

The subjective analysis of musical tones

Every one who has attempted to analyse a musical sound by the unaided ear and has acquired some experience at such work will recognise the peculiar nature of the difficulties met with. The first stage is, of course, to learn to concentrate attention on the particular partial sound sought to be recognised, and this is greatly assisted by previously sounding a note of the same pitch and firmly fixing it in the memory, as recommended by Helmholtz in his *Sensations of Tone*. But even after one has acquired this habit of attention and has had years of practice and experience in acoustical work, the difficulty is only diminished and is not removed, as is shown by the fact that one may fail in some cases to distinguish a partial even if it be present, and that the use of a resonator is always a great advantage.

Helmholtz, in a chapter on the subject in his *Sensations of Tone*, has discussed the difficulties experienced in the subjective analysis of sound at great length, and considers them to be the result of a natural tendency to fix attention on the synthetic rather than on the analytic characters of a compound sensation. This explanation is psychological rather than physical. That it does not go to the root of the matter is shown by a fact which Helmholtz himself mentions, namely, that it is easier to hear the unevenly numbered partials than the evenly numbered ones; this suggests that we should seek for a physical and mechanical explanation rather than a psychological one. Further, it is possible to work under conditions which eliminate any explanation of the difficulty of subjective analysis as due to lack of attention. When the observer has carefully prepared himself, as indicated above, *immediately* before an observation is made and his faculty of attention is at its highest level, he succeeds in observing the partial only in certain cases and not in others. From this, one may reasonably infer that the power of discrimination is limited chiefly by circumstances depending on the physical character of the sound and of the auditory mechanism of the ear, rather than by factors dependent on nervous perception.

Some observations recently made by me indicate that the difficulty felt in the subjective analysis of musical tone arises mainly, if not entirely, from the phenomenon of the masking of pure tones of higher pitch by those of lower pitch discovered by A M Mayer (*Philos. Mag.*, 2, 500, 1876), whose results have more recently been confirmed and extended by R L Wegel and C E Lane (*Phys. Rev.*, 23, 266, 1924). Mayer discovered that sounds which are of considerable intensity when heard by themselves are liable to be weakened and even completely obliterated by graver sounds of sufficient force. The surprising character of this

phenomenon must be experienced to be fully appreciated. That the auditory masking of pure tones of high pitch by those of lower pitch is the explanation of the difficulty felt in the subjective analysis of musical tone may be shown by simple experiments with a monochord. The observer selects a particular partial, say the 5th, for examination. By gently touching a node of this partial with one finger, and plucking the string repeatedly with another finger, the attention of the ear is fixed on the pitch of this partial. The damping finger is then removed, and the string is plucked sharply at a point not far from the end to elicit the full series of partials. The observer listens carefully for the 5th partial for a second or so, and then touches the string exactly at its node so as to damp out all the partials lower than the 5th. The 5th partial then sings out, and though theoretically its intensity should have been the same, actually a large *apparent* increase of intensity is usually perceived. The sound of the 5th partial, previously masked by the sound of the graver partials, asserts itself with vehemence when they are removed.

A further confirmation of these ideas is furnished by studies of the manner in which the audibility of the upper partials alters when the absolute intensity of the sound or its quality is varied. These details are reserved for consideration in a forthcoming paper.

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