nitude. It thus appears likely that at least one of the first two distributions is not Gaussian.

Summarizing, we may say that the mean absolute magnitudes of the K0 and M giants are probably not far from $+0^M.7$ and $-0^M.2$, respectively. The agreement between these values and those derived from considerations of proper motion and parallactic motion strengthens the previous conclusion that the trigonometric parallaxes, at least those of Allegheny, are not affected by large systematic errors.

[1] van Rhijn, P., *Publ. Kapt. Astr. Lab., Groningen*, No. 34, 1923 (1–80).

MEASUREMENTS ON THE EXPRESSION OF EMOTION IN MUSIC

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All musical expression of emotion is conveyed in terms of pitch, intensity, duration, and extensity, which are the four elemental attributes of all sound. In their compound forms these attributes furnish us *timbre*, which on the basis of harmonic analysis is a complex of pitches and accounts for all the so-called qualities of sound from the pure tone to the purling of the brook; *rhythm*, which is a combination of intensity and duration effects in sound patterns, with all related time variants, such as tempo, staccato, and glide; *consonance*, which is the foundation for all phenomena of harmony and melody; and *volume*, which is the principal spatial and intensive aspect of sound.

This classification is probably complete, and we now have instruments and technique in the laboratory for the measurement of all these factors in terms of the sound wave; because the frequency of waves determines pitch, amplitude determines intensity, duration of the single wave determines extensity, and the form of the wave determines timbre. Thus, by combining measurements of frequency, amplitude, duration, and form of sound waves, we are enabled to take adequate account of every factor that enters into sound.

Now, when we stop to realize the situation, we find that everything in the way of musical expression that the singer conveys to the listener is conveyed in terms of the sound wave: when we eliminate sight and other senses which are merely accessory, there is only one avenue that can convey the musical message and that is the sound wave. The sound waves may be intercepted, recorded, measured, and analyzed by instruments

of precision so that we secure a detailed and faithful objective record of what the musician conveyed through this medium. Thus we can isolate, describe, and classify all types of variants, from the cold, non-emotional and mechanical production of tones to the most highly artistic expression of aesthetic emotion. This claim may sound crass and extravagant in the face of all our traditional regard for artistic expression of emotion as something elusive, indefinable, and intangible, and the general inability of experimental psychology to cope with the problem up to the present time. But let us take some examples showing how it works out.

One of the most characteristic evidences of the tender emotion effectively expressed in singing is the vibrato. There is no end of confusion among musicians as to what the vibrato is, its desirability, how it may be acquired or eliminated, what it really means, and the factors that control it. It is, however, universally admitted that the vibrato represents an attempt to express emotion musically.

The study of the vibrato was first taken up by Dr. Schoen in our Iowa laboratory and is now continued by Mr. Kwalwasser. Recording and analyzing the sound waves to determine what constitutes the vibrato, we find that it is a synchronous pitch and intensity pulsation averaging about six oscillations per second. A particular vibrato can therefore be expressed adequately in terms of the three variables, pitch, intensity, and time; i.e., the range of pitch fluctuation, the range of intensity fluctuation, and the rate, regularity, and form of these two synchronous fluctuations. Within these three factors we shall then find all the possible variants of the emotional expression of the vibrato. Thus, for different singers, or for a given singer at different times, it may be primarily pitch pulsation; or primarily intensity pulsation; and regarding these as constant, the rate, the regularity, and the degree of approximation toward a sine curve in the pulsation are variables descriptive of emotional quality.

With all these factors under control, we may now take great singers and study the personal characteristic of each singer and the laws for the expression of different kinds of emotion through the vibrato. For this purpose phonograph records are of inestimable value because they produce the vibrato faithfully and thus furnish fair examples of the singing in vibrato when it was not known to the singer that this was a factor under observation. With the objective facts in hand, we only correlate the vibrato with principles of neural discharge showing the relation of artistic expression in music to nervous instability in terms of neurological concepts, for a tender emotion is a condition of nervous instability. We may here investigate the relation of a feigned emotion or a genuine emotion, according as the music was or was not actually expressed emotionally.

Another attribute of emotional expression is timbre. This is measured in terms of the form of the sound wave which may be analyzed into its

harmonic components by mechanical instruments and the harmonic elements may be combined into the complex wave form. Our question here resolves itself into the determination of types of the beautiful in timbre. These range, for various purposes, from the pure tone, as represented in the sine curve, to the richest tone reproducible, with significant peaks and valleys of affective tone. Types of beauty and ugliness may be traced and expressed in terms of the number and relative prominence of overtones.

Again, much of the emotional effect is expressed in terms of time, not only in rhythm and tempo and the various forms of acceleration or retardation, accentuation or holding of notes, but even more effectively in the form of attack and the release of tones.

These illustrations must suffice to show that everything in the nature of musical emotion that the musician conveys to the listener can be recorded, measured, repeated, and controlled for experimental purposes; and that thus we have at hand an approach which is extraordinarily promising for the scientific study of the expression of musical emotion.

It is, perhaps, superfluous to point out that in such study we are not concerned with the cause or character of the emotion of the musician except in so far as it is necessary for the understanding of what emotion is expressed. In the same manner, we are not concerned with the experience of emotion on the part of the listener except in so far as it is necessary for the understanding of what is actually transmitted in the tonal message.

The objective study of emotion has been approached profitably but remotely from the physiological point of view, as in the work on the glands of internal secretion and the autonomic system in general, as well as certain reactions through the skeletal muscles; but the bulk of our common knowledge of emotional expression rests upon crude observations of gross behavior in emotional situations, as in the study of animal behavior. The method of which I am speaking gives a new approach to a rigid and analytical behavioristic study of emotion in musical expression which will not only aid in the scientific analysis of musical emotion, but should throw valuable light on the fundamental laws of all emotional expression. There is nothing radically new in the technique; but, as in many another advance in science, the new step consists in realizing a new application of means already at hand.

Incidentally, it may be noted that this method may be used in retracing the emotional elements of primitive music as recorded by the phonograph, as many of the emotional features of musical expression are faithfully reproduced in such records. Heretofore we have had no objective method of evaluating this important element; a permanent graphic enlargement of the sound waves may be made from the fresh record, thus preventing deterioration and making the optical record available for detailed examination and measurement.