hl* W, *hl* R, *hl* W, *lh* W, *lh* R; 240, *hl* R, *lh* R, *lh* R, *lh* R, *hl* R.

Charlie (Pasi). May 31st, p.m. Second sitting. Least perceptible difference, 4 vibr. per sec.

253·01, *lh* S, *lh* R, *lh* R, *lh* W, *lh* W; 252·00, *lh* S, *hl* W, *hl* R, *lh* R, *lh* R, *lh* R, *hl* W; 250, *hl* R, *lh* R, *lh* R, *hl* R, *lh* R; 252·00, *lh* R, *lh* R, *hl* R, *lh* R, *lh* S; 253·01, *lh* R, *hl* S, *hl* W, *lh* S, *hl* S.

The data furnished by these experiments in Murray Island and in Scotland are presented in a concise form in the four following tables. The columns L_1, L_2, L_1', L_2', etc., give the vibration-frequency of that tone, produced by the variable fork, which could just be adjudged correctly lower than the fixed tone ($c' = 256$ vibr. per sec.) produced

[1] The zero-point for the clamp was situated a short distance above the point of origin of the arms of the fork.

TABLE XXV.

Murray Island Children.

Name	Age	L_1	N_1	L_2	N_2	L_3	N_3	L_4	N_4	Remarks
Jimmy Dauar ...	10	242	$\frac{16-20}{39}$ A	242	$\frac{36-40}{55}$ A	...	...	...	...	
Depoma	10	247	$\frac{1-5}{18}$	242	$\frac{36-40}{49}$ A	...	...	...	...	Inattentive towards close of first sitting.
Harry	10½	240	$\frac{23-27}{33}$	240	$\frac{21-25}{40}$ A	...	...	...	...	
Manowar	11	253	$\frac{32-36}{37}$	...	...	...	...	...	...	
Abau	11	237	$\frac{25-29}{49}$	234	$\frac{21-25}{61}$	237	$\frac{16-20}{30}$ A	...	...	
Tom (Tanu)	11½	240	$\frac{14-18}{25}$	250	$\frac{31-35}{35}$	250	$\frac{11-15}{29}$	252	$\frac{26-30}{30}$	Method of procedure slightly different at the first sitting.
William (Tat) ...	11½	240	$\frac{2-6}{22}$	244	$\frac{21-25}{35}$	242	$\frac{11-15}{38}$ A	...	...	Inattentive towards close of first sitting.
Captain	11½	242	$\frac{11-15}{15}$	247	$\frac{6-10}{15}$	247	$\frac{46-50}{70}$ A	...	...	Had forgotten at the third sitting what was required of him.
Jimmy Rice, jun.	12½	240	$\frac{15-19}{26}$	240	$\frac{23-27}{33}$	252 254 A	$\frac{76-80}{89}$ A	...	...	
James	13	244	$\frac{27-31}{61}$ A	247	$\frac{1-5}{45}$ A	...	...	...	...	Complains of fatigue at the end of first sitting.
Poï (Pasi)	13	253	$\frac{36-40}{78}$ A	...	...	...	...	...	...	
Apori	14	247	$\frac{16-21}{21}$	252	$\frac{56-60}{65}$ A	253·01 254·75 A	$\frac{66-70}{100}$ A	250	$\frac{46-50}{54}$ A	Method of procedure slightly different at the first sitting.

TABLE XXVI.

Aberdeenshire Children.

Identification-letter, Sex and Age	L_1'	N_1'	L_2'	N_2'	L_3'	N_3'	Remarks
A. ♂ 9½	247	$\frac{6-10}{50}$ A	242 244 A	$\frac{18-22}{28}$ A	250	$\frac{22-26}{38}$ A	Too inattentive at a sitting between the last and penultimate sittings to obtain a result.
B. ♂ 10¼	237	$\frac{14-18}{40}$ A	252	$\frac{46-50}{55}$ A	...	...	
C. ♀ 10¼	247 249 A	$\frac{56-60}{75}$ A	...	...	...	...	
D. ♂ 11	237	$\frac{11-15}{25}$	240	$\frac{3-7}{25}$ A	237	$\frac{12-16}{23}$ A	Had forgotten at the third sitting what was required of him.
E. ♀ 11½	253	$\frac{31-35}{46}$ A	...	...	...	...	
F. ♂ 12	249	$\frac{26-30}{60}$ A	249 252 A	$\frac{27-31}{36}$ A	...	...	
G. ♀ 12	237 240 A	$\frac{26-30}{30}$ A	...	...	...	...	
H. ♀ 12	242	$\frac{26-30}{40}$ A	249 252 A	$\frac{46-50}{52}$ A	252	$\frac{13-17}{27}$ A	
J. ♀ 12½	253·01	$\frac{50-55}{75}$ A	...	...	...	...	
K. ♂ 12¾	244	$\frac{11-15}{35}$ A	252 253·01 A	$\frac{23-28}{33}$ A	...	...	
L. ♂ 13	249	$\frac{46-50}{65}$	255·67	$\frac{52-57}{70}$	252 253·01 A	$\frac{36-40}{45}$ A	Not so attentive as before at the last sitting.
M. ♀ 13½	249 252 A	$\frac{66-70}{75}$ A	250	$\frac{9-13}{45}$ A	...	...	

TABLE XXVII. *Murray Island Adults.*

Name	Age	L_1	N_1	L_2	N_2	L_3	N_3	Remarks
Charlie (Pasi)...	16	...	...	252	$\frac{8—12}{28}$	...	...	First sitting incomplete.
Berò...............	17	234	$\frac{7—11}{17}$	244 247 A	$\frac{51—55}{60}$ A	...	...	
Madsa............	18	247	$\frac{12—16}{16}$	253·01	$\frac{30—34}{42}$ A	254·75	$\frac{50—55}{65}$ A	Felt 'sleepy' at end of third sitting.
Tapau	20-25	240	$\frac{16—20}{50}$ A	...	...	...	...	
Dubwai	20-25	237	$\frac{6—10}{37}$ A	...	...	...	...	Very slow at learning what was required.
Meiti	25-30	242	$\frac{44—48}{48}$	...	...	...	...	
Dick Tui	30-35	249	$\frac{27—31}{38}$	247	$\frac{29—33}{51}$	249	$\frac{6—10}{73}$ A	Tired at end of third sitting.
Jimmy Rice ...	30-35	240	$\frac{29—33}{54}$	...	...	...	...	
Mabo	30-35	244 247 A	$\frac{45—49}{53}$ A	249	$\frac{31—35}{59}$ A	...	...	
Charlie Boro ...	30-35	240	$\frac{17—21}{56}$ A	242	$\frac{36—40}{64}$ A	...	...	Slow at learning what was required.
Oroto	35-40	237	$\frac{11—15}{35}$ A	...	...	...	...	
Billy Gasu	35-40	237	$\frac{11—15}{41}$ A	...	...	...	...	
Pasi...............	40-45	237	$\frac{12—16}{25}$ A	224	$\frac{28—32}{41}$ A	247 250 A	$\frac{60—64}{64}$ A	Possibly a little tired before second sitting.
Capsize	40-45	242	$\frac{26—30}{55}$ A	...	...	...	...	Learnt unusually quickly.
Wasalgi	40-45	240	$\frac{14—18}{36}$ A	240	$\frac{16—20}{30}$	...	...	
Smoke............	45-50	?	...	...	...	...	...	See p. 159.
Tibi...............	45-50	240	$\frac{51—55}{64}$ A	...	...	...	...	Slow at learning what was required.
Alo	45-50	240	$\frac{21—25}{51}$ A	...	...	...	...	
Kriba	50-55	240	$\frac{18—22}{43}$ A	...	...	...	...	
Komaberi	50-55	242	$\frac{21—25}{50}$ A	...	...	...	...	
Azò	55-60	240	$\frac{16—20}{30}$ A	...	...	...	...	
Ulai...............	55-60	240 242 A	$\frac{34—38}{58}$ A	242	$\frac{31—35}{59}$ A	...	...	
Harry [Mamus]	over 60	?	...	...	...	...	...	See p. 159.

TABLE XXVIII. *Aberdeenshire Adults.*

Group	Identification-letter, Sex and Age	L_1'	N_1'	L_2'	N_2'	L_3'	N_3'	Remarks
I. Unmusical	A. ♀ 16	244	16—20/45 A	...	...	...	...	
	B. ♀ 24	237	21—25/45 A	...	...	...	...	
	C. ♀ 25	253·01	21—25/33 A	...	...	...	...	
	D. ♂ 30	252	50—54/61 A	...	...	...	...	
	E. ♂ 33	249	18—22/30 A	...	...	...	...	
	F. ♂ 35	249 250 A	31—35/41 A	...	...	...	...	
	G. ♂ 35	237	26—30/35	...	...	...	...	
	H. ♂ 37	237 240 A	26—30/35 A	237	16—20/34 A	244 249 A	52—57/61	What was required had to be re-explained at each sitting.
	J. ♂ 43	240	21—25/43	...	...	...	...	
	K. ♂ 43	240	16—20/29 A	...	...	...	...	
	L. ♂ 43	253·01 254·75 A	56—60/68 A	...	...	...	...	
	M. ♂ 45	254	36—40/55 A	250	16—20/30 A	...	...	
II. Doubtfully musical	N. ♀ 35	250 253·01 A	25—29/33 A	...	...	...	...	
	O. ♂ 45	249	38—42/45	252	16—20/35 A	...	...	
	P. ♂ 50	254	21—25/49 A	255·67	19—23/63	255·20 255·86 A	49—53/57 A	
III. Musical	Q. ♀ 27	254	41—45/50 A	...	...	...	...	
	R. ♂ 28	252	42—46/67	...	...	...	...	
	S. ♂ 33	252	36—40/45 A	250 252 A	19—23/33 A	253·01	16—20/30 A	
	T. ♂ 33	249	11—15/38 A	...	...	...	...	
	V. ♂ 34	254 254·75 A	26—30/37 A	...	...	...	...	
	W. ♂ 47	250 252 A	36—40/45 A	...	...	...	...	

by the higher fork. The columns N_1, N_2, N_1', N_2', etc., contain fractions, the denominator of which expresses the number of times the two forks were presented at the sitting, the numerator showing where in the series the five judgments of the least perceptible tone-difference occurred. L and N apply to the Murray Islanders, L', N' to the Aberdeenshire folk. L_1, L_2', N_3', etc. show whether it is the first, second, third, etc. sitting of the subject. Where the letter A occurs in the N or N' columns, it implies that towards the close of that sitting the subject has been each time told whether his judgment is right or wrong. Where the letter A occurs in the L or L' columns, it follows a figure which gives the alteration in threshold occasioned by this procedure. The figure in the same square immediately above, unaccompanied by the letter A, shows the threshold determined at that sitting before the procedure of confirming or correcting the judgments was begun. Where A occurs in the N columns, and not in the L columns, it signifies that the threshold was not altered. Thus $L_1' = \frac{249}{252}$ A, $N_1' = \frac{66\text{—}70}{75}$ A, means that an Aberdeenshire subject at his first sitting was presented with the two forks on seventy-five occasions, that he was able to appreciate a difference of (256 − 249 =) seven vibrations per second, that after being told that his judgments were right or wrong, he could detect a still smaller difference of (256 − 252 =) four vibrations per second, and that the (at least four) correct judgments of the latter pitch-difference were given between the sixty-sixth and seventieth presentation of the pairs of forks.

The Order of Presentation of the Tones.

Here, as in nearly all our experimental work among the Murray Islanders, it was impossible to obtain introspective information of any value. But an objective examination of the five thousand judgments of tone-differences, which I obtained in the Torres Straits and in Scotland, undoubtedly shows that by some (whom I will call Class I) a greater number of correct answers was given when the fixed fork was presented first, by others (Class II) a greater number of correct answers was given when the variable fork was presented first, while many subjects (Class III) appeared wholly uninfluenced by the order in which the forks were sounded.

I find that of thirty-one Murray Island adults and children, twelve belonged to Class I, seven to Class II, and twelve to Class III. In Scotland the proportions were very similar. Of thirty-four, fourteen belonged to Class I, six to Class II, and fourteen to Class III.

I give two examples of Class I and of Class II from Aberdeenshire and Murray Island. As before, R indicates a right, W a wrong answer, S a judgment of equality. The fixed fork vibrated 256 times per second. The frequency of the variable fork is given each time it was changed. The letters *hl*, *lh*, indicate the order of presentation of the forks, the higher preceding or following the deeper fork.

CLASS I.

Aberdeenshire.

S. 253·01, *lh* S, *hl* R, *lh* S, *hl* S; 252, *lh* S, *lh* R, *hl* R, *lh* R, *lh* S; 250, *lh* R, *lh* S, *hl* R, *hl* R, *lh* R, *lh* R, *lh* R; 252, *lh* S, *lh* S, *hl* R, *hl* R, *hl* R, *hl* R, *lh* S; *lh* R, *hl* R, *hl* R, *hl* R, *lh* R; 253·01, *lh* R, *hl* R, *hl* S, *hl* R, *lh* S.

Murray Island.

Abau. 240, *lh* W, *lh* R, *hl* S, *lh* R, *hl* R; 237, *lh* W, *hl* R, *lh* S, *lh* R, *hl* R; 234, *lh* R, *hl* R, *lh* R, *lh* R, *hl* R; 237, *lh* W, *hl* R, *hl* R, *lh* R, *lh* R; 240, *lh* W, *hl* R, *lh* W, *hl* R, *lh* R; 240, *lh* W, *lh* W, *hl* R, *lh* W, *hl* W.

CLASS II.

Aberdeenshire.

P. 255·86, *lh* R, *hl* S, *hl* W; 255·67, *lh* W, *hl* W; 255·20, *lh* R, *hl* R, *hl* R, *lh* S, *lh* R; 254·75, *lh* R, *lh* R, *hl* S, *hl* W, *hl* W; 254·00, *lh* R, *hl* R, *hl* R, *hl* R, *lh* R; 254·75, *hl* R, *hl* S, *lh* R, *lh* R, *hl* S?; 255·20, *lh* R, *hl* R, *hl* S, *lh* R, *hl* R; 255·67, *lh* R, *hl* W, *hl* R, *lh* R, *hl* R?; *hl* S, *lh* R, *lh* W, *hl* R, *hl* W; *hl* W, *lh* R, *hl* R, *hl* W, *lh* R, *hl* W; 255·86, *lh* R, *hl* R, *hl* W, *lh* R, *lh* R, *lh* R; 255·9 ??, *lh* S, *hl* W, *lh* R, *lh* W.

Murray Island.

Jimmy Rice, jun.

244, *lh* W, *lh* W; 242, *lh* W, *hl* W, *hl* W, *lh* R, *lh* R, *lh* R, *lh* R, *hl* W; 240, *lh* R, *hl* W, *hl* R; 237, *lh* R, *lh* R, *hl* R, *hl* R, *lh* R, *hl* R; 242, *lh* R, *hl* W, *hl* W; 240, *hl* W, *hl* R, *hl* R, *lh* R, *lh* R; 242, *lh* R, *hl* R, *hl* R, *lh* W, *hl* W, *hl* W.

It will be seen that of the answers given by the two subjects in Class I, 87 °/₀ and 83 °/₀ were correct when the fixed fork was presented first, while only 50 °/₀ in each were correct when the variable fork was presented first; and that of the answers given by the two subjects in Class II, 81 °/₀ and 75 °/₀ were correct when the variable fork was presented first, while only 43 °/₀ and 47 °/₀ were correct when the fixed fork was presented first.

The influence of the order of presentation of the two forks is seldom noticeable at the first sitting. It does not usually appear until the subject has had some practice in determining small differences of pitch. Possibly I have somewhat over-estimated the number of persons whose judgments were found to be affected by the order of presentation. But before deciding on each case, I went carefully through the results of every sitting, and ruled out several apparent instances, which were really due to an accidentally preponderating number of one particular order of presentation in the neighbourhood of the smallest perceptible tone-difference.

To what these differences of behaviour are due, whether some subjects form an absolute pitch-impression, whether others retain or recall an auditory image of the first tone for comparison beside the second tone or whether their judgment is based on differences of more or less sub-conscious adaptation, I cannot as yet decide. In Scotland one of my adult subjects, M, informed me that the discrimination appeared easier if the fixed fork were sounded first: he returned nearly 67 °/₀ correct answers under these conditions, but only 25 °/₀ when the variable fork was sounded first. He thought that practice had enabled him to recognize the fixed fork as soon as he heard it, and that it was easier to judge between this and the variable fork, if the recognition of the former had preceded the hearing of the latter. However, when I sounded one of the forks singly and asked him if he could say whether it was the fixed or the variable fork, he seldom returned a correct answer. On the other hand, the Aberdeenshire adult P, whose answers I have recorded above, thought it far easier to detect a pitch-difference if the variable fork were sounded first; two others were unable to discover that their decisions were in any way influenced by the order of presentation of the forks.

Unfortunately the two forks which I used were so arranged, that the fixed fork gave always the higher, the variable fork always the lower tone. It would be interesting to observe the effect of reversing these conditions; indeed it would be imperative to do so, before one could attempt to interpret the significance of the influence of order on the judgments of comparison of two nearly identical tones. It may be, as Schischmánnow[1] has suggested, that a rise of pitch can be recognized more easily than a fall. It may be that this is complicated by the factor that more correct judgments are given when the variable follows the standard than *vice versa*, or again wide individual differences of type may exist, as Martin and Müller[2] have observed in their experiments upon the comparison of weights. But a further discussion of the meaning of these results is impossible until a more extended series of experiments has been made. All I would here point out is that the Murray Islanders and the Aberdeenshire people show no apparent differences in the way they are affected by the order of presentation of the tuning-forks.

Conclusions.

Two important considerations must not be forgotten, in concluding from Tables XXV—XXVIII that the adults, and to a less extent the children, of Aberdeenshire surpass the people of Murray Island in their power of distinguishing two tones of nearly identical pitch.

In the first place, as I have before pointed out, the results given by the children of the two districts are more comparable with one another than are those given by the adults.

Secondly, owing to their greater inattention and for other reasons, a smaller number of experiments was made on certain islanders, especially upon the children, at their first sitting than on the Aberdeenshire folk.

It becomes difficult, therefore, from the above data to deduce a numerical measure

[1] *loc. cit.* S. 598. However, L. W. Stern (*Ztsch. f. Psych.* Bd. xxi. 1899, S. 376) on inadequate grounds concludes that a fall of pitch is more easily recognized than a rise, so long as the pitch-change is discontinuous.

[2] *Zur Analyse der Unterschiedsempfindlichkeit*, Leipzig, 1899, § 6, S. 29 ff.

of relative pitch-discriminability in the primitive and civilized races. Some idea, however, of the existing differences may be gained, if we dismiss from consideration (i) the results given by those subjects, on whom the number of observations made at their first sitting did not exceed thirty, and (ii) the improved results, gained by telling the subject if his judgments were right or wrong. After these eliminations, we find that the average difference of vibration-frequency ($=\Delta$) just distinguished by the adults of Murray Island and of Aberdeenshire at their first sitting is 15·4 and 7·6 vibrations per second respectively, and that the average difference just distinguished by the children of Murray Island and of Aberdeenshire at their second sitting is 12·5 and 4·7 vibrations per second respectively,—*i.e.*, in each case a difference of nearly 8 vibrations per second between the Papuan and the Aberdeenshire peoples for the tone c'. Accordingly the absolute discriminative sensibility $\left(=\frac{1}{\Delta}\right)$ of the Murray Island adults and children is 0·065 and 0·08, that of the Aberdeenshire adults and children is 0·13 and 0·21.

It is noteworthy that, excepting Smoke and Harry, all the 68 subjects readily distinguished an interval less than a tone. Of the six, who in each community failed with an interval just exceeding a semitone, three had only one sitting, two showed subsequent improvement, and one remained stationary.

As would perhaps be expected, the improving effect of practice is greater among the adults of Murray Island than among those of Aberdeenshire. The weak discriminative sensibility of the former is probably due to their lack of familiarity with European musical notes, precise intervals and instruments. But they show themselves capable of becoming quickly adapted to their new experiences[1]. On the other hand, the effect of practice among the island children is rather less evident and less continuous than in Aberdeenshire.

The influence of the order of the presented tones hardly needs reconsideration here. Both in Murray Island and in Aberdeenshire preference was more often shown for hearing the fixed fork before the variable than for the reverse sequence. The subject requires fuller investigation before it can be discussed further.

Finally, the general results of these experiments are not without interest from the standpoint of comparative music. For if it be supposed that smaller intervals are employed by primitive than by civilized communities—if, for instance, third- and quarter-tone music be at all widely spread among savage peoples—we should expect them to show evidence of extremely high sensibility to minute differences of pitch. That this is not the case, so far as the Murray Islanders are concerned, is shown by the experiments described in this section. Nor could it be expected, since the intonation of native songs by the older men was often so variable and so inaccurate, that the intended intervals were only evident when several islanders sang them together[2].

[1] It is noteworthy that both Preyer (*loc. cit.* S. 37) and Wolfe (*loc. cit.* S. 569) found that the improving effect of practice in discriminating minute intervals did not simultaneously facilitate the discrimination-power for larger intervals.

[2] A description of their music will follow in volume IV.