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Temporal stability in repeated listening tasks

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ABSTRACT

Empirical research on stability of temporal judgments in music has increased considerably during recent decades. The context of this paper is the question whether a piece of music has one and only one 'right' tempo, and if so, whether this seemingly well-established concept possesses an absolute or right time framework in the mind of the listeners. This paper will review the literature on (a) the nature of timing in music from a biological perspective, (b) stability of motor and perceptual tasks during music performance, (c) personal or preferred tempo judgments, and (d) stability of tempo judgments in music listening.

More specifically, the paper will focus on the use of internal clock-based mechanisms to represent musical timing and tempo in repeated musical tasks that may help us advance our understanding of the activity of the human body and consciousness in terms of what they reveal about motor programs and precise tempo preferences involved in the musical experience. Thereby, the theoretical framework of the Lapidaki (2000) study and the discussion of findings will be will be expanded and discussed in a new light.

Finally, I will propose that large-scale timing in music appears to reflect forms of "implicit cognition," a term that has been used in psychological research to characterize situations in which mental processes can influence perception outside of phenomenal awareness and voluntary control.

The material of this paper may prove useful in integrating a range of data and stimulating new research about the temporal organization of nervous system interactions and internal clocks with regard to tempo judgments in a complex nonverbal auditory domain.

Keywords

tempo perception, stability of timing, absolute tempo, internal clocks.

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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

sic 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-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). Along these lines, examining the relationship between tempo preference and heart rate, using a music stimulus, Iwanaga (1995) found that subjects tended to prefer a tempo similar to that of their heart rate, whereas tempo that was 1.5 times, or twice as fast as the heart rate was less preferred.

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). Hoagland depicted the effect of body temperature on the frequency of subjectively counting seconds and tapping rhythms, in the so-called Hoagland's "Arrhenius plot". Clock time seemed to pass slower to subjects with higher temperatures and hence accelerated biochemical changes; therefore, they counted or tapped faster. On the other hand, subnormal temperatures and hence a decrease of metabolic rate had the opposite consequence to subjects' rate of tapping and counting (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 AND PERCEPTUAL TASKS 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 that refers to the existence of an internal or psychic tempo. For instance, Fraisse (1963) showed that there exists a zone of *optimal tempo* from about 300-800ms at which people are best able to process incoming events in a sequence. Fraisse also observed that subjects' preference for metronomic tempi appears to lie within this zone. Jones (1986), however, proposed the idea of *cyclic attention* whose rate or *referent period*, determined by an internal oscillator (Large & Jones, 1999), is faster in some individuals than others but on the average falls within Fraisse's optimal zone.

Pöppel (1976) opted for a period of 20 to 30 ms as the perceptual moment or time quantum, which has been defined as the least time wise 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. Pöppel (1989) 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 listeners, if they are not tuned to this clock in our brain that underlies tempo control in music.

Concerned with the precision of selecting and maintaining the 'right tempo,' 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).

Furthermore, two studies by Clynes & Walker (1982, 1986) on stability in performed tempo are worth noting. Repeated performances by the same musicians and of the same compositions were timed over a number of years. Findings suggested a high degree of consistency and precision in the execution of tempo. Concurring with Epstein, the researchers reasoned that music appeared to engage and program a psychobiological clock or clocks which functions subsoconsciously but gives conscious read-outs and thereby seems to guide the performers' realization of tempo in an exact and stable manner. These findings are consistent with the timing of a symphony orchestra in several performances of the same compositions over several years at different music halls of the world measured by Winckel (1962). Similarly, Wagner's (1974) timing of different performances on the piano of the same piece by Herbert von Karajan showed highly consistent tempi. 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. Total durations of two recordings of Bach's *Goldberg Variations* played by Glenn Gould (Gould, & Page, 1982/19831982) as much as 26 years apart showed an extraordinary large-scale stability greater even than that of individual sections of the composition.

In a 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 stability in 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).

EMPIRICAL RESEARCH ON PERSONAL OR PREFERRED TEMPO JUDGMENTS

In the process of exploring the literature concerning tempo consistency in musical and nonmusical environments, it is of interest that most investigations were performed around the first half of the century and were often referred to as "personal," "preferred" or "mental" tempo studies (e.g., Braun, 1927; Frischeisen-Köhler, 1933; Harisson, 1941; Miles, 1937; Mishima, 1956; Rimoldi, 1951; Wallin, 1911). Most commonly, subjects were asked either to tap a telegraph key as their response task or to use a metronome to indicate what tempo appeared to be the most natural. In other words, subjects had to judge whether the speed of metronome clicks was neither too slow or to fast. In Wallin's (1911) study, subjects listened to pairs of different rates of a metronome and were asked to state which tempo was felt to be more appropriate. There were considerable individual differences in the preferred rates. In fact, these ranged between the extreme rates offered by the metronome. Braun (1927) asked subjects to produce a steady series of taps at any rate they chose; he recorded the tapping rates of six subjects in 11 sessions, at intervals of several weeks between each session. Braun found that subjects were relatively consistent in their preference rate, and that the variance within subjects was very small in comparison to the variance between subjects. Furthermore Miles (1937) experimented with subjects who were instructed to tap regularly a rate that seemed more satisfactory to them. He concluded that each subject had his or her own preferred range of rates.

Moreover, with regard to subjective consistency in rate of self-paced movements of specific parts of the body, Harisson (1941) found no similar tempi between any of the tasks performed. Three decades later, Smoll (1975) maintained that individuals were relatively consistent concerning their personal tempo manifested in situations involving repetitive motor responses. However, Mishima (1951-52) pointed out that “mental tempo is constant within a field, but it varies with different fields” (p. 27). Furthermore Rimoldi (1951) reported that “fast individuals are consistently fast and slow individuals are consistently slow within relatively long periods of time (from two to four weeks)” (p. 301), while Frischeisen-Köhler (1933) concluded that the effect of time between sessions on the variability of tempo appears to be inconsiderable.

EMPIRICAL RESEARCH ON STABILITY OF TEMPO JUDGMENTS DURING MUSIC LISTENING

There is near unanimity in the definition of musical tempo as the time of a composition (London, 1980). According to Gabrielsson (1986), “tempo designates the perceived rate of the beat or pulse, while the latter terms [rate, rapidity, speed] refer to the ‘total’ impression of speed” (p. 148). Similarly, Fraisse (1982) pointed out that tempo “corresponds to the number of perceived elements per unit time, or to the absolute duration of the different values of durations” (p. 151).

Nevertheless, does a piece of music have one and only one correct tempo for the listeners, and if so, does this seemingly well-established concept possess an absolute or correct time framework in the mind of the listeners? Or can a composition survive a wide range of tempi? The literature is far from consistent on these questions.

In addition to the above mentioned studies that employ listening to stimuli like metronome clicks or tapping tasks, of particular interest are those investigations that ask the listener to make judgments about tempo with hardware that allows for variable-speed control over the musical stimulus. Farnsworth, Block, & Waterman (1934) designed a study that examined whether there is one tempo consistently associated with familiar waltz and fox-trot tunes. In that study, subjects (non-music major college students) were blindfolded and placed in front of a Duo-Art reproducing piano with the tempo lever in hand. The task was to place the lever at the position considered to give the “proper tempo” for the tunes played by the piano. Subjects were also placed at a telegraph key, so that they could tap the “proper tempo” for the same tunes; the taps were recorded on a polygraph. According to the findings, the variations of the means for the proper waltz tempo were slight but for the fox-trot were equivocal in some degree. Findings seemed to suggest a mean of controlling “absolute tempo” of about 120 beats per minute. In addition, the findings reported a positive correlation between the tapping behavior and the setting of the Duo-Art tempo lever, that is, “between the more motor and the more sensory aspects of tempo” (p. 233).

Five years later, Lund (1939) repeated this study and arrived at similar findings, although in his experiment tempi for waltz and fox-trot were slightly faster. Moreover, measuring the principal tempo of an extensive number of selected recordings known as the “Carnegie set, Hodgson (1951) proposed that all music is based or geared to one underlined human or psychological beat or tempo between 60 and 70 beats per minute, which indicates a strong preference tempo.

The Farnsworth, et al. and the Lund research were important studies because of their use of real music with hardware that allowed subjects to have control over tempi. They were also limited in that they only investigated popular ballroom dance music which subjects might associate with familiar body movement. However, as Donington (1963/1974) observed: “Dance steps can only be performed correctly within narrow margins of speed” (p. 392).

Behne (1972) used both a mechanical device, the so called “Springer-machine,” for manipulating the tempo of recorded music, and real renditions of the same piece in different tempi as well (p. 70). All pieces were composed particularly for the study. The findings showed that listeners judged the tempo of certain pieces as correct within a relatively wide range of tempi. In addition, the listeners’ judgments appeared to approach halfway the composer’s metronomic designations (p. 123). Behne’s findings seem to suggest “the existence of a certain ‘tolerance width’, that is, of different possible tempi” (translated from German by E. Lapidaki, p. 129). Therefore Behne concluded that the existence of a single right tempo for a piece of music is an “exceptional case.”

Moreover Halpern (1988) conducted a two-part study on tempo perception with non-music major college students, which is remarkably similar in purpose and design to the 1934 work by Farnsworth and his associates. Nevertheless, it is noteworthy that Halpern does not note the Farnsworth study in the paper. More specifically, in Halpern’s two-part investigation, nineteen well-known popular songs served as stimuli and were presented to subjects by an Apple II computer controlling a synthesizer (Study 1). Most of the songs had the characteristic that no single reference version and, thus, no single uniformly correct tempo existed—e.g., “Happy Birthday,” “Twinkle, Twinkle, Little Star,” “London Bridge is Falling Down.” Instead of manipulating the tempo lever of a player piano, as was the case in Farnsworth’s study, subjects could change the tempo of the tunes by manipulating the software interface on the computer until they sounded “correct.” Moreover, instead of tapping on a telegraph key, subjects were instructed to set a metronome to coincide with what they imagined to be the correct tempo of the songs.

Results reported a generally positive relationship between the metronomic evaluations and the setting of the tempi on the computer, that is, between "imagined" and "perceived" correct or preferred tempi for each tune. The results are indeed similar to those found by Farnsworth and his associates concerning the positive correlation between the tapping task and the setting of the tempo lever. It was also found that imagined tempi seemed to regress to a middle range of approximately 100 beats per minute, between the faster and slower perceived tempi. In Study 2, though, which utilized 10 of the tunes of Study 1 and only the "imagery" task (e.g., the metronome setting), it was reported that the mean preferred tempo was 109 beats per minute, significantly faster than the mean imagined tempo from Study 1 and much closer to the mean tempo of 120 beats per minute reported in the Farnsworth, et al. study. Both parts of Halpern’s research suggest that familiar, popular tunes are represented in our mind with a particular tempo.

Levitin & Cook (1995) conducted a similar two-part study in order to investigate if we remember a song in its original tempo. In Experiment 1 of the study 46 college students unselected for their musical background were asked to choose a song they knew very well among fifty-eight CDs containing the best known popular songs and to hold it in their hands. They were instructed to close their eyes and imagine that the song was actually playing. Then they were told to try to reproduce the song from memory by singing, humming, or whistling. After the first reproduction subjects were instructed to repeat the procedure with another song of their choice. The durations of each subjects’ reproduction was then compared with the corresponding original excerpt on the CDs. Results showed that long-term memory for tempo is very accurate.

In Experiment 2 Levitin performed new analyses replicating Halpern’s (1988) research (Study 1) in order to investigate tempo variability in singing. Subjects recruited without regard to musical training were first asked to sing one of three well known popular tunes, such as “Happy Birthday,”. When they finished, they were asked to sing it as fast and then as slow as they possibly could. Their productions were directly recorded to a computer or to a DAT. Subjects were told to repeat the same procedure for the other two songs. Results showed that the variability in tempi for popular songs that lack a single correct tempo is large (in the 10%-20% range), supporting the claim that memory for the tempo of songs was not driven by their lyrics.

Interesting as these results may be, they do not demonstrate whether judgmens of tempo are consistent across separate trials over an extended period of time, especially, when subjects are presented with musical compositions from Western art music of different style periods. Also of importance would be how these judgments might differ among subjects with different musical backgrounds.

Lapidaki & Webster (1991) conducted a study to determine whether highly skilled adult musicians and non-musicians could consistently set tempi when listening to musical compositions drawn from Western art music of different styles and familiarity. Results from previous studies were reported and served as a conceptual basis for this work. Three specific questions were posed: (1) is there a consistent judgment of tempo across three separate trials of the same musical excerpt utilizing varying initial tempi for each trial; (2) is the judgment of tempo affected by the musical background of the subjects; and (3) is the judgment of tempo affected by the style of the excerpt?

Subjects (n=20) heard the same three musical examples on three separate occasions. Each session systematically varied the order of the presentation and the initial tempo of the examples in order to eliminate the possibility of contextual cues. The musical pieces were digitally recorded and performed in real time with a computer controlling a MIDI equipped synthesizer. The software program employed had the ability to allow for musical stimuli and for no overall alterations of any musical attributes of the sequences other than tempo, so that subject could listen to the “real” pattern of timing and loudness which illustrate the compositions’ expressive character. Subjects were asked to listen to each composition and indicate whether the experimenter should change the tempo until it sounded “right.” The experimenter changed the tempo as directed until the subject was satisfied.

The findings of the Lapidaki & Webster study showed that when tempo is judged by highly skilled musicians in repeated listening tasks of the same compositions, initial tempo has a dominant effect on correct tempo judgments. Simply stated, no single correct tempo emerged as a consistent entity of individual or group performance across the trials. The sample of adult non-musicians indicated a basis for a similar conclusion. These results did not support the observations reported by Farnsworth, et. al. (1934), Lund (1939), Halpern (1988), and Levitin & Cook (1995) that there is one tempo consistently associated with particular listening examples. On the contrary, listeners’ perceptions of correct tempo for a particular composition varied dramatically from one individual to another.

More recently, 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 trials 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), in contrast to Pöppel's (1989, p. 89) assumption that "for humans, there is in music no freedom for tempo." Moreover, there was evidence that the degree of consistency in right tempo judgments gradually increased from preadolescence through adulthood. Support of this developmental evidence has been provided by the findings of Baruch, Panissal-Vieu, and Drake's (2004) study who suggest that whatever the context, children prefer the fastest tempi, while adults appear to show absolute tempi preferences and thus to be more consistent in their tempo judgments. It is noteworthy that in the Baruch et al. study infants displayed a lack of tempo preference, although their tempo discrimination ability was functional.

Furthermore, findings strongly suggested that musical 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.

ABSOLUTE TEMPO

A closer look at the range separating the fastest from the slowest tempo judgments of individual subjects for each piece often revealed strikingly small discrepancies in the Lapidaki (2000) study.

In a new analysis of data, in order to determine how great these discrepancies are, and whether they are perceptible, it is reasoned that the range between the slowest (T1) and the fastest (T2) tempo judgments reflects the degree of consistency among individual tempo judgments across all four trials. Thus, if the difference between T1 and T2 is virtually imperceptible, then the four tempo judgments of the same piece on the four trials are considered consistent. Ideally, T1 and T2 should be in exact 1:1 ratio to be considered consistent. If this was not the case, the following formula (Epstein, 1995, p. 519) was used that expresses by what percentage of time T1 and T2 can deviate from the 1:1 ratio and still be regarded as consistent:

$$\Delta = \frac{(r \times T1) - T2}{T2'} = 1 - \frac{T1}{T2}$$

Where

T1 = beat duration of T1 (e.g., longest beat duration)
T2 = beat duration of T2 (e.g., shortest beat duration)
T2'= beat duration of ideal T2 (which should be in exact 1:1 ratio to T1–that is, equal to T1)
Δ = the percentage by which the actual T2 varies from T1 (or the ideal T2) [1]
r = ideal ratio 1:1 (or its decimal equivalent 1.0)

It should be noted that all calculations have utilized the real-time version (e.g., duration of beat in seconds) of metronome markings (M.M.= beats per minute)[2]. According to Epstein (1995, p. 519), the practical import for converting metronome markings to real time beat durations is that their relation is direct rather than inverse, as is the case with metronome indications. In assessing whether Δ is perceptually negligible, a tolerance level has been set at five percent, commonly known as the "Weber fraction." Percentages or deviations which are equal or below 0.05 should imply "good" individual tempo consistency. To be sure, the use of T1 (the tempo with the shorter beat duration) instead of T2 (the tempo with the longer beat duration) as the base tempo is arbitrary. However, a number of studies in psychophysics of time also use the shorter duration as the base time period (Hirsh, Monahan, Grant, & Singh, 1990; Macar, 1985; Halpern & Darwin, 1982).

One must keep in mind that the Weber fraction seems extremely strict when applied to real musical stimuli of considerable density and duration such as those of this study. Therefore, I used the Weber fraction merely as a measure of individual ranges of tempo judgments, since no other criterion appeared to apply in this case, for the time being. "In its absence, we must use the available criterion of the Weber fraction for whatever degree of measurement and precision it can provide" (p. 521), proposed Epstein (1995) referring to his research on "proportional tempi" of the same motives in one movement or among various movements of a composition.

As an example, Table 1 presents the 'right' tempo judgments of individual subjects who exhibited extraordinary small ranges between the fastest and the slowest tempo judgments for Debussy's *Clair de Lune*. These have been selected according to the ratios of the fastest against the slowest judgments for this particular musical example that represent percentages below perceptible limits as determined by the criterion of the Weber fraction. These percentages are found in the row— designated as Δ—below the tempo judgments on each trial.

It becomes clear that these statistically insignificant consistent individual responses, do not represent the larger spectrum of listeners selected for this study who have been affected by the initial tempo in their tempo judgments. Therefore, these 'consistent' subjects should be regarded as isolated cases that allow only tentative conclusions. As Macar (1985) wrote with regard to studies concerned with physiological time bases:

> Although large individual variations are the rule, it is surprising to observe that systematic trends may affect

[1] The difference between the actual T2 and the ideal T2 is called the "just noticeable difference" (JND) or the "differential threshold" in psychophysical research of time.

[2] Formula for converting metronome markings (M.M.) to real time in seconds: $\text{Beat duration (secs)} = \frac{60\ [\text{sec/min}]}{\text{M.M.}}$

temporal judgments quite noticeably, though this is generally true for only one or two subjects per experimental group… Clear hypothesizing and clever experimental designs may uncover more of these idiosyncratic strategies" (p. 124).

Table 1. Subjects with the Most Consistent Right Tempo Judgments for Debussy's Clair de Lune.

Musical Example	Subjects ([a]musicians–[b] non-musicians)				
	1[a]	7[a]	10[a]	11[a]	14[b]
DEBUSSY					
Trial 1: Fast IT	47	42	52	50	56
Trial 2: Slow IT	48	42	50	50	56
Trial 3: Fast IT	47	41	51	52	56
Trial 4: Slow IT	49	42	50	50	56
Δ	0.04	0.02	0.04	0.04	0.00

Along these lines, it appears that this relatively small number of listeners (e.g., adult musicians and non-musicians) possesses an exceptional ability with respect to acute stability of large-scale timing in music. This ability to give over time consistent tempo judgments to a piece of music in conditions seemingly devoid of an external tempo reference (a score or the body interaction involved in performance) may be referred to as "absolute tempo," analogous to "absolute pitch."

It should be noted that "absolute tempo" has been observed with musical examples that were thoroughly known by the subjects, according to a questionnaire about familiarity with and preference for the listening examples. Nevertheless, this finding should be treated with caution, since these subjects did not exhibit "absolute tempo" with respect to all pieces for which they had the same level of familiarity. Contrary to absolute pitch, one might suppose with respect to "absolute tempo" that the same person seems to follow different cognitive strategies of timing for each individual piece, which leaves one wondering whether this stability is to some extent discrete more than continuous.

Interestingly enough, these subjects reported that they were surprised when they heard that their right tempo choices were virtually precise across trials. Thus, it would seem that physical, psychological, and environmental factors, such as, fatigue, mood or time of day, did not seem to have an effect on their tempo judgments. Concurring with Epstein (1985), Clynes and Walker (1986), Pöppel (1989), and Kohlmetz, et al. (2003), among others, one might say with regard to absolute tempo 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, the assumption that consistent tempo judgments occur subconsciously or intuitively– outside of phenomenal awareness and voluntary control–is supported by the notion of implicit cognition that has been the subject of increasing interest and debate in psychological research (Underwood & Bright, 1996). Implicit cognition 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, Vines, Vieillard, & Reynold, 2004). With regard to consistency of right tempo judgments, I agree with Epstein (1995) who summarized this position as follows: "Ultimately decisions about rightful tempo rest upon intuition. Intuition is not absolute, however: it, too, can modify, our perception of music enriched by concepts structural, affective, historical, neural" (p. 107).

In sum, absolute tempo provides evidence that thoroughly known pieces appear to exist in the mind of some listeners as an entity with a precise temporal size or a rigorous pulse that may destroy the expressive quality of music if violated. Nonetheless, it must be noted that this ability of stable and precise large-scale timing in music listening appears to be atypical for the large community of listeners in the same way that precise stability of timing is "atypical of the large community of performers," as Epstein (1995, p. 502) points out with regard to music performance.

IMPLICATIONS

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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