# *ON THE BEATS OF MISTUNED HARMONIC CONSONANCES.*

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The present Paper forms a continuation of one presented to the Association a short time ago. The subject was first put prominently before the Association in Mr. Spottiswoode's Paper "On Beats and Combination Tones." I subsequently showed some of the elementary experimental methods by means of which I attempted to deal with the questions raised. Since that time I have been placed in possession of much larger means for dealing with these questions. I propose to give to-day some account of the experiments and results I have since arrived at. The apparatus does not differ in principle from that formerly exhibited to you; and as the improvement in its efficiency is principally due to the introduction of a large bellows driven by a steam-engine, and the experiments themselves are not suitable for verification by an audience, I have not attempted to bring any of the apparatus here.

The practical question I have dealt with is, What are the actual sounds produced where consonances such as the octave, twelfth, fifteenth, &c., are slightly mistuned?

König has established that beats are heard in these cases, even when the notes employed are of great purity. He did not ascertain experimentally the nature of the beats—that is to say, what the notes were that varied in intensity; and did not prove to my satisfaction that the beats consisted of sounds other than musical notes. My efforts have been directed to supply this information by simply listening to the sounds, which were produced continuously and for a long time together.

## Experiments.

The engine and bellows* being adjusted to run continuously and quietly, I began to follow the course of König's experiments at the point where he deals with the combinations of the note C, following his form not accurately, but with such divergences as the difference in the apparatus suggested. After going through one or two sets in the way hereinafter described, I concentrated my attention on the analysis of beats,

* See *Philosophical Magazine*, October, 1880.

and specially on those of mistuned consonances of the form $h : 1$. It will be seen that after a time I entirely discarded resonators, having convinced myself that, so far as they were concerned, the beats of mistuned consonances, other than unisons, with the beat notes, difference and combination tones of all orders, and, in fact, all that I had to observe, were of a purely subjective nature, and were extinguished by resonators properly used, so far as my arrangements enabled me to perceive.

The mode in which I then pursued the observations on the beats of the mistuned consonances in question was, to adjust the notes and leave them sounding uniformly and continuously by the hour together. I then walked about the room, listening to the combination in all the various forms in which it presented itself; went outside and came in again, always keeping in view the question—what are the sounds that these beats consist of?

It is hard to believe that a question to which the answer is tolerably simple could be so difficult. Yet it is *very* difficult; it is one of the most difficult things I ever tried to do, to analyse these apparently complicated sounds into their elements by the ear alone. And when I state my results, I must not be taken to mean that the elements I mention are all that are present. In fact, one of the great difficulties is that there appear to be such a number of different sounds. Some of these are probably due to the imagination; others probably exist in small intensity. And I am satisfied that there still exists a large field of work in the further prosecution of this subject. But of the main result I have no doubt whatever, and that is:—

The beats of mistuned consonances of the form $h : 1$, where $h$ is nearly some whole number, consist mainly of variations of intensity of the lower note when the beats of the harmonics are eliminated.

I was prepared for this result in the case of the octave by my preliminary experiments (*Philosophical Magazine*, viii., p. 293), but did not proceed further till I had verified it and got my ear to perceive it readily under the new conditions, which required two or three days. I then got Mr. Parratt to come and listen. He was much disturbed by the trifling noises from the engine, belts, &c., and I blew the bellows myself for a time. Eventually he came to the same conclusion, but with an amount of hesitation and difficulty which showed me what an important element practice is in these observations.

I then started these observations with the mistuned twelfth, proceeding in the same way. I seemed to have the same difficulty as before in seizing the phenomenon; and when I eventually decided that these beats were also on the lower note, it was not in pursuance of any preconceived conclusion; for I had no idea at that time of the explanation I now give,

and certainly none of the presence of the second difference-tone, or its identity with one of König's beat notes.

Having got so far, I found the remaining verification, of the beats of the mistuned double octave, somewhat easier. These are also on the lower note when they are heard. I have never heard the beats of a mistuned consonance with any wider interval, with the notes I employ, as clear and unmistakable phenomena. Such beats may be discernible by more acute ears, or with notes of a more powerful quality, as they were discerned by König. But in such cases it will be incumbent on the observer to purge the beats from the suspicion of containing the beats of harmonics, as I have done.

Mr. Parratt subsequently convinced himself, as before, that the beats of the twelfth and double octave were all heard on the lower notes. I endeavoured, as far as possible, to make his observations independent by avoiding communicating my conclusions to him beforehand.

The elimination of the beats of the harmonics depends on the following considerations: The notes employed were examined, with and without resonators, as to the presence of harmonics. These, so far as they are objective, are readily detected with resonators. The beats of the harmonics, where they existed objectively, were also examined with resonators. After a little practice the sound of these beats became familiar enough to prevent their being confused with the beats of the low notes, and the two sets of beats could be observed independently.

The only harmonic that exists in these notes in sensible intensity is the twelfth; and this does not appear to originate in the same manner as the principal note. It is heard separately, as it were, and as if it had an independent origin. It seems probable that it arises in connection with the movements of the air about the mouthpiece, and not by resonance in the cavity of the bottle, like the principal note. At all events, whatever the cause may be, the effect is that the presence of this note is readily distinguished and allowed for, and there is no risk of its being mixed up with the rest of the phenomenon.

The notes employed are of moderate strength. It seems to me that the employment of notes of great power is open to the objection that it introduces all sorts of transformations depending on the greatness of the displacements; and in this respect alone König's procedure is open to considerable objection. I have confined myself to notes of moderate strength lying in those regions of the scale which are in ordinary use in music. It is phenomena thus presented that we really seek to understand; and I do not think that any thing is gained by pushing the investigation into those extreme regions where

it is possible and highly probable that the ordinary laws of hearing become modified.

The first series of notes examined in the above manner were the set of pairs:—

C : *c*
C : *g*
C : *c'*

C : *e'*
C : *g'*
C : *c''*

The beats produced by mistuning, when cleared of the harmonic beats, were heard only in the first three cases.

The second set of pairs was:—

*c* : *c'*
*c* : *g'*

*c* : *c''*
*c* : *e''*
*c* : *g''*

The beats in question were only heard in the first two cases.

The third set was:—

*c'* : *c''*

*c'* : *g''*
*c'* : *c'''*

The beats in question were only heard in the first case.

In the few experiments hitherto made with notes of higher pitch, the beats of mistuned consonances of the form $h : 1$ were not heard when the beats of the harmonics were eliminated, unless the power of the notes was very greatly increased. In this region, however, König's own observations are very full and complete.

We notice at once the decrease in the range within which the phenomena are heard as we rise in the scale. This is at once accounted for on the hypothesis of transformation, by the consideration that the displacements to which the higher notes give rise are much smaller than those of the lower notes. If we knew the law of the decrease, we might obtain a relation between the coefficients of the different terms in the expression for the character of the transforming mechanism. König has attempted to formulate a law of decrease; and I have done so on a previous occasion; but this part of the subject is as yet too hypothetical to admit of satisfactory treatment.

## Objective and Subjective Phenomena.

### *Resonators.*

On beginning work I endeavoured, in the first instance, to ascertain what evidence resonators are capable of furnishing as to the nature of binary combinations. There are a few points in connection with their use which require attention.

I have always found difficulty in getting results of a definite character with resonators, whether applied directly to one ear in the manner described by Helmholtz, or connected with one ear by means of a flexible tube, as practised by others. There are three difficulties which occur: (1) pressing the tube or orifice into the ear is apt to close the inner passage of that organ; (2) if the tube or orifice is applied lightly, it does not completely occupy the passage, and external sound comes past it into the ear; and (3) it is impossible so to stop the unused ear as to prevent the external impressions from arriving there and causing confusion.

The method I ultimately adopted was as follows: A copper tube of $\frac{1}{2}$-inch diameter was bent into a semicircle, the diameter of which was nearly 8 inches. At the middle of the tube, and at right angles to its plane, another copper tube was inserted, 2 inches long, which tapered down to an orifice $\frac{1}{8}$-inch in diameter; this served to communicate with the interior of a resonator by means of a small flexible tube. The extremities of the semicircle were turned inwards and upwards; and into them two brass tubes were inserted, $\frac{1}{4}$-inch long and $\frac{1}{8}$-inch in internal diameter, screwed on the outside. Over each of these was fitted a brass tube, screwed inside, carrying an ivory nipple, such as is used for ear-trumpets. I generally covered the nipple with a couple of thicknesses of thin india-rubber tube.

When used, the semicircle is passed under the chin with the resonator attachment projecting in front. The nipples are at first screwed back as far as possible, brought opposite the orifices of the ears, and then screwed forward until they enter the ears. They are then gradually advanced until the passages are closed to external sounds. Something depends on the way the tube is held. With practice it is possible to hold it so that the passages are closed to external sounds without screwing the nipples in very tight. When they are screwed very tight it is rather unpleasant, and even painful. But it is necessary constantly to be on one's guard against being deceived by an occasional entrance of external sounds if the nipples are not quite tight. This instrument was made for

me some time ago by Mr. Walters, of Moorgate Street; it has already been described ("Proceedings of the Musical Association, 1879-80," p. 18).

The resonators I employ are bottles fitted with corks having apertures of various sizes. I sometimes tune them with water, in the same way as the bottle-notes; sometimes I insert tubes into the apertures to lower the pitch. A bit of small glass tubing passed through the cork is connected by an india-rubber tube with the above-described ear-piece.

By means of these arrangements I some time ago examined the nature of the ordinary first difference tone, and convinced myself that it is not capable of exciting a resonator (*loc. cit.* p. 20). This conclusion has also been arrived at by others.* In short, the difference tone of Helmholtz, or first beat note of König, as ordinarily heard, is not objective in its character. It is therefore subjective. (See Helmholtz, "Tonempfindungen," fourth edition, p. 259.) In making the experiment of listening for the difference tone through a resonator, it is necessary to be careful that the ears are both closed to external sounds; otherwise the external notes will penetrate through, the difference tone will appear, and the completeness of the cut-off effected by the resonator will be entirely lost.

When beginning the regular course of experiments according to the general outline of König's work, I was careful, in the first instance, to examine the various masses of sound presented, with resonators arranged as above indicated. In examining, for instance, the intervals made by the note C with the various notes of the octave above it (up to *c*), I first fixed the resonator at some one pitch, and then ran the movable note up through the octave. Then, as this did not seem a good process for analysis, I set the mistuned octave beating, or any other combination it was desired to examine, and ran the pitch of the resonator up and down with water to see if anything could be detected. And here I came across an observation that puzzled me for some time.

Suppose the mistuned octave C : *c* was sounding, and I examined the lower note with the resonator: sometimes it appeared loud and steady, at other times as if beating powerfully. On removing the resonator attachment from the ear, the lower note was always heard to beat powerfully. The explanation was simple. When the nipples of the resonator attachment fitted tightly into the ears, nothing reached the ear but the uniform vibrations of the resonator sounding C. But if there was the slightest looseness between the nipple and the passage of either ear, the second note (*c*) of the combination got in, and gave rise to the subjective difference tone (first beat note of König), by interference of which with

* Preyer, "Akustische Untersuchungen," p. 13.

the C I explain the beats on that note. *These beats are therefore subjective.*

A considerable number of combinations, including examples of the principal forms of beat, rattle, or roll, were examined in this way; and when the precautions above indicated were attended to, the results were in all cases to negative the objective existence of all forms of beats and beat notes or difference tones, except the beats which arise from the interference of approximate unisons, which beats arise from both notes acting on the resonator simultaneously. This of course includes the beats produced by objective harmonics.

## Course of General Experiments.

The following is the detailed examination of the combinations of the note C, made in a continuous and connected manner. The results have a general correspondence with those of König. The numerous rattles and rolls of beats mentioned were not further analysed for the most part: the analysis of these is very difficult; and, as has been already stated, a separate investigation is required in every such case. Some attention was devoted to beats of the mistuned fifth, both in the case mentioned and in others; but no final result was arrived at. In two different cases of mistuned fifths (2 : 3, nearly), I had a strong impression that the note 7 formed an important part of the beat. This would be a summation-tone of the second order, thus $2 \times 2 + 3$. I am confident that it did not arise from harmonics.

These experiments were made after some experience had been gained:—

$C_1$ : C.
Rattle up to—
C : F.
Slow beats up to—
C : G, smooth fifth. Roll only perceptible when the ear is held close to the two sources of sound.
——, 5 beats sharp. Perception of pitch very difficult in this part of the scale. There is a heavy beat like a knock, which appears to affect the whole mass of sound.* The low beat of $C_1$ is only distinguishable with difficulty, or hardly at all.
(Another occasion.) Mr. Parratt describes the fifth C : G, beating slowly, as consisting of E♭ and $C_1$ in addition to the primary notes; the mass of the beat is at

* I take this entry to show that no progress had been made with the resolution of the phenomenon into its elements.

least partly on E♭. I do not hear the E♭, but seem to hear the note E.

(Another occasion.) Mr. Parratt is clear that the beat of the mistuned fifth C : G is on $C_1$ alone; but he still hears the E♭ in the mass of tone. I seem to hear the beats both on C and $C_1$; but I have a difficulty in separating the octaves in this deep pitch.

——, 8 beats sharp. Clear rattle, with suspicion of roll beside it.

——, 10 beats sharp. Beats just distinguishable. Roll.

C : B♭. Rattle emerges.

Below—

C : *c*, 8 beats can be counted.

——, 4 beats very distinct. Consist entirely of variation of intensity of lower note. This effect is very clear and remarkable.

——, a very slow beat flat. Here it was easy to recognise the effect of the shift of phase in the apparent great increase of volume of the lower note at one period of the change. The upper note was not perceptibly affected.

C : *c*. A slight rich roll with smooth tone. The production of the roll depends a good deal on the phase, as is seen by leading up to *c* with a very slow beat.

The twelfth of the C was plainly distinguishable, but it appeared to keep separate from the mass of tone; it was perfectly steady and unaffected by combination with *c*.

C : *c*, 2 beats sharp. Phenomena undistinguishable from 2 beats below.

——, 4 beats sharp. Perhaps a little less roll in the strong part of the beat.

——, 8 beats sharp. The mass of the beats is of pitch near C; but the exact pitch is very difficult to distinguish. It is a deep heavy rattle, quite distinct in pitch from the upper note.

C : *e*. If there is any slow beat in passing through this, it is very difficult to distinguish. I am inclined to negative it.

C : *f*♯. Roll.

Slow beats up to—

C : *g*. These beats consist of alternations of intensity of C. They are more difficult to count than those of C : *c*. I counted them at 5 below.

——. Slow beats above.

C : *b*♭. Rattle, turning into beats easily counted at 4 below *c'*. These beats also consist of variations of intensity of the lower note.

C : *c'*. The beats above *c'* were also counted at 4 above, while the engine was going, without difficulty.

Above this, in the neighbourhood of the binary consonances C : $e'$ &c., I have never been able to obtain slow beats in such a way that they could be readily perceived (even without the engine) or certainly counted.

The mode adopted to examine cases in which the beats could not be perceived was to introduce a third note, such as $c'$, which gave beats with the C, and tune it true. Then any note, such as $e'$ or $g'$, could be readily tuned so that the whole three notes gave 1, 2, 3, or 4 beats. When this had been done, the intermediate note $c'$ was removed. If the pair examined was capable of giving beats at all, they should then have been audible.

The details of the above course furnish no new results; I have not, therefore, thought it worth while to give similar courses for other sets of notes. Those results which are worthy of mention have been already stated.

## Theory of the Beats of Mistuned Consonances of the form $h$ : 1.

Let $n$ be the frequency of the lowest note, $m$ the number of beats per second. Then the mistuned octave is $n : 2n \pm m$; the mistuned twelfth is $n : 3n \pm m$; and so on.

Beats of the mistuned octave:—

$$n : 2n \pm m.$$

Number of beats $= m$.

$m$ variations of intensity of the lower note ($n$) are produced by interference of notes $n$ and $n \pm m$; and $n \pm m$ is the first combination tone (difference tone of form $p - q$) of the primaries $n$ and $2n \pm m$.

This rests chiefly on the observation that the beats, when the octave harmonic is eliminated, consist entirely of variations of intensity of the lower note.

The existence of the first combination tone in question ($p - q$) is well known. It is easily demonstrated in the neighbouring case of intervals not far removed from the fifth, when the beats of the first two combination tones are specially prominent (secondary beats of König).

Beats of the mistuned twelfth:—

$$n : 3n \pm m.$$

Number of beats $= m$.

$m$ variations of intensity of the lower note ($n$) are produced by interference of notes $n$ and $n \pm m$. And $n \pm m$ is the second combination tone (difference tone of form $2p - q$) of the primaries $n$ and $3n \pm m$.

This rests also chiefly on the observation that the beats,

when the third partials are eliminated, consist entirely of variations of intensity of the lower note.

The existence of the second combination tone in question $(2p - q)$ is demonstrated in many cases by König. It is easily heard in the case of intervals near the octave high in the scale. It is also easily detected by the secondary beats which it forms with the first combination tone in the case of intervals near the fifth—also less easily by the secondary beats which it forms with the third combination tone in intervals near 2 : 5, at which point the second and third combination tones coincide.

Beats of the mistuned fifteenth or double octave :—

$$n : 4n \pm m.$$

Number of beats $= m$.

$m$ variations of intensity of the lower note ($n$) are produced by interference of notes $n$ and $n \pm m$. And $n \pm m$ is the third combination tone (difference tone of form $3p - q$) of the primaries $n$ and $4n \pm m$.

This rests also chiefly on the observation that the beats, when the fourth partials are eliminated, consist entirely of variations of intensity of the lower note.

The existence of the third combination tone in question $(3p - q)$ is demonstrated in many cases by König. It is heard not so easily as the lower combination tones, in the case of intervals near the twelfth high in the scale. It is also less easily detected by the secondary beats which it forms with the second combination tone in the case of intervals near 2 : 5, at which point the second and third combination tones coincide —also, much less easily, by the secondary beats which it forms with the fourth combination tone in the case of intervals near 2 : 7, at which point the third and fourth combination tones coincide.

Beats of the mistuned tierce (two octaves and a major third):—

$$n : 5n \pm m.$$

These beats are much less easily detected in pure notes of the ordinary strength than any of the foregoing. They are recorded by König; but I have never heard them clearly. As it is certain that König's notes were not perfectly pure, and he does not analyse the beats, we cannot tell whether the variations of the lower note were produced in his experiments. If they were, they are to be accounted for in a similar manner.

Number of beats $= m$.

$m$ variations of intensity of lower note ($n$) are produced by interference of notes $n$ and $n \pm m$. And $n \pm m$ is the fourth combination-tone (difference-tone of form $4p - q$) of the primaries $n$ and $5n \pm m$.

The existence of the fourth combination-tone in question $(4p-q)$ is demonstrated directly by König in the case of intervals near the double octave $c''' : c^{v}$. It is also less easily detected by the secondary beat which it forms with the third combination tone in the case of intervals near 2 : 7, at which point the third and fourth combination tones coincide.

Beats of the mistuned consonance of the nineteenth are recorded by König :—

$$n : 6n \pm m.$$

Number of beats $= m$.

$m$ variations of intensity of lower note ($n$) might be produced by interference of $n$ and $n \pm m$. And $n \pm m$ is the fifth combination tone (difference tone of form $5p - q$) of the primaries $n$ and $6n \pm m$.

The existence of the fifth combination tone in question $(5p-q)$ is not anywhere directly demonstrated. Secondary beats, which might be produced by its interference with the fourth combination tone, are recorded by König in the neighbourhood of the interval $c : d''$.

Beats of the mistuned consonance 1 : 7 are recorded by König. These might be produced by a sixth combination-tone (difference tone of form $6p-q$) of the primaries $n$ and $7n \pm m$.

Beats of the mistuned consonance 1 : 8 are recorded. These might be produced by a seventh combination tone (difference tone of form $7p - q$) of the primaries $8n \pm m$.

As far as my own experience goes, however, I have no direct and palpable evidence of beats of mistuned consonances higher than 1 : 4, or of the existence of combination tones higher than the third $(3p - q)$ in recognisable intensity. Up to this point the phenomena are quite clear; and there is no possible doubt as to their nature.

But in considering these limited results it must be remembered: (1) that I have restricted myself to notes of very moderate intensity, so that the phenomena might correspond as nearly as possible to those which are presented to our ears in practice; and (2) that, although I was unable to get rid entirely of the presence of upper partials in all cases, yet the phenomena were subjected to a careful and prolonged analysis by listening under varied conditions, until the effect of the upper partials could be separated out and eliminated with certainty. And we have at all events no security that these upper partials did not give rise to many of König's results; indeed, it is almost certain that they must have entered into those results.

## Conclusions.

There can be no doubt that the beat notes of König are the same as the higher difference tones of Helmholtz; that they

really exist; and that they are the cause of the beats which are the subject of this paper. There can be no doubt also that these beat notes or higher difference tones are capable of originating directly from the primaries without the intervention of the lower difference tones. The theory of this question is somewhat abstruse, and is unsuitable for a communication to the Musical Association. I have attempted to deal with it elsewhere.* This removes the objection raised by König and others to the theory of difference tones as commonly stated.

The actual beats heard in consonances such as the octave, twelfth, and fifteenth, when cleared of the beats of harmonics, consist of variations of intensity of the lower note of the combination. These beats are caused by the interference of the lower note of the combination in question with the beat notes of König, or higher difference tones of Helmholtz, in the manner already detailed.

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## DISCUSSION.

Mr. A. J. ELLIS, F.R.S.—I wish I had had the opportunity of reading Mr. Bosanquet's printed paper on this subject, so that I might have known some of its details. At present I can only express my great gratification that this very difficult subject is being investigated by so competent an observer, and that he has got results of very considerable acoustical importance, which show that these beats are variations of intensity, and not, as was supposed, beats of the upper partial tones, or anything of that kind. I suppose your theory of the way in which they are produced is published?

Mr. BOSANQUET.—It was read before the Physical Society a year ago, and was published in their "Proceedings" about the middle of this year.

Mr. ELLIS.—It is a mathematical theory?

Mr. BOSANQUET.—Yes.

Mr. ELLIS.—One is often obliged to leave out a great deal of detail to get it into mathematical form, as Helmholtz has done in a great many cases, which is always more or less hazardous. May I ask if you are able to attack the whole problem, or are you only able to attack it when reduced into a very abstract form?

Mr. BOSANQUET.—To attack the whole problem would need an intimate knowledge of the whole framework of the ear. One is obliged to frame certain hypotheses.

Mr. ELLIS.—Another point of great importance is that the

* *Philosophical Magazine*, 1881. Series v., vol. xi., p. 492.

beats are subjective, not objective. I consider that of very great importance to establish. I did not quite collect from your observations whether you got that result with regard to the composition of the difference tones which König made out to consist of particular beats.

Mr. BOSANQUET.—I consider those are prior to the beats; that the so-called beat tones are really the difference tones of different orders, and it is by their dissonance with other notes that the beats appear. It so happens that it does not matter whether you reckon forward or backward; you come to the same thing.

Mr. ELLIS.—I think it will rather revolutionise our ideas in many respects of the theories of the beats of dissonances, because when you have very compound tones beating together, such as these reed tones, of course you have only a succession of simple tones which are beating together, and therefore it is only a greater complication than this simple one; and I think it is rather opening out a new view of the subject, which I am very glad has been opened out by a person who is capable of doing it in a scientific manner, like Mr. Bosanquet. In König's paper, which was brought forward at this Association by Mr. Spottiswoode, who translated it, there were a great many gaps left to be explained, and it was not at all clear what the beats were which were produced. I think the acoustical world may be very much indebted to Mr. Bosanquet for his observations on this subject, especially for his having succeeded in bringing out something like a mathematical theory of the subject.

Mr. BLAIKLEY.—I should like to join in thanking Mr. Bosanquet for having taken up this subject and working it out so thoroughly. It is a matter of very great interest, and, owing to the great difficulty different observers have of really judging what they do hear, it has certainly become confused. Shortly after the time that Mr. Spottiswoode read his paper here, I had an opportunity in Paris of seeing Mr. König and speaking with him on his experiments; and my own opinion was rather different to his as regards the extent of purity that existed in the tone of his two large forks. He took a pair of forks, a mistuned octave, and there was a beating note heard. He said to me, "You hear distinctly—there can be no doubt about it—that the beating note is the lower one." I could not say that I heard it so. I heard distinctly the octave beating, and I said, "It is the upper fork beating with the second partial of the lower fork." He said, "The second partial does not exist in sufficient strength to be heard." It is just a question of the difficulty two observers may have, both competent to hear these notes, to observe exactly what does take place. I am sure, when we come to hear Mr. Bosanquet's paper fully, we shall be all much interested in informing our-

selves of the methods he has taken to eliminate all chance of error as regards what is actually observed in the matter.

Mr. BOSANQUET.—The only indications given in any of Mr. König's papers as to the nature of the notes that vary in intensity is in one place where he is speaking of the beats of a mistuned octave, where he says distinctly that the effect is that lower and higher notes appear alternately. I have never had the opportunity of experimenting with any good example of a continuous-sounding fork, and I have always thought, in the small observations I have been able to make with forks that are only struck or bowed, that his description appeared to be very accurate, as far as I could judge. It always seemed to me that there was some wave in the octave as well as in the lower note.

Mr. BLAIKLEY.—In those cases where the forks were only bowed or struck, his strong point was that the beat was on the lower fork only, as I understand. I have no doubt, now, it was both the lower fork and the octave. What was beating to me was the octave, and I could not get that out of my head, so that I did not observe the beat, if there were any, on the lower fork.

The Rev. T. HELMORE.—Is it not true that different human ears hear very differently?

Mr. BOSANQUET.—I think very possibly, but there is scarcely any instance to my knowledge where any definite difference that would depend on the mechanism of the ear has been satisfactorily proved. There is one small difference, I believe. I have succeeded in proving a difference in what would be called a damping power between Mr. Parratt's ear and my own—the gentleman with whom I have made a great many observations. But the difference is so small that it might possibly be due to errors of observation. It cannot be said that there is anything approaching a mechanical difference between the ears of different people in the broad sense, that is at all demonstrated. Of course in the nerve power of the ear there are differences of an enormous character, but that is quite a different thing to the mechanical constitution.

The Rev. T. HELMORE.—A friend of mine was exceedingly fond of music, and had a good ear generally, but he could not hear the chirping of crickets or grasshoppers when I could hear them very distinctly.

Mr. BOSANQUET.—In that sense there is a difference. Those differences may be due to the absence of the top of the mechanism of the ear. I was thinking of the ordinary region of the scale.

The CHAIRMAN.—Ladies and Gentlemen, I think I may have the privilege of offering to Mr. Bosanquet, and to the other gentlemen who have favoured us with their remarks on this subject, your cordial thanks. It is of great consequence

to us musicians that persons with also a capacity for music are now devoting attention to the scientific elements of which music is composed. It has been in former times much to be regretted that when physicists directed their care to musical subjects they had not a practical knowledge of music to bring to bear on the investigation. So while musicians were striving in one direction, and men of science were working in another, the results of their labours were not united, because they did not come together on sympathetic grounds. Very large advances have been made in the investigation on the scientific side of music in recent years, and there can be very little question that practical music itself, and the theory of harmony more particularly even than the structure of instruments, will derive some light from all the investigations which are being made. The point which is brought before us this afternoon appears to be urgent, and one which will be of great importance to the future attention of persons who may thoroughly investigate it. I believe that beyond what is at present obvious to our general capacity to understand, there is a deeplying truth in what is put forward, and that it will be of very great consequence to us all to come to a clear comprehension of it. It is a very interesting point which was just mooted, as to the different powers of different ears. I could cite many instances of persons who could hear lower or higher notes than others were able to detect, and that bears also upon the question of the possibility that smaller animals can hear acuter sounds, and that the larger animals can hear graver sounds than our ears can detect. Another very important point for reflection is as to how far one's own inclinations are concerned in the supposed fixity of the sound that is offered to the attention, and how far subjectivity and objectivity are to be taken into account in the analysis of a given sound. That it has not escaped the care of Mr. Bosanquet and his previous ally in his observations, Mr. Parratt, helps very much to give us confidence in the remarks that have been brought before us, and for my part I tender to the reader of the paper my best thanks, in which I hope you will all concur.

Mr. BOSANQUET then proposed a vote of thanks to the Chairman, which was carried unanimously.