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Music, Emotion and Autonomic Function

It has been known for many years that perceptual and emotional musical experiences lead to changes in blood pressure, pulse rate, respiration, the psycho-galvanic reflex and other autonomic functions. These autonomic changes represent the vegetative reflections of psychological processes. The nature and extent of such somatic changes, as well as the determining factors, have been accurately analysed by the use of modern recording techniques.

Our extensive and detailed investigations have led us to the following conclusions.

1. The autonomic response depends on (a) its reactivity, that is the lability or stability of the autonomic regulatory processes. This in turn is influenced by constitution (predisposition), age, sex, mode of life, physical fitness, general state of health, or such temporary factors as fatigue, drinking alcohol or coffee, and so on; (b) emotional reactivity; and (c) attitudes toward music, the importance of music in the subject's life, and also upon his immediate attitude towards the piece of music presented in the test situation.

The subject's current attitude can be disturbed by the setting of the test (the laboratory and the use of apparatus), but individual associative ties with the piece of music may also lead to spurious results. In this case such changes as are observed may be due to an event which the subject associates with the music rather than to the music itself. For these reasons subjects must be familiar with the laboratory setting and, furthermore, pieces of music unknown to them should preferably be presented with subsequent exploration of their attitudes, personal impressions resulting from the music and associations with other events.

Figure 1a shows the marked autonomic changes which occurred when the subject was completely involved in the piece of music which was being presented. When the same piece of music is critically analysed by the same subject, that is, without emotional involvement, these autonomic changes are not demonstrable (Figure 1b). Nevertheless, the enjoyment of music may be just as profound. In individuals with a musical background and

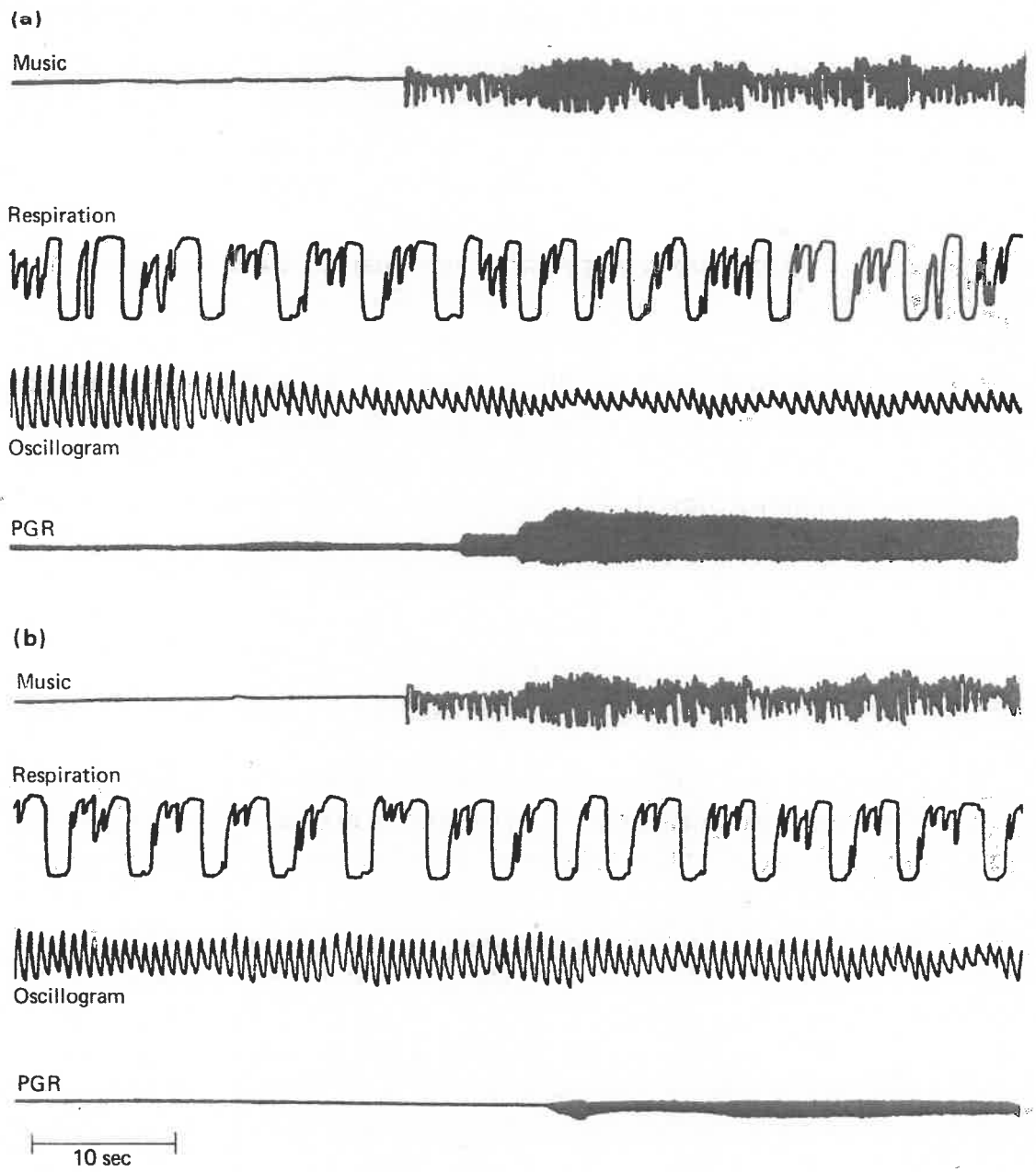

Figure 1 Vegetative Diagram. (a) with and (b) without emotional involvement.

education the aesthetics of a piece of music may be experienced even more pleasurably by an objective rather than a subjective approach.

Music may lead to an autonomic reaction although the sounds are not consciously perceived, for example, in sleep, with "background" music such as incidental music for plays and films, and "functional" music which is provided in places like factories, elevators and milking parlours.

The nature and extent of the autonomic changes also depend upon (d) the kind of music which is presented. The nature of a subject's perception

of music depends upon his prevailing attitude, indifferent or emotional, towards the music, his manner of listening and on his current mood, *inter alia*. The reproduction of music should be technically impeccable and the sound volume must be adjusted for each subject. Arbitrary changes in the sound volume made by the person who is testing may change the autonomic diagram.

2. The system of maximal response (comparing cardiovascular with respiratory and galvanic skin responses) depends mainly on (a) the character of the subject's individual autonomic response. In some persons psychological stimuli such as stress give rise to respiratory changes predominantly, whereas in others marked circulatory or galvanic skin response alterations are elicited by the same type of stimuli; (b) the type of music which is being played. There are pieces of music such as dance music or orchestral marches which produce predominantly motor responses, while other types of music are more liable to elicit respiratory or cardiovascular responses. The resulting autonomic diagram is based upon the effectiveness of factors (a) and (b) and reflects both the reactivity of a certain system of organs and the "organotropism" of the piece of music which has been presented.

3. There are marked differences in reactivity between the performer and listener. As to the former, reactions due to physical strain must be separated from those which reflect the emotional accompaniment. The extent of the emotionally induced changes is often surprisingly great. During the act of conducting, for instance, the highest pulse frequencies are not reached at moments of greatest physical effort but occur at passages producing the greatest emotional response. Thus, the maximum increase of pulse frequency telemetrically recorded from Herbert von Karajan while conducting the Leonora Overture No. 3 was obtained during those passages with the greatest emotional impact upon the conductor. These were the same passages which the conductor singled out in a subsequent conversation as being the ones he found most profoundly touching. At these moments the pulse rate increased for a short while to twice the level of the initial value (Figure 2a). When shortly afterwards the tape of the performance was played back to von Karajan and a further pulse record made there was evidence of considerable qualitative parallelism between both tracings, but the changes were much greater while he was conducting.

Our data suggest that the artist's emotional concomitants may be even more important than artistic perfection as far as success and acceptance by the public are concerned.

In this context it might be interesting to present further data on von

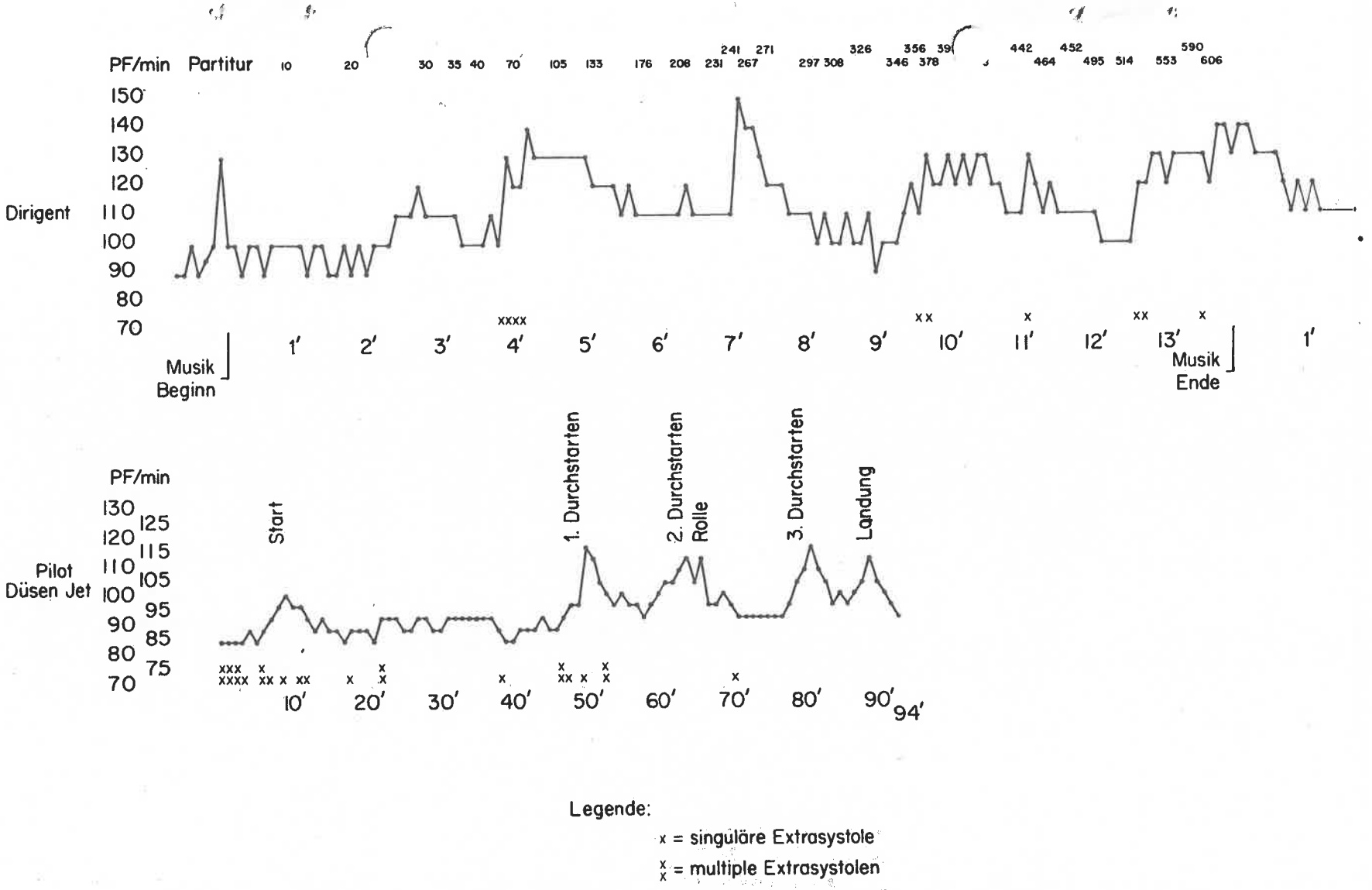

Figure 2 Pulse rate (Herbert von Karajan). (a) while conducting (b) while piloting a jet aircraft.

Karajan's pulse rate in a variety of situations and in special circumstances. Yoga exercises have enabled him to reduce his pulse rate by 10 to 15 beats a minute within a very short time. We also had the opportunity of recording his pulse rate while he was piloting his own jet aircraft. He had been asked to carry out several special tasks: three times he had to execute a landing manoeuvre consisting of almost touching the runway and then making an immediate steep ascent. This was associated with an increase of pulse rate during the approach to the runway, but the response was clearly smaller than the music-induced effects (Figure 2b). It is interesting to note that the tachycardic response is marked whenever this response-type seems to be desirable but small when it could affect the required task adversely.

As already mentioned, active performance of music gives rise to stronger autonomic responses. In contrast with the responses to music heard, these powerful reactions cannot be suppressed by deliberate detachment.

4. Autonomic reactions impinging on various systems: (a) Cardiovascular system. The pulse rate is technically easy to record among the various parameters and it is also quite a sensitive indicator. In general increases occur in response to music, and even in short lasting tests a decrease of pulse rate below the initial level is seldom detected. An increase of pulse rate may be an expression of pleasure and approval, but also of displeasure and disapproval.

Pulse tracings are fairly consistent when the same piece of music is played several times to the same subject. There may be repeated episodes of premature beats at one or two special points. Syncopated rhythms are particularly capable of producing such extra-systoles, as might be expected. It is sometimes possible to "drive" the pulse rate by dynamic changes in volume such as the crescendo and decrescendo of a rolling drum beat. The same phenomenon can be obtained by a change in rhythm. Hence an acceleration may lead to tachycardic responses and a deceleration of rhythm to a slowdown of the pulse rate (Figure 3). In some subjects synchrony of activity between external "pacemaker" and pulse rate are noted within certain limits.

Relaxing and pleasure-charged passages, and sometimes the ending of a piece of music, may give rise to changes in pulse rate synchronously with the respiratory rhythm. Third order fluctuations are also noted, probably due to changes in the central vasomotor tone.

In subjects with some degree of cardiac disease marked qualitative electrocardiographic changes may occur as the result of music, like those seen with physical stress. In cases of purely functional cardiac disturbances such changes may be seen with music only and not as the result of muscular stress.

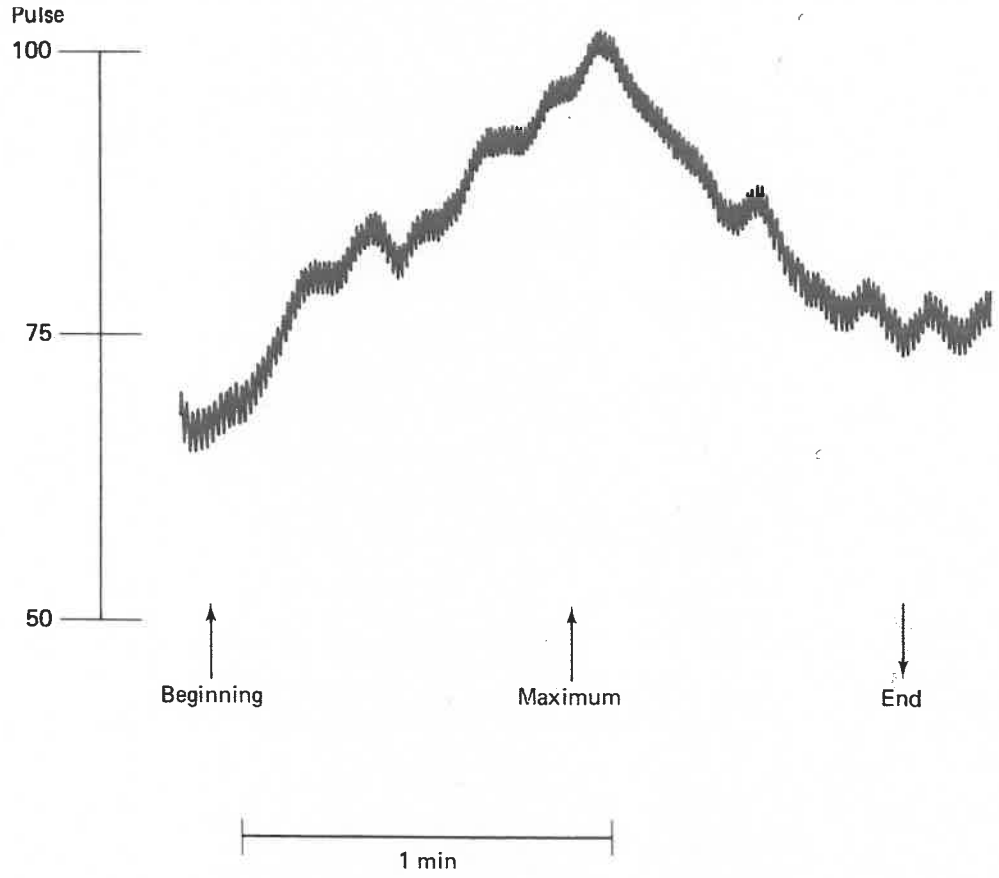

Figure 3 Pulse rate at crescendo and decrescendo of a rolling drum beat.

Oscillographic and plethysmographic changes may also occur which suggest an increase or, in certain circumstances, a decrease in the vasoconstrictor tone. It is worth-while mentioning in this context the noise induced peripheral vasoconstrictor response.

In these investigations no recordings of the blood pressure were carried out during the presentation of music.

(b) Respiration. Recordings of respiratory movements during the playing of music are very informative. Not only do changes in frequency and depth of respiration occur, but the relation between inhalation and exhalation may also be changed and this may be true of other respiratory characteristics. These include tendencies towards rhythmical or arrhythmical respiratory activity.

Figure 4 illustrates the pneumograms of five different subjects (A–E) while listening to the same piece of music (negro drumming from Uganda). Subject A exhibits a gradual adjustment of the respiratory rate to the gradually accelerating and temporarily slowing beat. The same mode of reaction is shown by subject B except that the respiratory rate is much slower. The subjective experience of fatigue manifests itself by a sighing

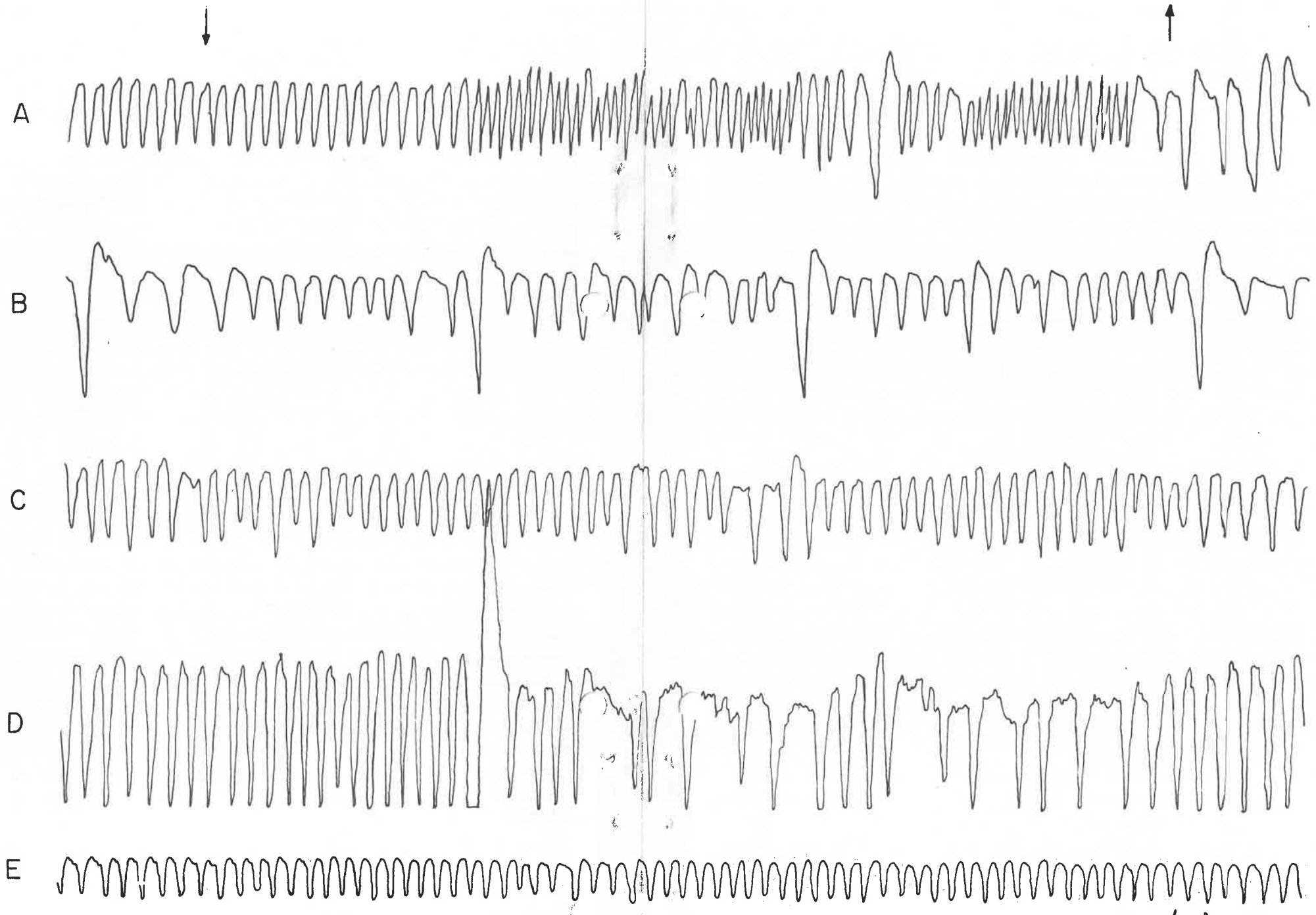

Figure 4 Pneumogram of five different subjects (A–E) listening to the same

respiration. While subject A shows an equal length of the inspiratory and expiratory phase, the expiratory period is clearly lengthened in B, while the tracing of subject C occupies an intermediate position. The tracing of D is characterised by a slowing of the respiration at the period of the fastest drum beat; this type of response is found when an intrinsic biorhythm is unable to follow the extrinsic pacemaker any further, and a shift is made to a different subharmonic relation between intrinsic and extrinsic rhythms, for instance to a rate of 1 : 2 or 1 : 3. Subject E is characterised by consistency in the amplitudes; changes of rate are also smaller than those seen in the other subjects. These individual modes of response were widely reproducible whenever the tests were repeated with the same piece of music. Such pronounced inter-individual differences in the respiratory response, associated with marked intra-individual consistency, correspond with considerable differences of individual attitudes towards the presentations. These attitudes are clearly greater in younger subjects than in older ones; the latter regarded the bush drum music as disagreeable and not to be rated as "music". In conventional or "classical" music the inter-individual respiratory differences were less significant, and certain pieces of music elicited responses in all subjects.

In reaction to pieces of music with a prominent acceleration or deceleration of the rhythm, some of the subjects show a tendency towards a primary pulse synchronisation, others tend to exhibit synchronisation of the respiratory rhythm. This suggests that it might be possible to differentiate "primary circulatory reactors" and "primary respiratory reactors".

(c) Psychogalvanic reflex (PGR). This proved to be the most sensitive indicator in our investigations. Its disadvantage lies in the difficulties of signal calibration and also in a certain fatigue of the response in the course of a lengthy test. Here again, strong responses may be the expression of either pleasure or displeasure. Any sort of mental distraction, a person entering the room, or a noise, can lead to responses which may be misinterpreted.

(d) Motor activity. Simple observation of a concert audience with their different types of motor responses is an interesting experience. Under laboratory conditions it is possible to assess muscular activity electromyographically (EMG) during the perception of music. Figure 5 shows increased muscular activity during the process of listening to music (also noticeable in other states of mental and emotional tension) as evidenced by an increase in the number and amplitude of muscle action potentials. There are also quantitative as well as qualitative differences between various muscular segments; for instance, between cranial muscles

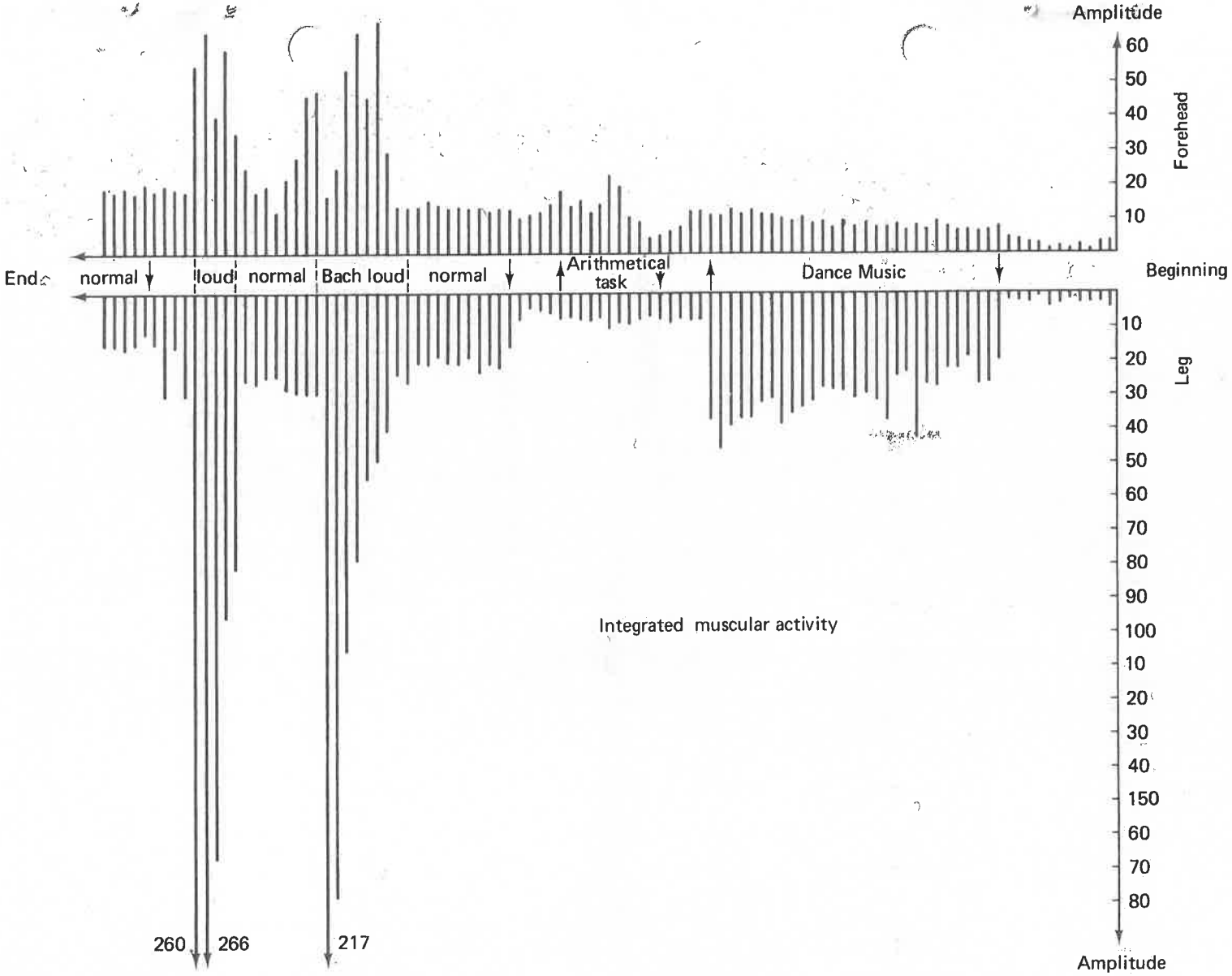

Figure 5 Integrated muscular activity shown electromyographically. Differences between the region of the forehead and of the legs while the subject is listening to dance music, during an arithmetical task; and listening to Bach's Brandenburg Concerto No. 6.

Figure 6 Polygraphy taken while the subject was listening to a performance of Bach's Brandenburg Concerto No. 1.

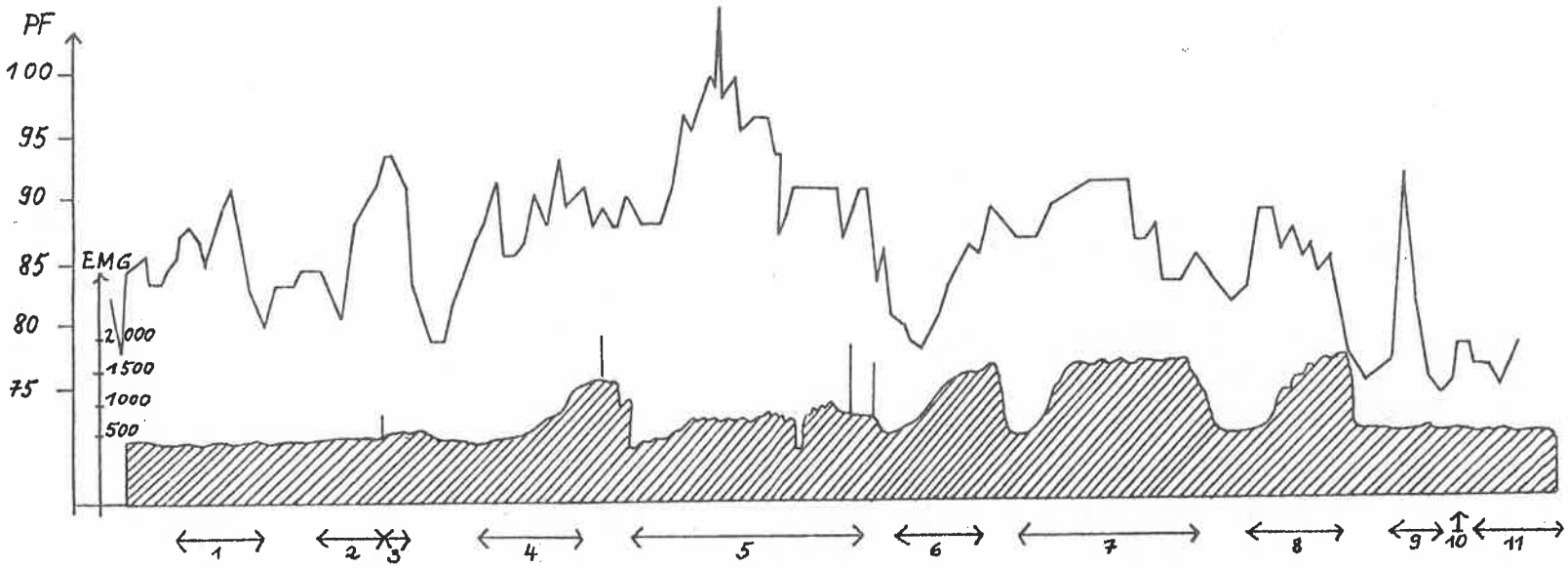

Figure 7 Pulse rate and integrated muscular activity while the subject was listening to: (1) Brahms' "Wiegenlied", (2) the hooting of sirens (firefighting vehicles), (3) the grating of a saw, (4) Concertino No. III in A flat, G. B. Pergolesi, (5) Kalinka, (6) Telemusic, K. Stockhausen, (7) Bach's Toccata in D minor, (8) Dixieland music, and (9) during an arithmetical task, (10) associated with a cough, (11) during relaxation.

When a subject is asked to squeeze an ergometer, an instrument to measure the strength of the handgrasp at regular intervals and with equal effort he will be unable to carry out the test properly while music is being played. Lullabies invariably decrease and march songs increase muscular strength.

5. Finally, the effect of tranquillisers is noteworthy. We observed an almost complete suppression of music-induced autonomic responses after the administration of tranquillisers within the limits of certain dosages. The suppressive effect was obtained without any concomitant reduction or alteration in the emotional musical experience. This dichotomy appears to be important with regard to the frequently expressed view that the physical and autonomic components of affect constitute an inseparable entity. When larger doses are administered both the autonomic and the emotional responses are suppressed. There is reason to believe that some individuals

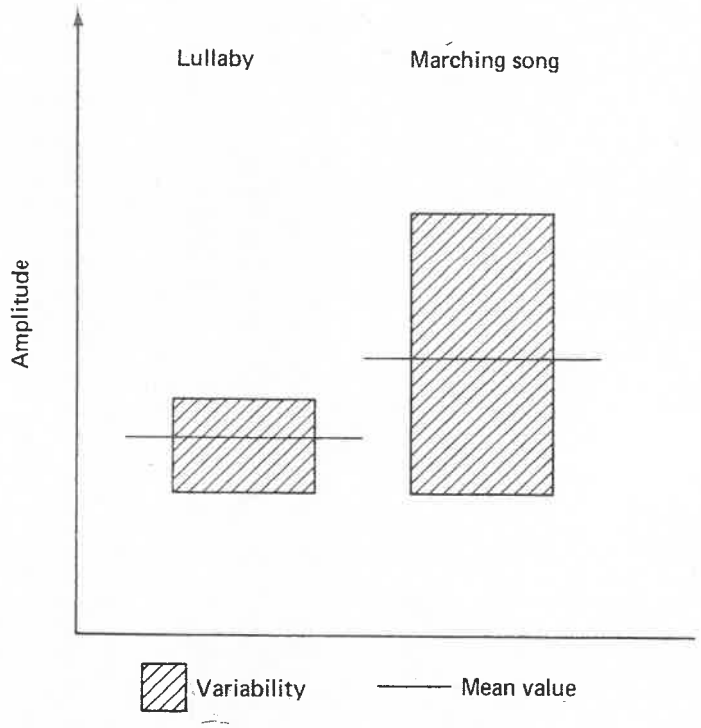

Figure 8 Music-induced changes of the ankle jerk.

will thus be able to give themselves up to the aesthetic pleasures of music in an undisturbed manner.

This work does not merely pertain to the experience of music and the set of accompanying autonomic processes, it may also serve as a contribution to basic research in the domain of the therapeutic use of music and, furthermore, as a contribution to the problem of mind-body relationships.