

About Musical Time –Effect of Age, Enjoyment, and Practical Musical Experience on Retrospective Estimate of Elapsed Duration during Music Listening

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Abstract. 237 participants listened to a 37 second extract of original music for solo piano, and were asked to retrospectively verbally estimate elapsed duration. Differences were found for age (mean estimate for ages 5-8: 76.11 seconds, ages 9-10: 66.38, 11-13: 54.88 seconds, ages 14 to adult: 65.17 seconds) and a correlation found between adult age and estimate. Estimates were found to be significantly longer for those who enjoyed the music, compared to those who disliked it. Elapsed duration was also judged significantly more accurately by experienced musicians and also marginally significantly more accurately by school teachers. Results are discussed in terms of memory, attention, and emotion.

Keywords: Music perception, music and time, retrospective estimation, age, enjoyment, memory, attention, emotion.

The phenomenological experience of elapsed duration is dependent on multiple and complex factors. These include, but are not limited to, working memory capacity, division of attention, and emotional state. Moreover, estimates of duration differ according to experimental paradigm employed (prospective or retrospective), length estimated (i.e., the sub- or supra-second level), and means of testing (verbal estimation, production, reproduction, or comparison).

Whether musical time conforms to current models of psychological time (for a review see [20]) - such as internal clock or contextual change models (see [4]), or more recently proposed models of timing based on neural networks [9-10,14] – or whether ‘temporal production and estimation have special meanings in musical contexts’ [23, p. 214], remains as yet unclear. However, studies demonstrate that musical features do appear to influence the experience of elapsed duration, and that the extent and nature of this influence varies depending on multiple musical parameters.

This study explores the effect of individual characteristics and preferences on estimates of elapsed duration during music listening, specifically, the effects of age, enjoyment, and level of musical training. Results are discussed with reference to memory, attention and encoding of musical information, and emotion.

1 Background

How we plan, conceive of, structure, and reflect on our daily lives and experiences depends on the notion of time. Our lives exist in time, or rather, the events of our lives occupy and shape the time available to us over our biological existence. Most investigations of psychological time employ one of four methods of measurement - verbal estimation, reproduction, production, and comparison (for a summary see [19]) - and relies on one of two timing paradigms; the prospective paradigm (or 'experienced duration'), in which a person is aware an estimation of elapsed duration will be required; and the retrospective paradigm (or 'remembered duration'), in which the person is unaware such judgment will be required. The former has largely been explored and theorised in terms of levels and foci of attention (for instance, the more attention paid to the passing of time, rather than the salient event, the longer the estimate) [4], and the latter chiefly in terms of memory resources (as the sequence of events experienced must be recalled, and time elapsed gauged) [4].

Prospective estimation of time is usually discussed in relation to internal-clock models [4], or, more recently, neural models [9] of time perception, while retrospective experience is most often represented by a form of 'contextual-change' model [4], which proposes that estimations of duration rely on recall of the number of 'changes' perceived in environmental context during the salient interval (the more changes registered, the longer the estimate of duration). Models also vary depending on the length of interval concerned, with different processes considered to be relevant for various lengths of duration whether at the sub- or supra-second level [26]. Neurological studies, which have implicated areas involved in time estimation including the cerebellum, cortex areas (SMA), and basal ganglia (for a summary see [20]), also suggest regions involved depend on length of duration in question [26,29].

Studies of experienced elapsed duration have most frequently employed the prospective paradigm, as this allows for collection of multiple data points per participant, whereas retrospective estimations require participants' ignorance of the purpose of the study (i.e., perception of time) until after the salient event. However, the latter paradigm perhaps better reflects the everyday experience of temporal duration, as daily events are rarely consciously timed but their duration may be reflected on in retrospect. Moreover, much existing empirical literature concerning time estimation employs intervals in the range of 100ms to 2-3 seconds, often examining implicit, or motor, responses. The retrospective paradigm is more directly applicable to the explicit estimation of longer durations (from a few seconds to an interval of minutes or more), but studies of this nature are currently few in comparison with their prospective equivalents.

It should however be borne in mind that the fine-grained distinctions and binary delineations in time perception models and paradigms sketched out above are often problematic, in that any one category in isolation may fail to sufficiently explain empirically obtained results, and hence risk limiting the scope of such findings. Importantly, studies exist which propose prospective and retrospective duration estimation may rely on similar mechanisms [7], and models have been developed which assign equal importance to processes of attention and memory [8], rather than aligning the former chiefly with prospective estimates, and the latter with retrospective. The theory of 'break points' in the different brain areas involved depending on the length of time in question has also been empirically challenged [29].

Data for the current study were collected during a nine-week residency at the Science Museum, London (each Tuesday-Thursday from 17th January to 17th March 2011, as part of the ‘Live Science’ programme in the ‘Who Am I?’ gallery). The study took place in a dedicated research room, in which temperature, ambient noise, lighting, visual information and stimulus volume were carefully controlled throughout the study (by use of a thermometer and a decibel monitor in the case of the first two measures). The chosen environment allowed for wide demographic penetration, and data from a breadth of age ranges from age 5 to adult.

The study employed a retrospective paradigm and verbal estimation method. Verbal estimation is one of the most common methods of assessing experienced duration during music listening (e.g., [3,25,36]). This is partly due to its suitability for assessing intervals in excess of 30 seconds, which is considered to be the upper limit of intervals suitable for the reproduction paradigm [19], and also due its relevance for the music listening experience, which rarely involves the tracking of passing seconds and minutes.

Study of the effect of music listening on retrospective estimation of time is a relatively new, yet growing, field of interest. Empirical investigation has suggested that atmospheric music influences perception of time [1-2,31], and that estimates may be influenced by music’s mode [36], familiarity [2], and harmonic variation [15]. This study aimed to assess whether two common findings concerning the perception of time – that there is an effect of age on time perception, and that enjoyment influences our perception of the passing of time – hold when the event concerned involves music listening. In addition, the study aimed to examine whether there is any evidence to support the notion that musical training may enhance awareness of elapsed duration during music listening, i.e., whether experienced musicians give significantly more accurate retrospective estimations compared to non-musicians.

Age has been shown to effect estimation of elapsed duration, with older adults and children giving less accurate estimations than other age groups [30], and older adults giving longer verbal estimations than younger [5]. It is thus predicted that the current study will find that estimates of the duration of the experience of listening to a piece of music become longer with age in teenagers and adults (hypothesis 1, H1). Time perception studies have also examined differences in time perception of young children, often in the age range of 5-8 years of age [12]. However, studies examining the development from age 5 (when a concept of time is thought to be under-developed, or at least not yet verbally expressible, see [17] for a review), to post age-8 (when a concept of duration is considered to emerge [17,32]), and into puberty, have been rare. As children develop a sense of units of time as expressed in seconds and minutes around the age of 8, it is predicted that the current study will demonstrate more variable, and hence on average higher, estimates from the age group 5-8 compared to that following development of durational expression at age 11-13 (hypothesis 2, H2).

Models and theories of time perception are increasingly recognising the significant role played by emotion in experience of elapsed duration; early internal-clock models such as those based on scalar timing [18] now incorporate an arousal component (see e.g., the ‘attentional-gate’ model, [4]), consumer studies acknowledge to an ever-greater extent the influence of affective state on experience of subjective time [1,20-21], and neurological studies have even begun to explore the notion that time

may indeed *only* be represented as a series of emotional moments [10]. Both arousal and valance (or enjoyment/liking/pleasantness of the stimulus) have been shown to influence estimates of duration, although studies vary with regard to whether negative or positive valance leads to higher arousal, and hence longer estimates [11].

The purpose of engagement in music listening is considered to be linked to music's power to induce emotion [23]. Hence it is no surprise that experience of duration during music listening appears to be no exception in the link between psychological time and emotion. Studies have suggested that retrospective estimates vary depending on music's valance, with positively valenced music leading to higher estimates [3], and on subjective ratings of enjoyment [1,36], where ratings of higher pleasantness have been shown to correlate with higher estimations [36]. It is hence predicted that the current study will demonstrate higher estimates from those who rate enjoyment of the music higher than others (hypothesis 3, H3).

Musicians have been shown to demonstrate more accurate motor timing than non-musicians [16,34] but little is known of musicians' estimation of durations exceeding the millisecond to 1-2 second range. On the basis of these previous studies, and given that awareness of elapsed duration during music engagement is a key skill in musicianship, it is predicted that the current study will demonstrate more accurate estimates from experienced musicians (age 18-40, see below for criteria used for categorisation) compared to non-musicians (hypothesis 4, H4).

As familiarity with a musical stimulus has been shown to significantly effect estimation of elapsed duration during music listening and ratings of preference of musical stimuli [2,33], a bespoke composition for piano solo, *Time To Go*, by Matthew Woolhouse, was used in this study. The piece was selected from a number of possible compositions after receiving feedback from prospective participants (who did not go on to participate in the current study, as it was required that they be unfamiliar with the chosen stimulus). The listeners rated the composition highly in terms of ease of listening and entertainment value, and hence it was considered an ecologically valid selection. Other criteria that influenced the choice of piece include the tempo (100bpm, which is considered to be the preferred tapping rate for young adults [20], who represent the average age of Science Museum visitors eligible to participate in the study¹) and timbre (piano solo, and hence effectively modified using software employed, *Logic Pro* and *Audacity*).

2 Method

2.1 Participants

Participants were museum visitors who volunteered to take part in the experiment. The age range of the 237 participants (118 female) was 5 to 79 years (mean: 27.18 years), after exclusion of 25 participants due to various data corruptions.²

¹ Although school children represent a large portion of museum visitors, they were unable to participate due to lack of parental consent.

² These include the following: other museum visitors walking into the room during the listening stage of the experiment, interruption of the listening stage by the museum voiceover announcement, visitors' failing to follow experimental instructions, and non-normal hearing.

After they had taken part in the experiment, all participants were asked to confirm they had not been aware that the experiment would ask for an estimation of time before they took part, and data for any who were aware of the purpose of the study were excluded.

2.2 Stimulus

All participants heard a 37 second extract (one-second fade out to end) taken from the beginning of an original tonal composition by Matthew Woolhouse, *Time To Go*, for solo piano (major key, consistent tempo of 100bpm). The stimulus was created using *Logic Pro* and *Audacity* from a midi recording made by the composer.

2.3 Procedure

Participants were informed that the experiment concerned ‘music and the mind’, and that they would be asked to listen to a piece of music and answer a series of questions, following which they would be offered the opportunity to discuss the project and results collected to date. They were told that the entire experience would last approximately 10 minutes and asked to sign a consent form.

Participants first listened to the 37-second stimulus through Sennheiser HD201 closed-back headphones, and were then asked to press ‘next’ on the computer at which they were sitting, and respond to a series of questions (designed for the current study). The first of these asked ‘Without looking at your watch or a clock, how long do you think you were listening to the music?’ (and gave a ‘minutes’ and ‘seconds’ box, one above the other).³ In terms of practical musical experience, participants were asked ‘Have you ever had any formal music training at any time in your life (i.e. instrumental or singing lessons)?’ and ‘Do you currently play a musical instrument and/or sing?’ If participants responded ‘yes’ to either question, they were also asked to state how long this engagement had lasted (in years). To obtain ratings of enjoyment, participants were asked ‘How much did you enjoy listening to the music?’ (1 = I didn’t like it at all, 7 = I liked it a lot). The question, and the use of a seven-point scale, was based on previous studies employing the retrospective paradigm to investigate experience of elapsed duration during music listening [25,36]. However, the term ‘pleasant’ (used for [25,36], in which participants were all university students) was rejected in favour of the simpler terms ‘enjoy’ and ‘like’, in order for the question to be as clear as possible for all ages (from 5 years old).

The study was granted ethical approval by the Psychology Research Ethics Committee of the University of Cambridge.

3 Results

Analysis was conducted using one-tailed *t* tests (as all hypotheses predict direction) and Pearson product-moment correlation coefficients, except where stated otherwise. Participants were separated into four age categories: 5-8 ($N = 9$), 9-10 ($N = 13$), 11-13 ($N = 17$) and 14 to adult ($N = 126$).

³ The question formulation, and the use of two response boxes, was based on previous studies of retrospective estimation using music and a verbal estimation method [see e.g., 1,3,25,36].

Responses ranged from 6 to 300 seconds.⁴ 49 of the 237 responses were underestimates of the actual duration of 37 seconds (20.7% of total response, the remainder being overestimates) and the average duration reported across all participants was 72.25 seconds.

While public access to the experiment allowed sampling across a wide range of ages and levels of musical expertise, it also meant that the make-up of the population of participants was, from time to time, subject to considerable change. 71 of the total 237 participants took part in the experiment during a school holiday week which occurred within the period of the experiment. Analysis confirmed a significant effect [$t(233) = -3.684, p < 0.001$] of the altered environment during this school holiday (age range: 5 to 67, mean age: 20.34, mean estimate: 89.8 seconds) on duration estimation, compared to the 166 non-school holiday participants (age range: 5 to 79, mean age: 30.49, mean estimate: 64.83 seconds). This difference is largely owing to the differences in the under-18 population. Comparison of under-18 year olds only between the school-holiday ($N = 47$, mean age: 10, mean estimate: 96.49 seconds) and non-school-holiday ($N = 48$, mean age: 11, mean estimate: 61.27 seconds) groups also revealed a significant difference in estimation [$t(93) = -3.214, p. < 0.01$]. Owing to these differences, data collected during the school holiday period has been excluded from all analyses detailed below.⁵

3.1 Age – Children (Three Groups: 5-8, 9-10, 11-13)

Mean estimates were: ages 5-8: 76.11 seconds, ages 9-10: 66.38 seconds, and ages 11-13: 54.88 seconds (see Fig. 1).

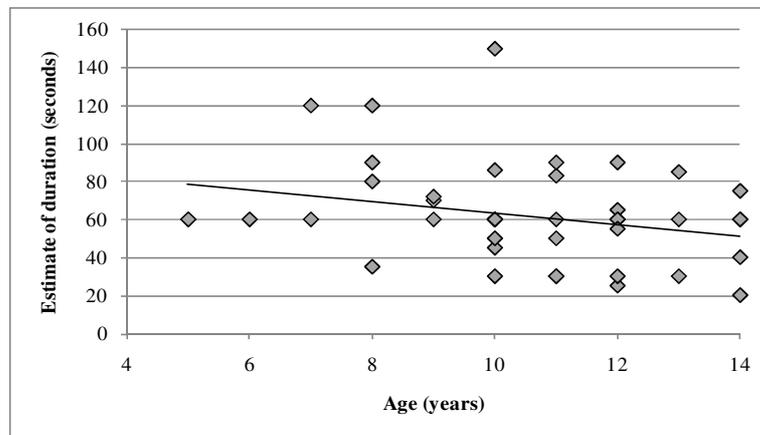


Fig. 1. Duration estimates for 37-second extract by participants 5-14 years of age

⁴ Two outliers (defined as more than 2SD from the mean) were removed from the total data set for all analyses discussed in this study; one outlier of 1,200 seconds from the school holiday under-18 group, and one of 600 seconds from the non-school holiday 5-8 group.

⁵ For examples of studies exploring the notion that 'our feeling for time is fundamentally inseparable from our subjective [emotional] experience of the environment' [see 11, p.512]. However, influence of *overall* atmosphere or holiday environment on experience of elapsed duration is currently little understood.

A significant difference was detected between the 5-8 and 11-13 [$t(24) = -2.048$; $p < 0.03$] categories, with older children giving shorter responses (no significant difference was detected between the 5-8 and 9-10, or 9-10 and 11-13 groups). The data also revealed that estimates in children became more accurate between the ages of 5 and 14 (Pearson's $r = -0.2712$, $t = -1.826$, $DF = 42$, $p < 0.04$).

3.2 Age – 14 to Adult

In participants aged 14 and above ($N = 126$, mean age: 36.63, mean estimate: 65.17 seconds) a correlation was also found between age and duration estimate [$r = 0.288$, $t = 3.348$, $DF = 124$, $p < 0.01$], with estimates increasing in line with age (see Fig. 2).

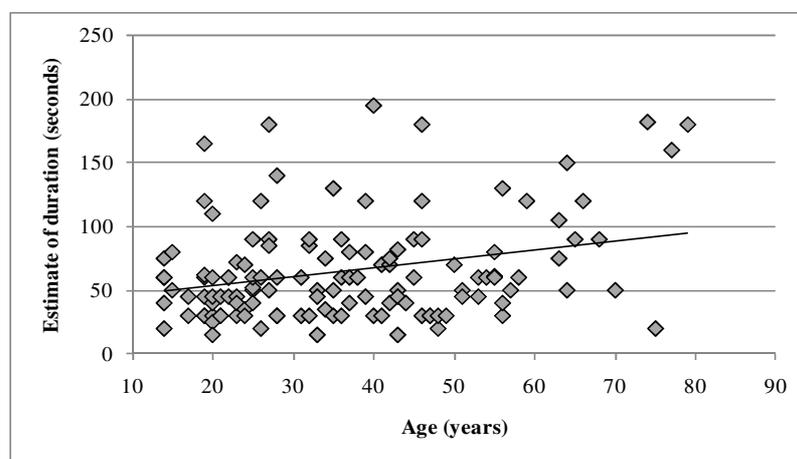


Fig. 2. Duration estimates for 37 second extract by participants aged 14 years of age and over

3.3 Enjoyment

Analysis of duration estimates of participants age 14 and above ($N = 73$, mean age: 39, mean rating: 4.89), and excluding experienced musicians and teachers (for reasons discussed below), revealed a significant effect of enjoyment, with those who reported enjoying the music giving higher estimations of elapsed duration (Pearson's $r = 0.1941$, $t = 1.667$, $DF = 71$, $p < 0.05$). There was no evidence of correlation for younger participants.

3.4 Musical Experience

A subset of the data was used to explore the effects of musical experience. Time estimations of non-musicians (defined as those who do not currently play a musical instrument and who responded with a maximum of 1 year to the question 'Have you ever had any formal music training at any time in your life (i.e., instrumental or singing lessons)?') were compared with experienced musicians (defined as having over 5 years' musical training and/or those who have engaged in regular playing of a

musical instrument for the last 10+ years). 18 years of age was selected as the lower limit, as UK schools offer instrumental tuition from year four (age 8-10) [27], and hence 18 would be the lower limit of participants possessing 10+ years of training. 13 of a total of 17 (76.47%) experienced musicians were evenly distributed within the range 18-40 (with the remaining third including disparate ages), and hence 40 was selected as the upper limit for inclusion of data from both non-musician and experienced musician categories. This delineation also ensured average age was relatively consistent across the two experimental groups (mean age = 28.41 and 27.15 respectively), as was enjoyment rating (average rating = 5.16 and 4.46 respectively).

Average estimates for the groups were 68.97 seconds for non-musicians ($N = 32$, mean age: 28.41) and 47.08 seconds for experienced musicians ($N = 13$, mean age: 27.15) respectively. Analysis revealed a significant effect of musical training [$t(43) = -1.767$; $p < 0.05$], with experienced musicians giving shorter, more accurate estimates.

3.5 Profession - Teaching

Qualitative data gathered during the study suggested that teachers considered themselves to have an accurate sense of elapsed duration. Due to the high volume of school trips visiting the Science Museum, a comparison was possible between estimates of teachers and non-teachers. Current teachers with over ten years' teaching experience ($N = 6$, mean age: 46, age range: 39-50) were compared to non-teachers within the same age range ($N = 13$, mean age: 43, age range: 39-48)⁶.

Average estimates for the teacher and non-teacher conditions were 46.67 seconds and 82.46 seconds respectively. Analysis revealed a marginally significant effect of being employed in the teaching profession [$t(17) = -1.467$, $p < 0.09$].

4 Discussion

The current study used a retrospective paradigm to examine verbal estimations of elapsed duration of a 37 second extract of bespoke tonal music. Age was found to be a determining factor in duration estimates, with 5-8 year olds giving significantly higher responses than children aged 11-13 (thus supporting H1). For participants aged 14 to adult, estimates were found to correlate significantly with age; increased age resulted in longer estimates (H2). Estimates of elapsed duration also became longer with increased rating of enjoyment (H3). Finally, estimates given by experienced musicians were found to be significantly shorter than non-musicians (H4). There was also some evidence that teachers' estimates of elapsed duration were also marginally significantly shorter than non-teachers.

Retrospective estimation of elapsed duration of a salient event requires recall of the information processed in memory. A contextual-change model would suggest that the more changes perceived in the interval, the higher the estimate. However, a purely memory-based interpretation does not suffice to explain the above findings, and a more attention-based explanation appears more relevant here.

⁶ Results collected during the school holidays were excluded, due to factors discussed above. There was no overlap between teachers and experienced musicians.

Firstly, the finding that estimates of elapsed duration become longer with enjoyment appears to challenge the notion that ‘time flies when you’re having fun’; however, this is consistent with previous studies and models demonstrating a difference between prospective estimates (when elapsed duration is estimated as being shorter if enjoyment is high) and retrospective (when the reverse is the case). The result is also in line with previous studies demonstrating a correlation between perceived time during music listening and valence [3]. The retrospective paradigm (in which attention is not consciously divided between the tracking of time and the salient event, when an attentional-gate model may be useful) invites the application of an information processing theory here; higher enjoyment of the event results in higher levels of engagement, more attention paid to the salient event, and hence a richer encoding of the information presented. When retrieved from memory, the information encoded is more extensive and detailed compared to those whose engagement was at a lower level, and a longer assessment of elapsed duration results.

Experienced musicians were found to give significantly shorter estimates than non-musicians, which could also be considered in relation to the above theory - musicians may have encoded the musical information more efficiently than non-musicians. A musician’s memory of the music as chunks of information (e.g., chords rather than separate notes) could lead to a shorter estimate compared to a non-musician. This would also be consistent with the contextual change model of time, which suggests that experience of time becomes longer as stimulus complexity increases [4], as a greater amount of information is processed and stored over the time interval. Experienced musicians may have found the stimulus less complex than non-musicians, and thus recalled shorter elapsed duration. Moreover, musical processing requires attention to hierarchical structures in time, with expectations of metrical pattern being formed based on rhythmic patterns [22]. With extensive expertise in processing metrical information, musicians may have been able to allocate attention to the music (at a constant 100bpm) more efficiently, and thus encode the information in a less detailed, more schematic way. Furthermore, owing to more accurate timing processing, musicians may have formed more accurate expectations of metrical events, compared to non-musicians. Non-musicians would therefore have experienced a greater level of violation of expectation (compared to musicians), resulting in an increase of affect (summarised in [28]), and thus longer responses.

The notion of attention remains central to the finding in relation to teachers. The teachers all visited the museum with their respective school groups, and attention is likely to have been diverted from the salient event (music listening), in favour of thinking through the distribution of the children in the gallery, and the logistics of the school visit. This diversion of attention would have resulted in lower levels of encoding of the musical information, and hence shorter estimates. However, participant numbers in the teacher and non-teacher conditions ($N = 6$ and $N = 13$, standard deviations = 24.22 and 56.73 seconds, respectively) were relatively small, and further research with larger sample sizes is required to further investigate this trend.

Results for the age group 5-8 compared to 11-13 year olds confirm that verbal expression of experienced time is not yet developed at this age, and hence the method may not have adequately reflected time perception [13]. However, results relating to participants age 14 to adult may be interpreted, as those discussed above, in terms of

attention allocation and resource. Studies have shown that the greater attention paid to a task, the shorter the estimate of elapsed duration (summarised in [6]). Teenagers may not have devoted as much attention to listening to the music as adults, which would lead less musical information encoded in memory, and subsequently to shorter estimates. Age differences could be present in the data because of differences in time perception that are apparent in temporal behaviour (spontaneous tapping rates) between children (350ms), young adults (600ms), and adults (700ms), as summarised by [20]. The 100bpm tempo would feel faster to older adults than to younger adults, and this could lead to an increase in pacemaker rate and higher arousal, and thus to longer estimates of elapsed duration.

Attention processes have often been neglected in retrospective estimation literature, in favour of theories of memory. However, the findings of the current study challenge this tendency, and call for attention to feature more adequately in retrospective models, particularly where emotional stimuli are employed. Moreover, the results herein could offer new directions for research concerning the effect of emotion on time perception, as it is recognised that: i) the field requires a standardisation of emotional stimuli in order to further elapsed duration models [11], ii) time discrimination has been shown to be better when the intervals contain *auditory* rather than *visual* information [35], and iii) music is considered an effective inducer of emotion [24]. There is therefore scope for affective musical stimuli to become the standard emotional stimuli required by the field of time perception and emotion.

Finally, the results of this study suggest that current theories of experience of elapsed duration are relevant to music listening, providing the process of attention is sufficiently accounted for in retrospective models. However, the findings also call for redefinition of these models in musical situations - musical structure exists, and is perceived, as a series of hierarchically organised events in time, and it is according to the perception of such a hierarchy (dependent on various factors, including musical experience and engagement) that experience of elapsed duration during music listening must be modelled.

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