Music Education Research, Vol. 2, No. 1, 2000

Stability of Tempo Perception in Music Listening

ELENI LAPIDAKI, *Department of Musical Studies, Aristotle University of Thessaloniki, Greece (e.mail: lapidaki@mus.auth.gr)*

ABSTRACT *This study was designed to determine whether listeners from different age groups and musical backgrounds (musicians and non-musicians) could set tempi in a consistent manner over an extended period. The variables of musical style, familiarity, and preference were also considered. Subjects heard the same six compositions on four separate occasions. The order of the presentation and the initial tempo of the examples were varied systematically in each session. Subjects were asked to listen to each composition 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 significantly dominated subjects' 'correct' tempo judgements: the slower initial tempo generally evoked slower tempo selections, and so on. However, a relatively small number of adults, mostly musicians, were remarkably consistent in their tempo judgements across all four trials. It appeared that these individuals possess an exceptional ability with respect to acute stability of large-scale timing in music.

There was also evidence that the degree of consistency in correct tempo judgements gradually increased from preadolescence through adulthood. Few statistically significant differences in consistency of tempo judgements were found as a result of musical background. The findings strongly suggested that the style of musical examples influenced the degree of tempo consistency across trials. Moreover, there was statistically significant evidence that an increase of familiarity with, and preference for, the musical examples and the musical styles resulted in an increase of consistency of correct tempo judgements. The study concludes with recommendations for music education.

Introduction

The question "Do listeners possess a concept of correct tempo for a piece of music, and if so, is this concept consistent?" is the main theme of this study. But there is also a

ISSN 1461-3808(print)/ISSN 1469-9893(online)/00/010025-20

second question, more difficult to answer, that underlines its intent: "Do listeners possess a time sense and ability for the proper pacing of time which enables them to render stable tempo judgements over a period of time?". The literature on stability of tempo perception is far from consistent on these questions.

Most experimental investigations concerning consistency of tempo choices were performed around the first half of this century (Frischeisen-Köhler, 1933; Harrison, 1941; Miles, 1937; Mishima, 1956; Rimoldi, 1951; Wallin, 1911). Most commonly, subjects had to tap their responses on a telegraph key or to listen to metronomic clicks proceeding at different rates, and were then asked which tempo was felt to be more appropriate. Generally, findings showed that subjects tended to be relatively consistent in their preferred rates.

More recently, two studies by Clynes and Walker (1982, 1986) on temporal stability in musical performance are worth noting. Repeated musical performance by the same musicians and of the same compositions were timed over a number years. The research findings suggested a high degree of consistency and precision in the execution of musical tempo. The researchers reasoned that music appeared to engage and programme a psychobiologic clock, or clocks, which functioned subconsciously, but which gave conscious read-outs, and thereby seemed to guide the performers' realisation of musical tempo in an exact and stable manner. These findings are consistent with those of Winckel (1962) who recorded and analysed the tempi of a symphony orchestra in several performances of the same compositions over several years at different concert halls. Similarly, Wagner's (1974) timing of different performances on the piano of the same piece by Herbert von Karajan showed highly consistent tempi.

With respect to this point about tempo stability in music performance, Epstein (1985) claimed:

> So powerful is this 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)

In addition to tempo studies that employed listening to stimuli like metronome clicks, tapping tasks or music performance, of particular interest were those investigations (Behne, 1972; Farnsworth, Block & Waterman, 1934; Halpern, 1988; Lapidaki & Webster, 1991; Levitin & Cook, 1996) that asked the listener to make judgements about the correct tempo of musical examples with mechanical or electronic devices (e.g. Duo-Art player piano with a tempo lever, the Springer-machine, or the software interface on computers) that allowed for variable tempo control over the musical stimulus.

More specifically, Farnsworth *et al.* (1934) and Halpern (1988) investigated the consistency between the 'perceived' and the 'imagined' correct tempo of stimuli. The perceived correct tempo was set by manipulating the tempo lever of a player piano or the computer interface, respectively, while the stimuli were played in real time. The imagined tempo was demonstrated by tapping in the Farnsworth *et al.* study, and by setting the metronome to coincide with what the subject imagined to be the correct tempo, in the Halpern study. The findings of both experiments reported relative consistency between the perceived and the imagined correct tempo. Both sets of results seem to indicate that there is one tempo consistently associated with familiar listening examples.

Furthermore, Levitin and Cook (1996) conducted a similar study in order to investigate if we remember a song in its original tempo. Forty-six college students, not selected

for their musical background, were asked to choose a song they knew very well among 58 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 tempo of each subjects' reproduction was then compared with the actual tempo of the excerpt on the CDs. Results showed that long term memory for tempi of well-learned songs is very accurate.

These studies were important because of their use of real musical stimuli with hardware that allowed subjects to have control over tempi. Nevertheless, they were limited in that they merely investigated well-known tunes, such as dance music (Farnsworth *et al.*) or familiar Popular songs (Levitin & Cook, Halpern). Moreover, these experiments were conducted solely with non-music major students.

Interesting as their results may be, they do not demonstrate whether judgements of correct tempo are consistent across separate trials over an extended period, especially when subjects are presented with musical compositions chosen because they represent a wide range of musical styles and familiarity. It also seemed important to investigate how tempo judgements might differ among subjects with different musical backgrounds.

To investigate these issues, Lapidaki and Webster (1991) conducted a study in which the subjects were 15 highly experienced musicians and 5 subjects who had little formal music education or involvement in musical activities. Three music examples were chosen (J.S. Bach's "Air in D Major" from the Suite Number 3 in D major; Chopin's Prelude Number 7, Op. 28 and Schoenberg's second piece from "6 Kleine Stücke" Op. 19) to represent a wide range of musical styles and familiarity. The findings of this 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 judgements. Simply stated, no single correct tempo emerged as a consistent entity of individual or group performance across the three trials. The sample of adult non-musicians indicated a basis for a similar conclusion. Nevertheless, this tended to vary according to the composition in question. These results did not support the observations reported by Farnsworth *et al.* (1934), Halpern (1988) and Levitin and Cook (1996) that one tempo is consistently associated with particular listening examples. On the contrary, listeners' perceptions of correct tempo for a particular composition varied dramatically from trial to trial. Few statistically significant differences in consistency of tempo judgements were found as a result of musical background and compositional style. Many of these tendencies suggested questions for further study.

It was obvious, however, that additional work was necessary with larger and more varied musical samples, and with better measures of individual familiarity with, and preference for judged compositions. Also of interest would be how these judgements might differ amongst subjects from different age groups and musical backgrounds.

The Study

The present study, therefore, followed this up by investigating the consistency of tempo judgements over a period of time observed in individuals during the listening process. More specifically, the purpose of the study was to examine the consistency of 'correct' tempo judgements of compositions of various musical styles among subjects with differing musical backgrounds, ages, familiarity with, and preference for selected music. Correct tempo is seen here as a *subjective* unifying construct of music in the listener's

mind whose function is the meaningful synthesis of musical elements in real time (Barry, 1990). It should be noted that the study was about the extent to which individuals can set consistent tempi across four separate trials. No attempt was made to establish whether or not these tempi were the same as those set by the composers in the original pieces. It was reasoned that if a 'correct' tempo did exist, subjects ought to be able to arrive at consistent judgements about the tempo of examples despite the examples being presented with differing initial tempi in every session.

The majority of empirical studies on tempo perception have been carried out on adults (Farnsworth *et al.*, 1934; Halpern, 1988; Hodgson, 1951; Lapidaki & Webster, 1991; Levitin & Cook, 1996; Lund, 1939). However, there is general agreement that the experience of musical time is not separable from the subjects' age (Bamberger, 1994; Petzold, 1963; Shuter-Dyson & Gabriel, 1981; Zenatti, 1993). To counter this deficiency, it has proved necessary to investigate the following question: "Is the capacity for consistent tempo judgements for particular pieces of music affected by the age of listeners (e.g. preadolescents, adolescents and adults)?". Once the age question has been answered, it might then be possible to set varied music educational standards for each age level by considering the often overlooked development of temporal perception in students and, in turn, create a more effective condition for the growth of musical experience.

Furthermore, the capability to perceive different musical parameters, such as tonality, harmony, form and rhythm, without being able to identify and analyse them, is considered to be the outcome of implicit musical knowledge or acculturation (Hargreaves, 1986; Francés, 1958, 1988; Bigand, 1993). In other words, in this situation what listeners know is not something they are aware of knowing, but rather it is acquired from knowledge that is implicitly or subconsciously built into their auditory systems through common everyday exposure to music in their cultural environment. There is general agreement among researchers, on the other hand, that this knowledge becomes explicit or conscious only after musical training (Dowling, 1993). In essence, musicians presumably possess a fuller understanding and appreciation of a piece of music, due in part to having a sophisticated scheme or set of rules for encoding musical events, in terms of musical meanings. Thus, they are able to assign to it a stable, structural description (Sloboda, 1994; Dowling, 1994; Wolpert, 1990; Lerdahl & Jackendoff, 1983). The study was therefore concerned with whether the listeners' musical background, that is, the level of formal music education and/or participation in specialised musical activities, affected the consistency in the perception of the correct tempo.

Another issue that this study investigated was whether the stylistic framework in terms of which listeners interpreted the specific musical examples influenced tempo consistency. According to Rosen (1972), the musical elements that make up the synthesis of a work of music, amongst which tempo appears to have an important role, "… cannot be divorced from its affective and sentimental, as well its intellectual, significance within the work and, consequently, more generally within the stylistic language" (p. 21). With respect to this point about the significance of style on perception, Barry (1990) pointed out:

> It [style] allows us to *adopt relevant criteria* which limit and direct attention onto specific areas for example, information relevant to a string quartet as distinct from a Mass setting; criteria for Baroque style, or comparing Pergolesi's original music with Stravinsky's reworking in *Pulcinella*. Such criteria

> are both the signposts bearing directions, and the lenses which focus attention on the work. (p. 23, original italics)

It was also assumed that familiarity with the musical examples and/or their respective musical styles or genres might affect consistency of judgements concerning 'correct' tempo. Familiarity with the relevant musical idiom or musical piece gained from prior formal or informal exposure to music contributes to the listener's ability to extract meaningful criteria that help to make sense of what is heard (Barry, 1990). According to Lerdahl and Jackendoff (1983), once a listener "becomes familiar with the idiom, the kind of organisation that he attributes to a given piece will not be arbitrary, but will be highly constrained in specific ways" (p. 3). Furthermore, there is ample evidence that children seem to show culturally favoured responses to music as they spontaneously or subconsciously become familiar with musical sounds heard in their social environment (Francés, 1988; Hargreaves, 1986; Imberty, 1981; Zenatti, 1993).

While there has been a large number of studies on the effect of tempo on listening preferences, inquiries on the nature of tempo perception have failed to take adequate account of the effects of familiarity. One reason for this seems to be that most musical material used in tempo research consists of music which is likely to be familiar to the subjects (Farnsworth *et al.*, 1934; Halpern, 1988; Levitin & Cook, 1996; Sheldon, 1994). Geringe & Hadsen (1987) also found a marked influence of excerpt familiarity on listeners.

Finally, it seemed worth considering whether musical preference might influence consistency of tempo judgements. The musical stimuli were therefore selected in order to vary widely in their likely preference to the listeners. The term 'preference' is seen here to reflect an individual's relatively transitory liking for one musical piece as compared with another (Hargreaves, 1988; Konecni, 1982; Zenatti, 1993). For instance, it is likely that listeners of the same age group with similar musical training and cultural background may not elicit judgements of a composition's correct tempo in a uniform way, or with the same degree of consistency over time. Because of their individual likes and dislikes in music, some listeners will tend to have a more positive attitude to some musical excerpts than others during the listening process, with a correspondingly higher degree of attention to, and concentration on, the organisation of musical events. For that reason, they may want to explore the preferred excerpts further or be more eager to arrive at a judgement (LeBlanc, 1987). As Barry (1990) noted:

> Individual preference as a selector highlights the importance of attention for perception…. Further, since organisation is a function of musical time, the way that time is felt to pass in music is also dependent on attention. (p. 21)

Moreover, the issue of preference seemed to be particularly crucial for the present study, since it uses large-scale pieces of music. According to Barry (1990), "individual preference plays a much larger and more important part in substantial sections or complete musical works than in the very short, stylistically neutral material used in many experiments in musical perception" (p. 21). Finally, it is worth noting that no other study in tempo perception appears to speak directly to the question of preference. As Hargreaves (1988) rightly pointed out. "When preferred styles are employed in experiments alongside the "high art" works that are the most common stimuli in psychological research on the arts, the results may be quite different" (p. 58).

Research Questions

Six specific questions were posed:

1 Is there a consistent judgement of 'correct' tempo, over four separate sessions, of the same musical examples using varying initial tempi on each occasion?
2 Is the consistency of tempo judgement affected by the age of the listener?
3 Is the consistency of tempo judgement affected by the musical background of the listener?
4 Is the consistency of tempo judgement affected by the style (or genre) of music?
5 Is the perception of tempo affected by (a) the familiarity or unfamiliarity (novelty) with the individual pieces and (b) the overall style the music?
6 Is the consistency of tempo judgement affected by the listener's preference for a particular musical example?

Methodology

Characteristics and Selection of Musical Examples

The six music examples used were: *C-major* and *A-minor Two-Part Inventions* (c. 1720) by J.S. Bach (Baroque); *Clair de Lune* from the "Suite Bergamasque" (1905) by Claude Debussy (Impressionist); *Piano Piece* (1993) by Michalis Lapidakis (Contemporary); *Yesterday* (1965) by John Lennon and Paul McCartney (Pop ballad); and *The Children of Piraeus* by Manos Hadjidakis (1960), title song for the film "Never on Sunday" by Jules Dassin, featuring Melina Mercouri (Dance music).

The musical examples used in the present study traverse almost three centuries. It was felt that the listening material should reflect the various degrees of flexibility set by composers with regard to the interpretation and perception of tempi. Nevertheless, due to the time constraints for each session, it appeared essential to limit the number of the stylistically diverse examples. Based on my experience with using listening examples in the classroom, all pieces were approximately one to two minutes in duration. The length of the musical examples appeared to be long enough to provide a more comprehensive interaction with the music, yet short enough to keep subjects' attention.

All examples were chosen because they represented a wide range of style, familiarity, and preference. For the sake of uniformity, all musical examples were chosen from the piano repertoire, except *The Children of Piraeus* and *Yesterday* which were originally composed for voice and instrumental ensemble. Both these pieces were recorded in piano versions for this study.

Only complete compositions were used as listening examples, so that listeners could have a sense of musical context, in contrast with stylistically neutral, trivial or fragmented auditory material used in many studies in music perception.

Subjects

In view of the four individual sessions for each subject, and the volume of data that would be generated, the maximum number of participants in the study was set at 90 ($n = 90$). Thirty were adults (28–52-years-old), 30 were adolescents (16–18-years-old) and 30 were preadolescents (10–12-years-old). Thus, there were three developmental stages or age groups, with 30 subjects per group. Within each age group half the subjects were musicians and half were non-musicians.

Adult Subjects. The adults ($n = 30$) used in the study were not sampled, but rather recruited on the basis of a set of criteria: age (28–52-years-old) and musical background. With regard to musical background, the group of adult musicians represented a wide array of significant experience in music. It consisted of 15 North American and Greek individuals from a pool of musicians who have strong career profiles. In addition, all subjects, except four, held a graduate degree in music from a European or a North American university.

The 15 adult non-musicians were professionals in fields other than music; all held a graduate degree in different disciplines. These individuals had no training in music but did have wide ranging backgrounds in music listening consistent with what might be expected for well-educated adults.

Adolescent subjects. The adolescents ($n = 30$) who participated in the study were junior and senior students (16–18-years-old) enrolled in a public high school in the United States. In selecting the high school for the study, a school was sought that met the following criteria in its music curriculum: (a) sufficient opportunities to experience music through performance; (b) a variety of musical media, such as choral groups, orchestra, bands, electronic and acoustic instruments, and ensembles with mixed instrumentation; and (c) the preparation of students for future professional involvement with music. The high school that met the characteristics cited above more than adequately is located in a northern suburb of Chicago and serves a generally affluent community. The makeup of the student body is approximately 82 percent Caucasian and 18 percent minority groups.

After consultation with the director of the high school's music program and orchestra conductor, 15 junior and senior students were randomly chosen to participate in the study from a pool of 25 orchestra members who had instrumental training and/or participation in a musical ensemble as members or soloists for more than six years. With regard to the adolescent non-musicians, a chemistry teacher and an English teacher at the same high school were asked to select junior and senior students from their classes who had never participated in the school's music programme or had had no music lessons or involvement in any kind of musical activity. A total of 46 students met the above criteria to comprise a pool from which 15 students were randomly selected.

Preadolescent Subjects. The preadolescents ($n = 30$) who participated in the study were fifth and sixth grade students (10–12-years-old) recruited from a pool of students at an independent Greek school in the Chicago metropolitan area. Like other ethnic groups in the United States, Greek-Americans demonstrate a strong connection with their language, heritage and culture which is transmitted to the younger generations through the Greek schools. These are private schools that children attend twice a week for approximately 3–4 hours each session, in addition to their attendance at public or private American elementary schools. In selecting this particular school for the study, an educational environment was sought that met the following conditions: (a) all students were comparable in ethnic background, socio-economic milieu and community traditions; (b) the school director, the teachers, the parents and the students were willing to support the study on the basis of scheduling and accessibility of private testing space.

In accordance with the district's request and the University's guidelines for research with human subjects, a consent form was sent home to parents of all students in the two fifth-grade classes and the sixth-grade class. From the replies 15 musically active students were identified by their teachers. The 15 non-musicians were randomly selected from each of the 3 classes.

Apparatus

Musical examples were performed on a Yamaha P-150 digital piano connected to a Macintosh computer that registered performance data in MIDI files format by means of a sequencing program. For the playback of the performance, data was stored in MIDI files in the microcomputer. The MIDI sound generator, Roland Sound Canvas SC-55, was used which was connected via an Opcode MIDI Translator to a Macintosh computer and a Peavey KB15 amplification/speaker system. "Piano 1" was the timbre of sound output and "Room 1" the sharply defined reverberation effect that simulates the natural echo of a room with a broad spread. Besides its realistic quality of piano sound, the Sound Canvas was used because of its compact size which allowed for its easy transportation to the various testing sites.

The software program used for both recording and playback of performance data was the professional MIDI sequencing program *Performer* from Mark of the Unicorn. This program was chosen mainly because of its ability to alter the graphic window display on the computer screen so that the metronome controls could be easily manipulated. In addition, the program had the capacity to vary the tempo precisely, without altering any other musical attributes (e.g. pitch, timbre, articulation, etc.).

The initial tempo of each musical example could be easily set by the experimenter prior to each session, and the mouse was used by the experimenter to manipulate the tempo, following the explicit directions of each subject. Set in manual tempo mode, the tempo slider of the graphic window display on the Macintosh was used to display and change the tempo, in real time, in the metronome window. Subjects were not asked to use the mouse themselves, since to do so would have required training for a number of subjects.

Procedures

Each subject was tested individually by the experimenter (author) in a private room, isolated from outside noise. All adults were tested at the experimenter's home music studio. The high school and elementary school students were tested in rooms made available to the experimenter in their respective schools. In all sites the testing set-up was identically arranged to ensure continuity. The computer was facing the experimenter and shielded from the subject's view, as it was felt that the subject ought not to view the tempo displayed on the screen while listening in order to minimise distractions in the decision making process.

For the four testing sessions, subjects were asked to listen to each composition and indicate whether the experimenter should set the tempo 'faster' or 'slower' until it sounded right to them. Each subject was encouraged to take as much time as was needed and to listen to the composition as often as necessary.

The following instructions were given to each of the subjects by the experimenter at the beginning of each piece in all four testing sessions: "I want you to help me find the tempo which you feel most comfortable with for this particular piece. There is no trick involved or right or wrong answer. If you want the tempo to increase, say 'faster' and, if you want it to decrease, say 'slower'. Then, when you have found the 'right' tempo, that is the most appropriate tempo for the piece in your opinion, tell me. There is no time restriction. Are you ready to begin?".

The experimenter changed the tempo as directed until the subject was satisfied. When the subject indicated that the tempo sounded right, the experimenter recorded the

TABLE 1. Order and initial tempi of musical examples in each trial

1st Trial		2nd Trial	
Musical Examples	Initial Tempo M.M.	Musical Examples	Initial Tempo M.M.
1.	20	1.	200
2.	200	2.	20
3.	20	3.	200
4.	200	4.	20
5.	20	5.	200
6.	200	6.	20
3rd Trial		**4th Trial**	
Musical Examples	Initial Tempo M.M.	Musical Examples	Initial Tempo M.M.
1.	20	1.	200
2.	200	2.	20
3.	20	3.	200
4.	200	4.	20
5.	20	5.	200
6.	200	6.	20

Notes: [a]Bach I refers to the *C-major Two-Part Invention*; [b]Greek dance refers to Hadjidakis' *The Children of Piraeus*; [c]Bach II refers to the *A-minor Two-Part Invention.*

metronome value, and then reset the computer for the next composition in the session. Once the six compositions were judged, the subject was asked to return within at least four days time for the next session. This slow pacing of trials was adopted in order to prevent memory carryover from one trial to another.

Each session for each subject systematically varied the order of the compositions and the initial tempo of the listening examples in order to eliminate the possibility of contextual cues. Two initial tempo were used: M.M. = 20 and M.M. = 200; all tempo judgements in the Lapidaki and Webster study (1991) had lain within this range. Each initial tempo was repeated twice: either in the first and third or in the second and fourth trials. Table 1 illustrates the order and the initial tempi in which the six examples were presented to subjects in the four testing sessions. All judgements were recorded by noting the beats per minute, usually referenced as the metronome marking (M.M.). These values were used as continuous scales for the statistical analyses.

In order to examine subjects' familiarity with the listening examples a questionnaire was handed to them at the beginning of the first testing session. Subjects were asked to answer questions concerning their familiarity with the music and its relevant style, after they had judged the correct tempo of the example. Subjects had to rank their familiarity with each piece on a scale of five levels based on the times they had heard the musical examples prior to the first trial (i.e. familiarity level 1 = *Never*, 2 = *Once, 3 = 2 to 5 times*, 4 = *6 to 10 times* and 5 = *more than 10 times*). Subjects had to rank their familiarity with each style on a scale of three levels (i.e. familiarity level 1 = *I just do not know this style at all*, 2 = *I have heard music of this style, but not very often* and 3 = *I really know this style of music*). Finally, with regard to the question of their individual preference for a particular musical example, subjects were asked to rate it on a scale ranging from 1 (*least-liked* or *poor*) to 4 (*most-liked* or *excellent*), after they

judged the correct tempo of the example at the fourth testing session. This information was recorded and used in later analyses.

Results

Consistency of Tempo Judgements across Trials

To test the hypothesis that listeners would make consistent judgements of tempo independently from the initial tempi, a one-way repeated measures ANOVA for each musical example was performed using tempo judgements across all subject groups at each of the four trials. The results for these analyses show that listeners did not exhibit significant consistency in their judgements across the four trials (Bach I, $F = 84.43$, $p < .0001$; Bach II, $F = 86.27$, $p < .0001$; Debussy, $F = 80.37$, $p < .0001$; Lapidakis, $F = 139.07$, $p < .0001$; Beatles, $F = 59.02$, $p < .0001$; Greek dance, $F = 78.856$, $p < .0001$).

Further examination of the average means across all subject groups for all trials of each musical example revealed that both means of tempo judgements for the trials with the fast initial tempi were higher than the means for the trials with the slow initial tempi with respect to all musical examples (see Tables 2a and 2b). In other words, there was a clear relationship between the initial tempi and listeners' final choices of most-appropriate tempo: the slower initial tempo generally evoked slower preferences, and so on.

Given this finding, it seemed appropriate to investigate differences between listeners' tempo judgements observed at trials with the same initial tempo (i.e. differences between trials 1 and 3, and trials 2 and 4). An independent samples paired t-test was performed for each musical example. The results did not show evidence that repetition of the fast initial tempo evoked more consistent judgements than the repetition of the slow initial tempo.

Age

To test the effect of age on the consistency of tempo judgements, the most appropriate way would be to perform a one-way repeated measures ANOVA for each listening example using tempo judgements of trials and age as variables. However, the sphericity assumptions for the univariate test for an age effect were clearly violated (p value $= 0.0000$).[1] Therefore, either a repeated measures MANOVA procedure or the adjusted univariate test had to be utilised for each musical example. Both analyses led to the same conclusion, namely that consistency of tempo judgements across the four trials for all examples were significantly influenced by the age group of the listener ($p < .02$).

Furthermore, in order to ascertain which age group exhibited the highest degree of consistency, the individual deviation scores (IDS) averaged over the four trials of each piece were used as an additional measurement of consistency of judgement. IDS reflect the standard deviation of the four different tempo judgements (Y1, Y2, Y3 and Y4) at the four trials for an individual.

IDS gives a more global sense for the deviations of each group. IDS was used as a primary response variable to answer questions about consistency associated with other factors of interest such as age, musical background, familiarity and preference. As shown

TABLE 2a. Average cell means for tempo judgments across all subject groups from individual trials of Bach I, Bach II and Debussy

Musical Examples	Trial average Mean	F
BACH I		
Trial 1: Slow I. T. (Initial Tempo)	53.000	
Trial 2: Fast I. T.	115.289	84.425*
Trial 3: Slow I. T.	58.389	
Trial 4: Fast I. T.	113.956	
BACH II		
Trial 1: Fast I. T.	158.200	
Trial 2: Slow I. T.	95.089	86.271*
Trial 3: Fast I. T.	147.900	
Trial 4: Slow I. T.	103.644	
DEBUSSY		
Trial 1: Fast I. T.	119.678	
Trial 2: Slow I. T.	63.667	80.367*
Trial 3: Fast I. T.	107.989	
Trial 4: Slow I. T.	60.200	

Note: $n = 90$. *$p < .0001$.

TABLE 2b. Average cell means for tempo judgments across all subject groups from individual trials of Lapidakis, Beatles, and the Greek dance

Musical Examples	Trial average Mean	*F*
LAPIDAKIS		
Trial 1: Fast I. T. (Initial Tem)	171.000	
Trial 2: Slow I. T.	82.144	139.072*
Trial 3: Fast I. T.	162.933	
Trial 4: Slow I.T.	86.733	
BEATLES		
Trial 1: Slow I. T.	83.878	
Trial 2: Fast I. T.	120.989	59.024*
Trial 3: Slow I. T.	88.000	
Trial 4: Fast I. T.	121.132	
GREEK DANCE		
Trial 1: Slow I. T.	93.978	
Trial 2: Fast I. T.	144.556	78.856*
Trial 3: Slow I. T.	95.600	
Trial 4: Fast I. T.	138.844	

Note: $n = 90$. *$p < .0001$.

in Table 3, results clearly indicated that adults were the most consistent and preadolescents the most inconsistent with regard to all musical examples ($p < .001$). In other words, the following consistency scale for all musical examples was observed with respect to the three age groups: preadolescents < adolescents < adults.

TABLE 3. Cell means for Individual Deviation Scores (IDS) averaged over the four trials arranged by musical example and subjects' age groups from ANOVA procedure

Musical Examples	Age Groups: Pre-adolescents[a] *M*	*Sd*	Adolescents[a] *M*	*Sd*	Adults[a] *M*	*Sd*	*F*
BACH I	51.168	35.200	39.592	35.200	18.592	25.733	8.90*
BACH II	49.654	26.973	37.046	21.557	22.769	23.376	9.37*
DEBUSSY	48.962	23.336	42.058	22.661	15.511	20.434	19.02*
LAPIDAKIS	64.351	28.047	55.758	30.590	37.551	30.765	6.31*
BEATLES	43.466	21.085	15.260	12.264	11.094	17.947	30.44*
GREEK DANCE	41.404	26.969	36.685	20.589	14.613	18.628	12.29*

Note: $n = 90$. [a]$n = 30$. $p < .001$.

Musical Background

To examine the effect of musical background, a repeated measures MANOVA for each musical example was employed using tempo judgements of each trial and musical background as variables. The reason that the regular repeated measures univariate analysis of variance (ANOVA) was not performed was that data did not exhibit sphericity. The results showed that the musical background of the listener did not significantly affect consistency of tempo judgements for all six pieces (Bach I, $F = 0.79$, $p < .01$; Bach II, $F = 0.73$, $p < .01$; Lapidakis, $F = 0.73$, $p < .01$; Beatles, $F = 0.47$, $p < .01$; Greek dance, $F = 0.97$, $p < .0001$), with the exception of the Debussy composition ($F = 4.00$, $p < .01$).

To investigate whether musicians were more consistent than non-musicians, an independent samples *t*-test was performed which used IDS among the trials of each piece as an additional measurement of tempo judgement consistency (see Table 4). The results clearly indicated that the only time musicians and non-musicians differed in consistency of tempo judgements was in the Debussy ($p < .01$).

TABLE 4. Cell means for Individual Deviation Scores (IDS) averaged over the four trials arranged by musical example and subjects' musical background (i.e. musicians and non-musicians) and *F* ratio from an independent samples *t*-test procedure

Musical Examples	Musical Background: Musicians[a] *M*	*Sd*	Non-musicians[a] *M*	*Sd*	*F*
BACH I	33.025	36.564	40.039	28.162	1.69
BACH II	33.305	26.237	39.673	26.145	1.01
DEBUSSY	27.235*	24.575*	43.786*	25.570*	1.08*
LAPIDAKIS	49.818	30.926	55.289	32.290	1.09
BEATLES	21.804	20.249	24.743	24.249	1.49
GREEK DANCE	27.981	23.292	33.820	26.578	1.30

Note: $n = 90$. [a]$n = 45$. *$p < .01$.

Musical Style

A repeated measures ANOVA procedure using style as the experimental factor (five levels corresponding to the five different musical styles of the pieces) was used, and the mean number of IDS averaged over the four trials of each style as the response variable was performed. The results revealed that the Pop ballad exhibited the highest degree of consistency ($M = 23.27$, SD = 22.54) followed by the Greek dance music ($M = 30.90$, SD = 25.02), Impressionism ($M = 35.510$, SD = 26.29) and Baroque ($M = 36.51$, SD = 29.53 (Bach I, $M = 36.53$ and Bach II, $M = 36.49$)), respectively ($F = 13.68$, $p < .0001$). The tempo judgements for the Contemporary piece were the least consistent among all styles ($M = 52.55$, SD = 31.56). In other words, the following consistency scale with respect to the musical styles was observed in subjects' tempo judgements: Pop ballad < Greek dance music < Impressionism < Baroque < Contemporary.

Familiarity with Musical Examples

To investigate the effect of familiarity level on tempo judgements, a repeated measures MANOVA was performed using tempo judgements for each example averaged over the four trials and the five familiarity levels based on the times they had heard the musical examples prior to the first trial (i.e. familiarity level 1 = *Never*, 2 = *Once*, 3 = *2 to 5 times*, 4 = *6 to 10 times* and 5 = *more than 10 times*) as variables. The results indicated that familiarity with musical examples significantly influenced tempo judgements ($p < .001$). A repeated measures ANOVA was performed using familiarity levels as the experimental factor and the mean number of IDSs averaged over the four trials of each musical example as the response variable (see Table 5). The results showed that an increase of familiarity had a significant effect on consistency of tempo judgements for all musical examples (Familiarity level 1, $M = 46.51$, $SD = 28.71$; level 2, $M = 42.802$, $SD = 27.80$; level 3, $M = 34.13$, $SD = 28.04$; level 4, $M = 24.13$, $SD = 18.56$; level 5, $M = 13.13$, $SD = 17.64$, $F = 25.17$, $p < .05$). Concerning the Lapidakis composition, the familiarity effect could not be estimated, since there was only one level of familiarity among all subjects (i.e. familiarity level = 1).

Familiarity with Style

All subjects had to rank their familiarity with each style on a scale of three levels (i.e. level 1 = *I just do not know this style at all*; 2 = *I have heard music of this style, but not very often* and 3 = *I really know this style of music*). A repeated measures ANOVA was employed using IDSs after averaging over trials and familiarity levels as variables. The results showed that an increase of familiarity with the style of the musical examples resulted in an increase of tempo judgement consistency (overall $F = 43.38$, $p < .0001$).

With respect to each individual style, the ANOVA tests of significance demonstrated that increased familiarity with the styles of Baroque ($F = 17.23$, $p < .0001$), Impressionism ($F = 11.57$, $p < .0001$), Pop ballad ($F = 40.22$, $p < .0001$) and Greek dance music ($F = 7.92$, $p < .0001$) significantly influenced the degree of consistency of tempo judgements. However, greater familiarity with the contemporary idiom did not lead to more consistent choices of the most appropriate tempo for the *Piano Piece* by Lapidakis ($F = 0.99$, $p < .0001$).

TABLE 5. Cell means for Individual Deviation Scores (IDS) averaged over the four trials arranged by musical example and level of familiarity reflected in number of times of previous listenings from ANOVA procedure

Musical Examples		Level of Familiarity 1 (Never)	2 (Once)	3 (2–5 times)	4 (6–10 times)	5 (>10 times)	F
		n	*n*	*n*	*n*	*n*	
BACH I		51	6	11	8	14	
	M	43.561	53.915	35.213	27.387	9.740	4.02*
	SD	34.348	33.297	34.108	19.117	8.921	
BACH II		56	7	13	2	12	
	M	42.429	37.232	24.867	31.864	21.702	2.48*
	SD	25.879	28.934	15.302	40.390	27.925	
DEBUSSY		63	3	9	6	9	
	M	44.700	23.918	23.899	11.098	2.935	10.29*
	ST	23.853	22.859	23.445	11.612	2.512	
LAPIDAKIS		90	—	—	—	—	
	M	52.554	—	—	—	—	—
	SD	31.558	—	—	—	—	
BEATLES		7	3	8	6	66	
	M	59.381	66.410	44.022	36.071	13.804	26.42*
	SD	12.628	27.560	16.691	15.570	14.942	
GREEK DANCE		23	7	12	11	37	
	M	44.241	46.940	50.851	27.472	14.123	13.06*
	SD	18.816	23.236	30.627	16.579	17.005	
Overall		283	23	45	27	72	
	M	46.506	42.802	34.131	24.133	13.135	25.17*
	SD	28.714	27.799	28.036	18.563	17.638	

Note: n = number of subjects out of 90 in each familiarity level.
*$P < 0.05$.

Preference

A repeated measures ANOVA procedure was performed using preference levels as the experimental factor and the mean number of IDSs averaged over the four trials of each example as the response variable. The results revealed that there was a significant influence of the degree of preference on consistency, with the exception of the Greek dance music ($F = 0.01$, $p < .001$), Lapidakis ($F = 2.29$, $p < .001$) and the Beatles ($F = 0.28$, $p < .001$). In other word, with regard to Bach I ($F = 6.07$, $p < .001$), Bach II ($F = 9.20$, $p < .001$) and Debussy ($F = 15.81$, $p < .001$), consistency clearly increased with preference.

Discussion

Consistency of Tempo Judgements across Trials

The results show little evidence to support the claim that correct tempo judgements are consistent in the face of initial tempo changes. It is quite clear that when tempo is judged in repeated listening tasks of the same compositions, the initial tempo has a dominant effect on judgements: the slower initial tempo generally evokes slower tempo selections, and so on.

However, it should be stressed, in this respect, that a relatively small number of adults, mostly musicians, were remarkably consistent in their tempo judgements across all four trials. It appears that these individuals possess an exceptional ability with respect to acute stability of large-scale timing in music. This ability to give, over time, consistent tempo judgements to a piece of music in conditions seemingly devoid of an external tempo reference (a score or the physical interaction involved in performance) may be referred to as *absolute tempo* (analogous to absolute pitch). Interestingly enough, these subjects

reported that they were surprised when they heard that their right tempo choices were virtually precise across trials. In addition, it seems that physical, psychological and environmental factors such as fatigue, mood or time of day, do not have an effect on the ability to make consistent tempo judgements. Another proposal is that absolute tempo is a form of 'implicit cognition' that has been the subject of increasing interest and debate in the most recent psychological research (Dorfman, Shames & Kihlstrom, 1996, p. 259; Underwood & Bright, 1996). The term implicit cognition has been used to characterise situations in which mental processes can influence perception outside of phenomenal awareness and voluntary control. For example, implicit cognition can refer to a subject's behaviour that is shown to be influenced by stimulus events such as tempo changes too subtle to be consciously perceived (Lapidaki, 1990). Concerning consistency of correct tempo judgements, Epstein (1995) summarised 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).

Finally, absolute tempo was noticed with regard to those musical examples with which listeners were familiar. Nevertheless, taken in isolation, this result should be interpreted with caution for a number of reasons. The major one is that these subjects did not exhibit absolute tempo with respect to all pieces with 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 of music. This leaves one wondering whether the stability is, to some extent, discrete more than continuous.

Age

There is evidence that the degree of consistency in correct tempo judgements gradually increases from preadolescence through adulthood. This should lead to the assumption that fluctuations among tempo judgements of the same pieces of music become smaller, as awareness of tempo develops with age. The interesting aspect of such an assumption is that tempo awareness does not appear to 'plateau' after the age of 10, as is the case with the perception of other musical parameters (Imberty, 1981). More specifically, when listeners between the ages of 10 and 12 are asked to choose the 'right' tempo for a piece of music, they tend to demonstrate an awareness of tempo which does not reflect simultaneous perceptual organisation and integration of other relevant musical features, such as harmonic, rhythmic and metric relationships. Therefore, preadolescents are experimenting with their 'correct' tempo selections with greater ease, which leads to greater tempo fluctuations across trials. In adolescence, tempo fluctuations become smaller. Finally, by adulthood, tempo perception is rather accurate, and thus tempo consistency greater. It is therefore likely, though not essentially certain, that only when the representation of music has stabilised in the mind through maturation, is the corresponding temporal consistency noticeable.

Musical Background

The musical background of the subjects may have some bearing on consistency of tempo judgements, but this study reveals no overall statistically significant results to support this contention. In fact, it seems that the musician's grasp of tempo behaviour is initially very similar to the non-musician's. A possible explanation, compatible with neuropsychological data as well as with Davidson's conclusions (1994) about song singing, is that

ability to make consistent tempo judgements in listening tasks is probably a maturational one, independent of music education. Nonetheless, this explanation is not necessarily true at high levels. In fact, results clearly indicated that adult musicians showed the smallest fluctuations in their tempo judgements and, thus, the highest degree of consistency.

Indeed, it must be acknowledged that musicians and non-musicians of all age groups significantly differed in consistency of correct tempo judgements for *Clair de Lune* by Debussy. It should be noted that this particular piece is the only case among the musical examples in which one notices a slow overall tempo and rapid movements within this slow tempo at the same time. Thus, tempo becomes a function not only of the beat rate but also of the number of unfolding events per unit of time.

This leads to the speculation that when musically experienced listeners chose the right tempo of a piece of music, they may use an integrated cognitive strategy that enables them to control and synthesise local-level temporal relationships into the large-scale, complex (yet hierarchic) and coherent musical structure. It is therefore crucial to entertain the possibility that musical training increases performance in listening tasks by alerting listeners' perceptual organisation of stimuli, especially when the regularity of stable musical patterns breaks down.

Musical Style

The findings strongly suggest that the style of the musical examples influenced the degree of tempo consistency across trials. Indeed, it becomes obvious that individual structural characteristics of the styles facilitate listener's criteria for determining 'correct' tempo. The style of Pop ballad exhibited the highest degree of consistency. Tempo judgements for the Contemporary piece were the least consistent among all styles. The results support the belief that tempo is not perceived entirely independently of the temporal, melodic and harmonic elements of a piece, but rather is part of its integrated sonic structure. On the one hand, regularity or consonance in both rhythmic and melodic elements facilitates tempo perception, as is the case of the Pop ballad. On the other hand, if the stylistic constraints of the piece are perceptually too demanding (complex) or unconventional in terms of typical rules of the tonal Western tradition, as is the case of the Contemporary idiom, listeners may not be able to develop a stable mental representation of the musical structure, and this results in corresponding temporal instability.

Familiarity

The results show that an increase of familiarity resulted in an increase of consistency of 'correct' tempo judgements for all examples. The straightforward implication of this evidence is that familiarity gained from formal or informal exposure to music, on the one hand, reinforces the ability to form a stable mental representation of music that enables the listener to render fairly stable tempo judgements across trials. On the other hand, novelty yields the opposite results. One might say that only when the representation of music has stabilised in the mind through familiarisation is the corresponding temporal consistency noticeable.

Moreover, there is statistically significant evidence that an increase of familiarity with the styles in question, except for the Contemporary idiom, significantly influenced the degree of consistency of tempo judgements. It is interesting that greater familiarisation with the Contemporary idiom did not lead to more consistent choices of most appropriate

tempo for the *Piano Piece* by Lapidakis. The reader should be reminded here that this composition was selected because it had never been publicly performed before the experiment. As a result, all subjects were unfamiliar with it.

This finding appears to suggest that exposure to, or familiarity with, the Contemporary musical idiom, which is not typical of conventional tonal grammar, does not appear to enhance our comprehension of 'right' tempo, nor the consistency of tempo judgements for Contemporary compositions. In this case, tempo consistency seems to depend on familiarity with the particular stimulus pattern that is heard rather than on familiarity with its style. Thus, one could argue that the Contemporary idiom does not set up a strong context that facilitates the formation of the concept of 'right' tempo for individual compositions. It is noteworthy, however, that both listeners who rendered absolutely consistent judgements across trials for the Lapidakis composition were composers.

Along these lines, it is worth noting that the finding of this study, regarding the effect of familiarity on tempo consistency in a listening task, may be compared with Clynes' and Walker's observation (1986). They found that the only time performances by the Sidney String Quartet showed low consistency was with the composition with which the string quartet was least familiar. According to the researchers: "Concepts need time to settle, to be established. This need of time for musical concepts to stabilise touches the essence of a musical concept" (p. 113).

The Variable of Preference

Tempo judgements across trials were significantly affected by subjects' preference for the listening examples. This implies that listeners tend to make more stable tempo judgements for the pieces they like than for the ones they dislike. A possible explanation is that listeners seemingly pay greater attention to the music which they prefer, noticing relationships within the large-scale musical organisation more thoroughly during the task of selecting the 'correct' tempo.

This explanation, however, does not imply that we cannot exhibit higher degrees of tempo consistency, or that we cannot listen attentively to something we do not like. For instance, it is quite likely that it was not necessary for listeners to like *Yesterday* by the Beatles, or *The Children of Piraeus* (the Greek dance) by Manos Hadjidakis (examples which received the highest ranking in familiarity), in order to exhibit great stability in their judgements for these pieces. Moreover, with respect to the *Piano Piece* by Lapidakis, which presented the greatest novelty amongst the listening examples, results also showed that preference did not significantly influence consistency of tempo judgements. Therefore, one might assume that familiarity or novelty has clearly a stronger effect than preference on tempo judgements here. However, it is obvious that many questions remain open at this point. It would therefore be premature to draw any firm conclusions.

Recommendations for Music Education

This study is based on the premise that tempo is a general cognitive constraint influencing the way we organise musical events in real time and, thus, make sense of them. Tempo constitutes an important element of music by enabling various sound events to be woven together in time. In turn, this temporal pacing is what gives music its unique motional, emotional and sensuous character, as has been acknowledged in

most discussions concerned with music aesthetics, theory and compositional or performance practice (Lapidaki, 1990).

If this is the case, then the development of a more refined or discerning concept of tempo in students should be considered crucial for a thorough understanding of the expressive qualities of music. Instead of focusing solely on reading of notated structural parameters of music (e.g. melody, rhythm, meter and the like), music instruction should promote the development of listening skills, especially with reference to those aspects of music which are more often represented imprecisely in conventional notation, as is the case with tempo (Lapidaki, 1992).

It is somewhat surprising to find, however, that tempo is commonly treated in music instruction at all levels as if it were solely applied to the metronome or to verbal designations. This leads us to believe that students are not supposed to have an awareness that tempo judgements lie deeply within the human mind which intuitively attempts to supply its own tempo to music. In other words, it is the relation of melody, phrasing, harmony, rhythm, timbre, dynamics, style and other musical features, to tempo that imbues them with a new and exciting perceptual dimension. Music educators can help students to gain a deeper sense of recognition and mastery of all kinds of relations in a piece of music by showing them the power that tempo exerts on their synthesis.

To help students of all ages find a use for the concept of tempo in music, music educators may consider the task used in this research, which proposes a creative and, most importantly, an intrinsically musical activity reflecting our need to organise and control the passage of time in music. More specifically, listeners were given the task of manipulating the tempo of a piece of music in real time while examining its influence on the way the music sounded. The ultimate objective was to come up with a tempo in which all elements of the piece would fit together naturally, in a 'right' pace.

On the one hand, listeners were provided with the opportunity to choose the most appropriate tempo in their opinion among a vast number of tempi available to them by means of the computer: something that cannot happen when you perform music, due to the technical limitations of the performer. On the other hand, listeners were faced with the problem of saying "this tempo is not correct" or "that tempo is correct" which is an important aspect of the creative process in music (Lapidaki, 1990).

However, in a real educational setting, students' musical decisions about tempo have to rest also on the teacher's guidance. The skilful music teacher will use musical materials, which are appropriate for each particular age level but will attempt to demonstrate how musical parameters are integrated and flow with a rightful pace in all music. The thoughtful use of examples, particularly from contemporary music and from music of various genres and cultures, may also help students to understand the different roles that tempo fulfils; aesthetic fulfilment, to inspiration of dance and song, to arousal of a certain emotional ambience. In addition, the teacher's suggestion that tempo is the parameter with the greatest degree of variability and possibility in music, will give students the freedom to experiment with music with greater ease and curiosity while focusing on the pacing of musical events.

Finally, by using tempo as a reference point in order to teach other musical elements we can open a new and intriguing dimension for listening. As Stockhausen (Cott, 1973) said referring to the importance of manipulating tempo in compositional practice:

> … a person who experiences this music becomes as much slower and as much faster in his reactions and experiential time as the music. This expands man [*sic*] and also his awareness of what music can be. (p. 193)

In this context, the finding that most listeners did not prove to be precisely consistent in their correct tempo judgements over a period of time becomes a secondary issue. Indeed, we all vary in the abilities with which our aesthetic perceptions operate. After all, we are not metronomes.

NOTES

[1] Test for Sphericity: Mauchly's Criterion = 0.0438711, Chi-square Approximation = 1681.188 with 5 df, Prob > Chi-square = 0.0000. Applied to orthogonal components: Test for Sphericity: Mauchly's Criterion = 0.0803042, Chi-square Approximation = 1356.0996 with 5 df, Prob > Chi-square = 0.0000.

REFERENCES

BAMBERGER, J. (1994) Coming to hear in a new way, in: R. AIELLO (Ed.) *Musical Perceptions*, pp. 131–151 (New York, Oxford University Press).

BARRY, B.R. (1990) *Musical Time. The sense of order* (Steyvesant, NY, Pendragon Press).

BEHNE, K.E. (1972) *Der Einfluß des Tempos auf die Beurteilung von Musik* [The Influence of Tempo on the Judgement of Music] (Köln, Arno Volk).

BIGAND, E. (1993) Contributions of music to research on human auditory cognition, in: S. MCADAMS & E. BIGAND (Eds) *Thinking in Sound. The Cognitive Psychology of Human Audition*, pp. 231–277 (Oxford, Clarendon Press).

CLYNES, M. & WALKER, J. (1982) Neurobiologic functions of rhythm, time and pulse in music, in: M. CLYNES (Ed.) *Music, Mind and Brain: the neuropsychology of music*, pp. 171–216 (New York, Plenum Press).

CLYNES, M. & WALKER, J. (1986) Music as time's measure, *Music Perception*, 4 (1), pp. 85–119.

COTT, J. (1973) *Stockhausen: conversations with the composer* (New York, Simon & Schuster).

DAVIDSON, L. (1994) Songsinging by young and old: a developmental approach to music, in: R. AIELLO (Ed.) *Musical Perceptions*, pp. 99–130 (New York, Oxford University Press).

DORFMAN, J., SHAMES, V.A. & KIHLSTROM, J.F. (1996) Intuition, incubation, and insight: implicit cognition in problem solving, in: G. UNDERWOOD (Ed.) *Implicit Cognition*, pp. 257–296 (Oxford, Oxford University Press).

DOWLING, W.J. (1993) Procedural and declarative knowledge in music cognition and education, in: T.J. TIGHE & W.J. DOWLING (Eds) *Psychology and Music. The Understanding of Melody and Rhythm*, pp. 5–18 (Hillsdale, NJ, Erlbaum).

DOWLING, W.J. (1994) Melodic contour in hearing and remembering melodies, in: R. AIELLO (Ed.) *Musical Perceptions*, pp. 173–190 (New York, Oxford University Press).

EPSTEIN, D. (1985) Tempo relations: a cross-cultural study, *Music Theory Spectrum*, 7, pp. 34–71.

EPSTEIN, D. (1995) *Shaping time. Music, the Brain, and Performance* (New York, Shirmer Books).

FARNSWORTH, P., BLOCK, H. & WATERMAN, W. (1934) Absolute tempo, *Journal of General Psychology*, 10, pp. 230–233.

FRANCÉS, R. (trans. 1988) *The Perception of Music* (trans. W.J. DOWLING) (Hillsdale, NJ, Erlbaum).

FRISCHEISEN-KÖHLER, I. (1933) The personal tempo and its inheritance, *Character & Personality*, 1, pp. 301–313.

GERINGER, J.M. & MADSEN, C.K. (1987) Pitch and tempo in recorded popular music, in: C.K. MADSEN & C.A. PRICKETT (Eds) *Applications of Research in Music Behavior*, pp. 204–212 (Tuscaloosa, AL, University of Alabama Press).

HALPERN, A.R. (1988) Perceived and imagined tempos of familiar songs, *Music Perception*, 6, pp. 193–202.

HARGREAVES, D.J. (1986) *The Developmental Psychology of Music* (Cambridge, MA, Cambridge University Press).

HARRISON, R. (1941) Personal tempo, *Journal of General Psychology*, 24 & 25, pp. 343–379.

HODGSON, W. (1951) Absolute tempo: its existence, extent, and possible explanation, *Proceedings of the Music Teachers National Association*, XLIII, pp. 158–169.

IMBERTY, M. (1981) Tonal articulation and perceptual structuring of musical time in children, in: *Basic Musical Functions and Musical Ability*, Publication No. 32, 2nd Edn, pp. 107–130 (Stockholm. The Royal Swedish Academy of Music).

KONECNI, V.J. (1982) Social interaction and musical preference, in: D. DEUTSCH (Ed.) *The Psychology of Music*, pp. 497–516 (New York, Academic Press).

LAPIDAKI, E. (1990) *L'Imagination au Pouvoir: some riddles on the issue*, Paper presented at the Indiana Symposium on Research and Teaching in the Philosophy of Music Education, Bloomington, IN.

LAPIDAKI, E. (1992) Time, in: B. REIMER & J. WRIGHT (Eds) *On the Nature of Musical Experience*, pp. 246–248. (Niwot, CO, The University Press of Colorado).

LAPIDAKI, E. & WEBSTER, P.R. (1991) Consistency of tempo judgments when listening to music of different styles, *Psychomusicology*, 10 (1), pp. 19–30.

LEBLANC, A. (1987) The development of music preference in children, in: C. PEERY, I.W. PEERY & T.W. DRAPER (Eds) *Music and Child Development*, pp. 137–157 (New York, Springer-Verlag).

LERDAHL, F. & JACKENDOFF, R. (1983) *A Generative Theory of Tonal Music* (Cambridge, MA, MIT Press).

LEVITIN, D.J. & COOK, P.R. (1996) Memory for musical tempo: additional evidence that auditory memory is absolute, *Perception and Psychophysics*, 58, pp. 927–935.

LUND, M. (1939) *An Analysis of the 'True Beat' in Music*. Unpublished doctoral dissertation, Stanford University.

MILES, D.W. (1937) Preferred rates in rhythmic response, *Journal of General Psychology*, 16, pp. 427–469.

MISHIMA, J. (1956) On the factors of mental tempo, *Japanese Psychological Research*, 4, pp. 27–38.

PETZOLD, R.G. (1963) The development of auditory perception of musical sounds by children in the first six grades, *Journal of Research in Music Education*, 21, pp. 99–105.

RIMOLDI, H.J.A. (1951) Personal tempo, *Journal of Abnormal and Social Psychology*, 46, pp. 280–303.

ROSEN, C. (1972) *The Classical Style. Haydn, Mozart, Beethoven* (New York, W.W. Norton).

SHELDEN, D.A. (1994) Effects of tempo, musical experience, and listening modes on tempo modulation perception, *Journal of Research in Music Education*, 42(3), pp. 190–202.

SHUTER-DYSON, R. & GABRIEL, C. (1981) *The Psychology of Musical Ability*, 2nd Edn (London, Methuen).

SLOBODA, J.A. (1994) Music performance: expression and the development of excellence, in: R. AIELLO (Ed.) *Musical Perceptions*, pp. 152–172, (New York, Oxford University Press).

UNDERWOOD, G. & BRIGHT, E.H. (1996) Cognition with and without awareness, in: G. UNDERWOOD (Ed.) *Implicit Cognition*, pp. 1–40 (Oxford, Oxford University Press).

WAGNER, C. (1974) Experimentelle Untersuchungen über das Tempo [Experimental investigations of tempo], *Österreichische Musikzeitschrift*, 29, pp. 589–604.

WALLIN, J. (1911) Experimental studies of rhythm and time (Part 1 & Part 2), *Psychological Review*, 18, pp. 100–133 & pp. 202–222.

WINCKEL, F. (1967) *Music, Sound, and Sensation: a modern exposition* (New York, Dover Publications).

WOLPERT, R.S. (1990) Recognition of a melody, harmonic accompaniment, and instrumentation: musicians and nonmusicians, *Music Perception*, 8, pp. 95–106.

ZENATTI, A. (1993) Children's musical cognition and taste, in: T.J. TIGHE & W.J. DOWLING (Eds) *Psychology and Music. The Understanding of Melody and Rhythm*, pp. 177–196 (Hillsdale, NJ, Erlbaum).