TIMING IN MUSIC WITH AND WITHOUT AWARENESS: IS THERE A RELATION BETWEEN INTERNAL CLOCKS AND STABILITY OF TEMPO JUDGMENTS WHILE LISTENING TO MUSIC?

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The nature of timing in music from a biological perspective

It is not always a simple matter to know when someone performs a consciously willed action or not, when performing, moving or listening to music. Researchers have explored the possibility that certain human biological functions, such as heartbeats, breath, body temperature, or neuron oscillations in the brain may play a significant role in the individual's experience of music, in general, and tempo (e.g., the rate of musical time's flow), in particular. As Winckel (1967) pointed out, "it is conceivable that some animals with an entirely different biological 'factor' are not capable of following the rhythm of our music" (p. 85).

Scholarly research on music experience has been, however, neglectful of the importance of the relationship between music and biology, mainly due to the hegemony of the formalistic philosophical tradition, especially after the end of the 18th century, which purports the detachment of music from the 'devalued' body and its organs. Nevertheless, more recent developments in anthropology and cultural studies call for a new understanding of the corporeality of music in a scientifically grounded sense. They disclose an almost universal recognition that the body is a basis of music production and, at the same time, the physical site where music is perceived (Bohlman, 2005). Referring to the 'correspondences' between musical and somatic structures and time, Lévi-Strauss (1994) wrote:

> Below the level of sounds and rhythms, music acts upon a primitive terrain, which is the physiological time of the listener....The inner, or natural grid, which is a function of his brain, is reinforced symmetrically by a second and, one might say, still more wholly natural grid: that constituted by the visceral rhythms.

More specifically, throughout western music history, until the end of the 18th century, there have been a number of attempts to support the belief that human pulse serves as a physiological basis of time sense and tempo in music. As early as 1698, Loulie constructed a pendulum (chronometer) with 72 different swing durations in an attempt to measure the musical effect according to an average number of pulse strokes. Moreover, music theorists during the Middle Ages and Renaissance through the Baroque period (e.g., Gafurio, Lanfranco, Ramos, Mersenne, and Quantz, among others) believed that the average human pulse was linked to a 'general' tempo area of M.M.=60-80, in order to standardize the musical beat.

In the beginning of the 20th century, when the empirical study of psychological time was initiated, researchers have been concerned primarily with the concept of preferred tempo in music. Along these lines, Smith (as cited in Isaacs, 1920, p. 281) maintained that subjects' choice of a preferred tempo is bound up with their individual pulse or respiratory rate. Dalcroze (1921/1980) also supported the view that the human heart provides a basis of rhythm. In an attempt to find the origin of time measure in music in a unified physiological function, J. L. Okunewski (Winckel, 1967) presented in a list the pulse count for a number of piano compositions, in which he measured the pulses of the pianists in relation to the number of breaths per minute. When Sachs (1953) "metronomized" Bach's Mass in B Minor—each movement separately and on various days—he found that "his beat was consistently near M.M.=80, covering now a quarter note, now an eighth, now even a half note (p. 34).

In addition, empirical research has been concerned with the study of "biological" clocks or rhythms that may be associated with both endogenous and acquired periodic processes in human physiology other than the previously discussed human heart rate or respiration. In a series of experiments it has been reported that judgments of subjective time depend on the speed of oxidative metabolism in the brain, a chemical process that is influenced by our internal body temperature. The results clearly demonstrate that raising our internal body temperature or lowering it elicits faster or slower—respectively—chemical motions in the cells of the brain that act as a "chemical clock" or "pacemaker" (Hoagland, 1933).

In an examination of the various factors affecting tempo behavior in repeated music performances, Brown (1981) observed that morning performances (between 8 and 9 a.m.) were significantly faster than evening performances (between 9 and 10 p.m.). Moreover, the evening performances were more consistent with respect to tempo. Brown (1981) concluded:

If tempi are more consistent at a particular time of day, the circadian body temperature variation may be the relevant factor. However, as body temperature has been reported to be at a maximum in the evening (Colquhoun, 1971), the expectation was for faster and not slower tempi at this time (p. 38).

A noteworthy manifestation of the relation between metabolic rate and time sense appears in the aging process. More specifically, researchers (e. g., Fischer, 1966) reported a rapid fall in both circulation and oxygen consumption of the brain from childhood through adolescence followed by a more gradual but progressive descent through the remaining years of life. Indeed, it is a familiar experience that time for the child appears to run much more slowly than time for an adult. According to Lapidaki (2000), who examined adult, adolescent, and preadolescent listeners with respect to the stability of their tempo judgments while listening to the same music compositions over an extended period of time, changes of metabolic rates related to aging may be the reason why children gave faster tempo judgments to all compositions than the adults. This result concurs with the evidence from the study by Vanneste, Pouthas, and Wearden (2001) who observed a strong effect of age, as elderly people spontaneously tapped at a significant slower rate than young adults, due to potential changes in internal clock speed or internal tempo with age.

Stability of motor programs during music performances

Many researchers assume that a possible basis for tempo perception in music may rely on neural oscillations in the brain proceeding with a remarkably stable rate. Mental structures might, therefore, display considerable morphological stability. Studies are concerned with time processes on intervals of a fraction of a second to several seconds.

For instance, Pöppel (1990) opted for a period of 20 to 30 milliseconds as the perceptual moment or time quantum, which has been defined as the least timewise element of psychological experience. Furthermore, Pöppel reported evidence postulating an "integration mechanism" in our brain with a controversial period of about 3 seconds that is roughly equivalent to the time span of the conscious or psychological present. This value has been established by studies in various fields, such as time psychophysics and visual perception. Pöppel proposed that this time limit of 3 seconds could be the basis for a central neural pacemaker or biological clock that causes tempi and tempo relationships in music to be "unbiological" and hence with unpleasant aesthetic consequences for listener with "traditional listening habits," if they are not tuned to this clock in our brain (p. 119, translated from German by E. Lapidaki).

Concerned with the precision of selecting and maintaining the 'right tempo,' the American musician and music theorist David Epstein (1985) investigated tempo relationships within pieces of music from different cultures. He wrote:

This (selection of a particular tempo) is not a matter only of music 'per se.' Our biological system is involved as well. Clearly this system entrains within itself the beat or pulse that pervades the music. This beat remains constant, entrained-embedded, if you will—in the time clocks of our system… So powerful is the element of pulse that if one violates it by distortion of tempo, one runs the risk of an unsuccessful performance. Such a distortion seems to be violating not only a "musical factor," but a biological one as well, one which sets ground limits to our aesthetic perception (p. 37).

Concurring with Epstein, an investigation of repeated musical performances over long periods of several years also indicates that "music engages and programs a "psychobiological clock, or clocks, which function subconsciously" and guide the execution of proportions of musical temporal parameters, such as duration, rhythm, and tempo (Clynes & Walker, 1986, p. 87). Moreover, it has been observed that changes in durations of subsections from one performance to the other often have a tendency to be balanced by changes in other subsections in order to preserve the same overall duration of the piece, although the performer is not aware of this. In a more recent study (Kohlmetz et al., 2003) of electroencephalogram recordings of an expert pianist playing Satie's "Vexations" for a continuous period of 28 hours, results demonstrated the high degree of stabilityin the execution of tempo, even in changing levels of consciousness (e.g., alertness, trance, and drowsiness). The researchers of the study suggest that free running neural oscillators appear to function as the underlying mechanism that interacts with circadian rhythms (which control periodic changes of blood sugar or cortisol).

Stability of motor programs during music listening

With regard to music listening, research on stability of tempo perception (Halpern, 1988; Levitin & Cook, 1996) reported that subjects have an accurate representation of tempo of songs and that they remember them at their original tempi. In addition, Lapidaki (2000) attempted to determine whether listeners (n=90) from different age groups, with both music and nonmusic background, are capable of forming consistent right tempo judgments on four separate occasions over an extended period of time, especially when they are presented with musical compositions chosen because they represent a wide range of musical styles, familiarity, and preference. Subjects were asked to listen the same six musical examples and indicate whether the experimenter should set the tempo "faster" or "slower" until it sounded right to them; they had to adjust an initially wrong tempo to a personally preferred tempo.

Results indicated that the initial tempo of presentation significantly dominated subjects' tempo judgments (Lapidaki & Webster, 1991). There was evidence that the degree of consistency in right tempo judgments gradually increased from preadolescence through adulthood. Findings strongly suggested that style, familiarity, and preference affected consistency of tempo judgments. Few statistically significant differences in tempo judgment consistency were found as a result of music background.

Nevertheless, a small number of adult musicians were remarkably consistent in their tempo judgments across all four trials. It appeared that these individuals possess an exceptional ability with respect to acute stability of large-scale timing in music that was labeled "absolute tempo." Interestingly enough, these subjects reported that they were surprised when they heard that their right tempo choices were virtually identical across trials. Thus, it would seem that physical, psychological, and environmental factors, such as, fatigue, mood or time of day, did not have an effect on their tempo judgments. One reason might be that music engages and programs psychobiological clocks or neural oscillations which function subconsciously but give conscious read-outs and thereby guide the listeners' choice of right tempo in an exact and stable manner. In addition, this result also raises issues concerning memory dynamics in repeated musical activities during which surface details fade from explicit memory but persist in implicit memory which affects behavior automatically without explicit cognitive control (McAdams et al, 2004).

Finally, much remains to be known about the temporal organization of nervous system interactions with regard to tempo judgments in music and about internal clocks and their anatomical characteristics, as well as the properties within the structure of the brain. This may help us expand our knowledge about the way the human body participates in all acts of music experience and discover new biological (and ontological) properties of music that may, in turn, have an influence on the human body and its jouissance (Barthes, 1975).

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