

DISCUSSION.

HELMHOLTZ' EXPLANATION OF DIFFERENCE TONES.

In a recent number of the BULLETIN,¹ Mr. Peterson takes me sharply to task for following Helmholtz in my explanation of the ear-generated difference tones.² " 'That these tones take their origin in the middle ear,' is just what recent investigations, so far as the writer is aware, do *not* show. If there is any part of Helmholtz' theory that has not stood the test it is just this part. Unfortunately, Professor Titchener cites no literature on these recent investigations."

I am afraid that Mr. Peterson has not consulted the literature cited in my *Text-book*. My first reference is to Schaefer's essay on audition in Nagel's *Handbuch*, where he might have read the following passage. "Helmholtz has . . . proposed the hypothesis that the drum-skin and the adjacent structures are to be regarded as the place of origin of the subjective combinational tones. I have convinced myself that this hypothesis is correct (*das Richtige trifft*) by an . . . experimental investigation which has shown . . . that telephone membranes and membranes of the form of the drum-skin . . . produce objective . . . combinational tones. The physical derivation (*Begründung*) of these tones must, it is true, be different from that attempted by Helmholtz for the drum-skin."³

The reading of these sentences would have recalled Schaefer's paper *Ueber die Erzeugung physikalischer Differenztöne mittels des Stentortelephons*, published in the same year.⁴ The author here

¹ Titchener on Helmholtz' Explanation of Combination Tones, PSYCHOLOGICAL BULLETIN, VI., 1909, 397 ff.

² *A Text-book of Psychology*, I., 1909, 112.

³ K. L. Schaefer, *Der Gehörsinn*, in Nagel's *Handbuch d. Physiol d. Menschen*, III., 1905, 568 f.

⁴ Drude's *Annalen d. Physik*, 4te Folge, XVII., 1905, 572 ff. Schaefer's abstract of this article in the *Zeits. f. Psych.*, XLII., 1906, 348 f., ends with the words: "It seems to me highly probable that Helmholtz was upon the right track with his hypothesis that the drum-skin is the place of origin of the combinational tones, although his mathematical derivation has often been disputed."

Both the essay in Nagel's *Handbuch* and the article in the *Annalen* are cited by Mr. Peterson in his *Combination Tones and Other Related Auditory Phenomena*, 1908. He finds (p. 101) that it is not clear whether Schaefer means to apply his results with membranes "to the inner membranes of the

refers to his experiments with plane and funnel-shaped membranes, and concludes with the sentence: "It appears that Helmholtz was upon the right track, although the explanation that he offered has met with a great deal of opposition."

In the next year, 1906, appeared Waetzmann's article, *Zur Frage noch der Objektivität der Kombinationstöne*.¹ I quote a single sentence. "The experiments just described . . . seem to me to furnish strong support to Helmholtz' derivation of the combinational tones, although it must be conceded that this derivation involves many errors of detail."

Here, then, in the experiments of Schaefer and Waetzmann, is the 'recent investigation' upon which I relied when writing the paragraph in my *Text-book*. It is strange that Mr. Peterson should have overlooked the evidence. However, to make my case complete, I must refer briefly to certain other studies that were available at the time.

In 1907, Bingham reported that "absence of the tympanic membranes does not prevent generation of 'subjective' difference-tones."² Mr. Peterson reminds us that Dennert made similar observations as early as 1887;³ he might have added that Schaefer confirms them, on

ear, as part of his explanation of subjective combination tones." I think that Schaefer is clear enough, although he does not go into detail; Mr. Peterson was, perhaps, preoccupied with Schaefer's earlier theory (*Arch. f. d. ges. Physiol.*, LXXVIII., 1899-1900, 505 ff.). Here, again, the *Handbuch*, p. 568, would have helped him.

¹ Drude's *Annalen*, 4te. F., XX., 1906, 837 ff. Schaefer comments, in *Zeits. f. Psych.*, XLIV., 1907, 292: "The author finds in his experiments, as I find in my own, a support for the Helmholtzian hypothesis of the origin of the subjective combinational tones in the drum-skin, though this may contain many errors of detail, especially in its mathematical derivation." Again: in the same *Annalen*, XXIV., 1907, 68 ff. (*Zur Theorie der Kombinationsstöne*), Waetzmann defends the Helmholtz theory against the familiar amplitude-objection: "bei unsymmetrisch elastischen Körpern genügen schon sehr kleine Amplituden, um höheren Potenzen der Elongation Einfluss auf die rücktreibende Kraft zu verschaffen." I understand that this defence applies to the drum-skin, though Waetzmann thinks that other structures (*e. g.*, the liquid of the inner ear) may replace the drum-skin without prejudice to the essential features of the theory. I have not seen the work *Zur Helmholtzschen Resonanztheorie* (Breslau Habilitationsschrift, 1907) of which this article is said to give an abstract.

² Studies from the Psychological Laboratory of the University of Chicago, communicated by J. R. Angell: W. V. D. Bingham, 'The Rôle of the Tympanic Mechanism in Audition,' *PSYCHOL. REVIEW*, XIV., 1907, 229 ff.

³ H. Dennert, 'Akustisch-physiol. Untersuchungen,' *Arch. f. Ohrenheilkunde*, XXIV., 1887, 171 ff.

the ground of unpublished communications, in 1905.¹ But, had he noted this latter fact, he would also have come upon Schaefer's explanation of it: Schaefer supposes that the membrane of the round window may now act as a telephone membrane, and may thus generate the tones in question. The assumption struck me as reasonable, and I accordingly discounted Dennert's objection.²

M. Meyer's theory of audition furnishes an explanation of difference tones;³ but as I had decided to mention only the Helmholtz theory in my *Text-book*, I was unable to refer to it.

Hermann's *Neue Untersuchungen über die Natur der Kombinationstöne*⁴ made less impression upon me at first reading than it does now, — probably because, at the time of writing, I was fully convinced of the existence of ear-generated difference tones. Hermann, of course, here ascribes the difference tones to the asymmetrical vibration either of some outside body or of the bones of the head.

There remains Mr. Peterson's own work upon *Combination Tones and Other Related Auditory Phenomena*.⁵ The author suggests that the conditions of origin of objective and subjective combinational tones are in principle the same, and that the subjective tones may be referred to the fluids of the cochlea.⁶ Neither suggestion is novel: Schaefer had argued from the analogy of telephone membranes to the

¹ Nagel's *Handbuch*, III., 569.

² Mr. Peterson writes: "These observations, of course, do not *prove* that the tympanic membrane and the ossicles *cannot* produce combination tones as Helmholtz supposed. They show, however, that Helmholtz' explanation is incomplete and for the most part useless; that it certainly does not touch the most important cause of combination tones." The first sentence is correct; but the second does not follow from the data. The removal of the normal cause may permit some other structure, under the changed conditions of stimulation, to take on a function that, with the normal cause present, it is prevented from discharging. And so the exposed membrane of the round window may perhaps take on the duties normally performed by the drum-skin; duties which, under ordinary circumstances, it is not called upon to perform.

³ 'An Introduction to the Mechanics of the Inner Ear,' *Univ. of Missouri Studies*, Science Series, II., 1907, no. 1. Writing of the earlier presentations of Meyer's theory, Mr. Peterson remarks: "It is questionable whether Meyer's theory is an improvement upon that of Helmholtz even with respect to the intensity difficulty. And this is the very thing Meyer's theory was devised primarily to explain" (*Combination Tones*, etc., 95). From the footnote on p. 91, and the statements on pp. 129 f., I gather that the appearance of the new work has not changed his opinion.

⁴ *Arch. f. d. ges. Physiol.*, CXXII., 1908, 419 ff.

⁵ The most important references are 16-25, 56-65, 69 f., 77, 90 f., 95, 99 f., 103-106.

⁶ See esp. 104.

assumed function of the drum-skin or (in default of a drum-skin) of the membrane of the round window; and Waetzmänn, himself not original in the proposal, had declared his willingness to substitute the liquid of the labyrinth for the drum-skin and ossicles of Helmholtz' theory. I therefore found nothing in this work that I had not already considered.

I am, nevertheless, quite ready to admit that my acceptance of the Schaefer-Waetzmänn view may have been prompted, in some measure, by the relief that every student of psychological acoustics must feel in getting 'back to Helmholtz.' In the winter of 1903-4 I took up with my Graduate Seminary the question of auditory theory; we worked through, with some care, the recent publications on the histology and physiology of the ear, and the whole long series of psychophysical hypotheses. We all, I think, ended the term with an increased respect for the resonance-theory; right or wrong, it explains more, as it also explains more neatly, than any of its rivals.¹ Stumpf, as is well known, has rejected it for two reasons: "weil es physikalisch so gut wie unmöglich erscheint, dass so winzige Gebilde auf die für uns hörbaren Töne noch mitschwingen sollen; aber auch wegen der Schwierigkeiten im Gebiete der Differenzttöne."² On the issue of physics we may, perhaps, be content to take Helmholtz' word; in the matter of difference tones, Schaefer and Waetzmänn seemed to make Helmholtz' original idea more plausible than critics had allowed,—certainly more plausible than the alternative proposed by Ebbinghaus.

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THE OBSERVER AS REPORTER: A CORRECTION.

My attention has just been called to a typographical error in my article upon 'The Observer as Reporter' in the *PSYCHOLOGICAL BULLETIN* of May 15, 1909. As this error concerns the formula for the computation of an important coefficient of report, I beg the opportunity to make the following correction: On page 159, formula 7, reliability of assurance should be computed as $c(r)/c$, not r/c as there printed.

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¹ Mr. Peterson apparently shares this opinion; *op. cit.*, 130. I cannot subscribe, unreservedly, to all the points made in his comparative table; but complete agreement in such a case is hardly to be looked for.

² Konsonanz und Dissonanz, *Beitr. z. Akustik u. Musikwissenschaft*, I., 1898, 51 f.