Vol. XIII. No. 5. May 15, 1916

THE

PSYCHOLOGICAL BULLETIN

GENERAL REVIEWS AND SUMMARIES

HEARING

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Köhler (7) gives us this year a lengthy discussion of his present attitude towards the problem of sound analysis. His paper reports few experiments, but many important observations, and contributes considerably towards the clarification of the more or less conflicting results which recent experimental research has brought forth. He now distinguishes "pitch," which involves the musical character of the tone and embraces Révész's "quality,"[1] from the "tone-body." The latter has two important aspects, "brightness," which appears the more fundamental, and "vowel character." It may also take on a "voluminosity," though this aspect is not specifically handled in the present paper.

The first discussion treats of the shifting of pitch in normal and pathological hearing. Révész has shown that in v. Liebermann's case the tone-body (called by him "pitch") is not affected in the paracusic regions. This appears also to be the case in v. Maltzew's observations of normal false-hearing.[2] Köhler observes that when a "u" is determined on the tone variator at 263 vs., if the head be brought nearer to the instrument, and the intensity of the tone thus increased, the "u" shifts to an "m"-like character. In this case both pitch and tone-body are altered.

The second discussion concerns tones without pitch. It is contended that pitch should not be regarded as the essential feature of the acoustic scheme. Both high and low tones lose their pitch

[1] See the BULLETIN, 1913, 10, 108.

[2] See the BULLETIN, 1914, 11, 99 ff.

while retaining their "body." In regard to the difficulty of obtaining a satisfactory "s" at the optimal vibration frequency of 8,460 vs., the single tone appears too open to imitate the spoken "s." However, with two Galton whistles sounding tones of this region with a frequency whose difference is great enough to eliminate beats a normal vocal "s" is produced.

This observation may be correlated with Lord Rayleigh's (11) failure to secure a satisfactory "s" with the single vibration frequency of this number. Rayleigh's attention was called to Köhler's results by Titchener, who reported before the American Philosophical Society experiments which indicated that his observers could not distinguish between an "s" made with the mouth and the whistle note of the above frequency. Rayleigh questions the full quality of the "s" and fancies that suggestion may have had its influence in this regard. At least, his own observations show that while the optimal frequency of the Galton whistle is that indicated by Köhler, that of an organ pipe was not the same. He also remarks that he believes the "s" to contain irregular vibrations of a dominant pitch but including subordinate components which are decidedly graver. No grounds are given to substantiate this conjecture, and it is therefore possible that Köhler's observation, recited above, may furnish the true explanation of the vocalized "s." Köhler's observations also indicate the "s" to be lacking in pitch. A melody hummed on "ss" is quite undetected, he states, by an observer who does not know it in advance or infer it from the rhythm.

Brief tones are also observed to lack pitch. Experimenting with a siren upon which all the openings save a few had been covered, the first sound obtained was the "*trockene Schlag*" described by Mach. This occurs before the pitch is noted, yet the "brightness" or "dullness" of the first sound is clearly heard. It appears that the temporal threshold for brightness, and also for vowel character, is lower than that for pitch. Amusia is of interest in that the amusic need not be deaf to speech, in which, of course, vowel sounds are essential. A case examined by Köhler enabled him to conclude that the pitch phenomena were lacking while tone-body remained to afford all the necessary differentiations of sound needed for ordinary speech. It is also inferred that many animals possess the capacity to discriminate in terms of tone-body, but are not sensitive to pitch. Certain simple consonant intervals, however, such as the octave, fifth and fourth, have so much greater stability

than the others that they occur in exotic and primitive forms of music while otherwise differences of brightness or tone-body play the dominant rôle.

A third topic of discussion concerns noise. Sounds above 20,000 vs. are noises, but the limit of hearing is not reached here. In passing from "s" to "f" sounds, Köhler noted that both brightness and volume are altered, the "f" has greater volume and less brightness despite its higher frequency of vibration. It is stated that with the König metallic plate at c^7 one may easily hear beside the shrill "s," also an "f" which is removed by appropriate interference. The conclusion is that noise is usually occasioned by numerous simultaneous tones of unharmonic frequency, and by numerous rapidly following tones of slightly different pitch. It also occurs as a correlate of the highest, lowest and shortest frequencies. In addition, we have the "roughness" effect of beats, and certain explosive sounds ("p," "t," "k," "b," "d," "g") which resist attempts to assign them to any special frequency of vibration. Noise is more a matter of "body" and less a matter of "pitch." But tones and clangs play but a relatively small part in sound. The original and most usual sounds are indeed of noise character. The inference is drawn that tone is an exceptional occurrence finding its correlate in the simplicity of the nervous process aroused. We need assume no separate organ for noise, but should rather regard the cochlear receptor as primarily an organ of noise, while tone is a later refinement of sound corresponding to a specific nervous impulse.

A fourth topic deals with speech and music. It is contended that music plays no important rôle in speech. So-called "speech melodies" contain no pitch other than what we choose to read into them. Speech is a matter of tone-body. The vowel character is not the quality of noise (Jaensch), but one of the aspects of tone-body, as is also brightness. The vowel character is given by the most intensive component, but this need not be the fundamental. Indeed, the fundamental is not necessarily the dominant component of a sound. Low tones on the piano may lose their fundamentals entirely when their partials are removed through interference. The notion is advanced that the partial impulses cooperate in the arousal of the pitch of a clang. The dominant pitch may thus be retained even though the fundamental itself be a very weak component. Combined clangs are usually heard as single sounds. The cochlear membrane responds by relatively large parts, rather than by single

resonators in the original Helmholtzian sense. This response is the correlate of the tone-body, while pitch has for its correlate the frequency of nervous impulse. Analysis is unnecessary to determine the pitch of an accord. This is more a physiological than a psychological phenomenon. Ordinarily the highest tone gives the pitch, but not always.

The consciousness of "absolute pitch" is found to be usually dependent upon timbre and similarity of tone-body. It is developed through practice with special instruments, chiefly the piano and violin, which are well adapted for such discriminations since their separate notes vary markedly in timbre. With the tones of the human voice, judgments are much less reliable, because the transitions of timbre are much less clearly defined, the human voice having as many as ten different "registers." Experimental training with the piano, attention being given primarily to the tone-body of different keys, enabled Köhler to improve his capacity for absolute pitch very materially. He was unable, however, to use his acquired ability to judge the pitch of tones on other instruments. Some cases examined indicated a true sense for absolute pitch, in that by inner reproduction of the sound the observers were able to name its place in the scale, but the author believes that the most usual cases depend simply on familiarity with the tone-body of sounds of particular instruments.

Some concluding remarks on terminology aim at the justification of analogical terms for describing the complicated phenomena of hearing. By analogy with the other senses, pitch appears to be an attribute. It is a "*niveau*" rather than a content, and has something of the nature of a spatial point. Brightness and the vowel character, however, belong to the qualities, such as color, smell and taste contents. Nor can we term pitch a specific musical quality for it does not belong to specific tones as such. The transposition of a melody does not alter the relative pitch, but it does affect the quality of the melody. The character of pitch is its localizing capacity. In this it is unlike brightness. If one produce a deep "o" followed quickly by an "a" at the same pitch, the brightness changes but there is no rise in pitch. Whenever the "o" is altered a semi-tone, however, although the brightness changes very little, the change in pitch or localization is very marked.

Modell and Rich (9) have tested Köhler's earlier work on the pitch of vowels, using as sources of sound tone variators, the piston whistle and the Galton whistle. Their results in the main sub-

stantiate Köhler. All five observers reported the vowel sounds, though one heard no pure vowels save "a." Some observers tended to place the entire series of vowels at a higher pitch than did others. The octave relation could be made out from the average results between "u," "o" and "a," and between "e" and "i," but hardly between "a" and "e." With three observers Rich (13) has tested the threshold of volume discrimination for tones of the Stern variator ranging from 100 to 6,400 vs. He found that judgments of this sort could be made with ease and great consistency; that they were made on an attributive basis, after practice, as immediately as those of pitch. The relative difference limen approximated .03+. It is thus different from pitch both in magnitude and course, since it indicates a judgment in terms of equal ratios of vibration frequency, rather than of absolute frequency as is the case with pitch. Sizes (14, 15) in two brief reports indicates the objective existence of partials below the fundamental. The details of his experiments are not reported with sufficient fullness to make his results easily comprehended. He notes that inferior harmonics may be easily detected in the tones of gongs and bells.

Hohenemser (6) discusses the problem of concordance and discordance as distinct from that of consonance and dissonance.[3] Riemann has asserted that dissonance is possible only when a third note enters into a binary combination, or is thought of in such a connection. It may therefore be regarded as a phenomenon of perception. The author challenges this. The contradictory cases of the semi-tone and whole-tone dissonances are cited. Reference is also made to Stumpf's distinction, and his controversy with Riemann over the chord c-e-g♯. The author's argument as concerns this chord is the same as that advanced in a different connection by the present writer.[4] The interval c-g♯ is a consonant minor sixth, when e is added it becomes dissonant, although the intervals c-e and e-g♯ are both consonant major thirds. The fact appears to be lost sight of that this chord is an impossibility in just intonation. It is impossible with a single note for g to secure a frequency which produces the relation of 5 : 8 with the lower tone, c, and at the same time the relation 4 : 5 with the middle note e. The chord in tempered intonation is dissonant because this discrepancy is heard. The author maintains that the tempered intervals are always heard as of just intonation. The tempered

[3] See the review of Stumpf's paper in the BULLETIN, 1912, 9, 117 ff.

[4] See the BULLETIN, 1911, 8, 95.

scale never completely sets aside the difference between the sharping of a note and the flatting of a note above it, even though the same key may serve for both. Hence concordance and discordance have their application in the sense of Riemann and Stumpf only in the tempered scale. In just intonation, concordance rests solely upon intervals whose tones fuse, and is therefore identical with consonance.

Peterson (10) reverts to his theory that combination tones are a product of disturbed superposition of vibrations in the liquids of the inner ear. So-called objective combination tones are also largely subjective in this sense. All arise from the primary tones and certainly not from other difference tones. He cites an experiment upon the summation tone produced by the ratio 2 : 3. The summation tone (5) might be occasioned by the primaries directly, or by the difference of their overtones, 10 : 15. If it were the former, the lowering of one of the primaries one vibration should produce one beat when the summation tone is sounded together with an auxiliary tone 5. If it be derived from the partials there should be five beats. The experiment demonstrated but one beat in such a case. The author finds no evidence that combination tones ever arise from partials, and is therefore inclined to regard them as originating solely in the primaries themselves. Wittmann (16) used a Forchhammer phonoscope with which the fluctuations of a flame set in vibration by tones from a series of Appunn pipes could be objectively determined. (Seashore's tonoscope[5] is a more elaborate instrument based on the same principles.) He was thus able to study the combination tones objectively produced by these means. He finds registered difference tones of the first order and of other orders, below the primaries, above them and between them. Experiments with interference, and the study of beats, which are also optically discernible, indicate the location of these secondary vibrations to be in the membrane of the capsule or in the flame itself, rather than in the tones of the producing instruments or in the air. It is also shown that these combination tones are dependent upon partial components, since they can be reduced or eliminated when the relevant partials are prevented through interference. K. Schaefer's attempt to locate subjective difference tones in the labyrinth is criticized adversely, while Ewald's "sound pictures" are noted as possessing many points of likeness to the flame vibration. It is not claimed

[5] See the BULLETIN, 1915, 12, 165.

that the flame picture is a true analysis of the sound stimuli. The author takes the ground that a physical explanation of such a phenomenon as that of combination tones must always prove inadequate. "Atomic" conceptions of psychological analyses, he thinks, are always erroneous. He is thus content to conclude that for a more or less definite clang sensation a more or less definite "sound picture" upon the basilar membrane suffices as correlate.

Bernfeld (4), aiming to point out the insufficiency of such tests of musical capacity as have been devised by Rupp,[6] discusses two cases of so-called unmusical persons in whom an apparent lack of interest and aversion was found to be coupled with some real musical ability. Psychoanalysis brought to light facts in the childhood of each person which accounted for their respective peculiarities. Heinitz (5) describes some experiments in musical reproduction performed on five persons of varied musical interest and ability. The attempt was made to indicate a method of experimental testing in which with different kinds of presentation—direct sounds and signs, musical notation, letters and numbers—the musical phrase should be reproduced by voice, by whistling, on the piano, violin and flute. The varying difficulties met with by the five subjects are described in detail, but the results proved too complicated to draw therefrom other than methodological conclusions.

Baley (1) studied the discriminability of different tones conducted simultaneously, but separately, to the two ears. A threshold as low as 6–7 vs. difference was demonstrated, though many different stages of judgment could be made out. With three tones, one of them common to both ears, the other two conducted separately to the two ears, a discrimination was possible with a difference of 4 vibrations. Peculiar spatial phenomena were reported in that the different tones were described as possessing differences in localization and "breadth." If the timbre of the tones differs, they are very readily discerned, even when at the same pitch. In a further investigation (2) various numbers of tones, up to ten, at intervals between the fourth and octave, were conducted separately to the two ears. With the practised observers of the Berlin laboratory few mistakes were made in judging correctly the tones of the right as compared with the tones of the left ear. This was true even when the observer was unaware which tones were to be given, or how many to each ear. Experiments with whole-tone intervals

[6] See the BULLETIN, 1915, 12, 167.

proved too difficult, largely because of the confusing presence of beats. The ability to localize seems to be general and immediate, without head movement. Though some errors were made, no indefinite localizations were reported.

Marage (8) notes some observations upon soldiers made deaf by the explosion of shells, etc., during battle. A large percentage of these cases showed improvement under treatment with the vowel siren.[7] Cases in which the middle ear is affected without external lesion suggest an analogy to certain forms of congenital deafness in which without parental defect the child is born deaf as a result of a shock which the mother sustained during the period of gestation. Bachrach (3) has attempted to test auditory acuity at different times of the day. The source of sound was a tone of 1,175 vs. produced by an organ pipe actuated by a wind chest. The sound was conducted to a telephone and its intensity measured by a microphone. The tones were received in a relatively quiet room. The results show no striking difference, save that the threshold appears to be slightly lowered towards 6 p.m. The author states in another connection that the observation room was less quiet at this hour than at others, owing to a greater amount of disturbance in the streets. We may therefore question if the somewhat greater effort required at this hour may not have been the real occasion for the increase in acuity, rather than the time of day or the general physiological conditions which attend it. Rich (12) has demonstrated that the frequency of vibrations in whistles and variators is altered appreciably with change of temperature. It varies, for instance, from .18 vs. for 100 vibration tones to 90 vs. for 50,000 vibration tones with an alteration of 1° C. in temperature. In calibrating such instruments temperature must accordingly be taken into account. To be comparable, the calibrations at different settings must be reduced to a standard temperature. The temperature at which the comparison is made need not be considered since both instruments vary to the same amount, but the results are valid only for the temperature at which the standard was calibrated unless a correction is made. In calibrating by Kundt's method the same holds true. Formulæ are given for performing the various corrections.

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AFFECTIVE PHENOMENA—DESCRIPTIVE AND THEORETICAL

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A few of the titles included in this report belong to a somewhat earlier period, but came to the attention of the writer too late to be noticed last year. The one work of outstanding importance in the year's publications in this field is Cannon's (2) admirably lucid account of his investigations on the bodily changes in pain, hunger, fear and rage. The results of these investigations, which deal with the diffused activities of the sympathetic nervous system, and especially with the excitement of the adrenals, are now fairly familiar. It is shown that in the phenomena studied there is increase