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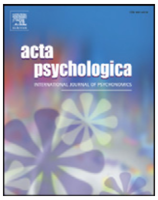

Time flies with music whatever its emotional valence

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ABSTRACT

The present study used a temporal bisection task to investigate whether music affects time estimation differently from a matched auditory neutral stimulus, and whether the emotional valence of the musical stimuli (i.e., sad vs. happy music) modulates this effect. The results showed that, compared to sine wave control music, music presented in a major (happy) or a minor (sad) key shifted the bisection function toward the right, thus increasing the bisection point value (point of subjective equality). This indicates that the duration of a melody is judged shorter than that of a non-melodic control stimulus, thus confirming that "time flies" when we listen to music. Nevertheless, sensitivity to time was similar for all the auditory stimuli. Furthermore, the temporal bisection functions did not differ as a function of musical mode.

Music is a complex temporal structure of sounds that has a deep emotional impact on listeners. Both its temporal and emotional qualities are likely to affect time perception. Quite surprisingly, only a small number of studies in the fields of music cognition and time perception have investigated time estimation in the presence of music (e.g., Boltz, 1998, 1999; Bueno, Firmino, & Engelmann, 2002; Jones, 1990). The present study assessed whether music affects time estimation differently from a neutral matched auditory stimulus, and whether the emotional valence of the musical stimuli (i.e., sad versus happy music) might modulate this effect.

It is generally assumed that time is perceived to pass quickly when listening to music. A period of waiting—when a telephone call is put on hold or when sitting in a doctor's waiting room—is judged shorter when there is accompanying music than when there is none (e.g., Guegen & Jacob, 2002; North & Hargreaves, 1999; Roper & Manela, 2000; Stratton, 1992). Moreover, this underestimation of time should be greater when the subjects enjoy this accompanying music (Cameron, Baker, Peterson, & Braunsberger, 2003; Kellaris & Kent, 1994; Lopez & Malhotra, 1991; Yalch & Spangenberg, 1990). For example, Yalch and Spangenberg (1990) found that young shoppers' time estimates were shorter when they listened to their favorite tunes from the charts than when they listened to other music. As discussed in more detail below, the internal clock models explain this temporal shortening effect in terms of attention processes. According to the internal clock models (e.g., Gibbon, 1977; Gibbon, Church, & Meck, 1984; Treisman 1963), the representation of time depends on the number of temporal units emitted by an internal clock and accumulated during the elapsed duration. When attention is distracted away from the processing of time, fewer temporal units are accumulated, and the duration is judged shorter (Hicks, Miller, Gaes, & Bierman, 1977; Thomas & Weaver, 1975; Zakay, 1989). Music is thus thought to divert attention away from the passage of time. As a result, "time flies" (see Bailey & Areni, 2006, for a review of atmospheric music).

To determine why music is able to divert attention away from time, it is necessary to identify the specific features of music which produce this effect. Jones and Boltz (1989) have suggested that one effect of music on time estimation is due to the perceptual expectancies that listeners develop when listening to a piece of music. The way musical accents are patterned through time leads listeners to anticipate the timing and nature of incoming events. When these events occur earlier or later than expected, this shortens or lengthens the time estimates, respectively. This finding highlights the considerable influence exerted by musical structures (pitch and rhythmic structure) on attention during the estimation of musical time (see also Firmino & Bueno, 2008; Firmino, Bueno, & Bigand, 2009). A different explanation of the effect of music on time estimation focuses on the emotional qualities of music *per se*. Indeed, music is remarkable in its ability to induce emotions in listeners (Juslin & Sloboda, 2007). Many studies conducted over the last decade have demonstrated the consistency of emotional responses to music (e.g., Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005; Peretz, Gagnon, & Bouchard, 1998). The mode and tempo of music have been found to have robust effects on perceived emotion, with pieces perceived as sounding happy when played in a major key and at a fast

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tempo and sad when played in a minor key and at a slow tempo. This effect of mode was reported as far back as the 19th century by Helmholtz (1863) who claimed that a piece of music in a minor key tends to induce a feeling of sadness. This has since been confirmed by several experimental studies (e.g., Crowder, 1984; Peretz et al., 1998). It has recently been suggested that the ability to discriminate between the happy and sad moods conveyed by the major and minor modes is universal (Fritz et al., 2009).

Two studies have been conducted to investigate the influence of the valence of musical emotions on time estimations by manipulating the mode of musical pieces (Bueno & Ramos, 2007; Kellaris & Kent, 1992). Kellaris and Kent (1992) tested the effect of mode using pop-style music which lasted for 2.5 min and was identical with respect to the other parameters (melodic contour, tempo, loudness, etc.). The pieces were either atonal or played in the major or minor mode. The results show that the music played in the major mode was judged longer (3.45 min) than that in the minor mode (3.07 min) or the atonal (2.95 min) music. However, these findings are not consistent with those obtained by Bueno and Ramos (2007) using a shorter duration (64.3 s). By contrast, Bueno and Ramos (2007) did not reveal any significant effect of major versus minor mode on time estimation. Only a significant overestimation of the duration of the music with a more complex scale structure (i.e., Locrian mode) was observed. There are therefore inconsistencies between the empirical data concerning the effect of musical mode on time estimation available to us at present and further studies are required. The aim of the present study was to further investigate the effect of musical emotion on time estimation on the basis of the temporal bisection task—a task which has already been extensively used in animals and humans to test the internal clock models (Church & Deluty, 1977; Wearden, 1991). In this task, participants are instructed to pay attention to time and to categorize stimulus durations as a function of their similarity to a short and a long anchor stimulus duration. In the present study, the stimuli to be timed were pieces of music played in the major or the minor mode or with neutral atonal sine waves. Peretz et al. (1998) showed that sad emotions tend to be associated with the minor mode and a slow tempo, while happy emotions are associated with the major mode and a faster tempo. To focus on the effect of mode, all the stimuli in our study were played at the same tempo. Music-like sounds were generated which reproduced the rhythm, tempo and melodic contour of the original music but which lacked all the relevant cues associated with western pitch structure that contributes to musical expressivity. The neutral stimulus was therefore matched with regard to the parameters of the associated musical stimulus. This allowed us to evaluate the influence of neutral and emotional music on time estimation and, in addition, to analyze a possible effect of emotional valence.

1. Experiment 1

1.1. Method

1.1.1. Participants

Twenty-five undergraduate students (17 women and 8 men, mean age = 28.2, *SD* = 4.3) at Clermont University, France, participated in return for a payment of 10 euros.

1.1.2. Materials

The participants sat in a quiet laboratory room in front a Macintosh computer that controlled the experimental events and recorded the responses via PsyScope. They responded by pressing one of two keys ("K", "D") on the computer keyboard. The stimulus to be timed consisted of a musical sequence. The participants listened to these stimuli through a Sennheiser headset which was connected to the computer. There were four different sequences of music selected from Peretz et al. (1998). Each excerpt was played with a piano-like sound by a computer in both the major and minor modes. All the other musical parameters (rhythm, tempo, meter, and melodic contour) were identical. The matched sine wave stimuli (referred to as sine wave music here) were created by replacing each musical event (tone or chord) in the original piece by a sine wave sound of identical duration that approximated to the fundamental frequency of the tone (in the case of isolated notes) or the soprano voice (in the case of chords). In order to remove any expressive cue due to tonality, the frequencies of the sine waves were intentionally chosen to violate the familiar harmonies of western music. In consequence, the sine wave music had the same temporal (rhythmic) structure and overall melodic contour as the original excerpt but without the defining tonal component. These stimuli were also of a very poor timbre compared to the piano-like sound of the original excerpts. This experimental manipulation resulted in a 4 music (M1, M2, M3, and M4) × 3 modes (major, minor and sine wave music) design.

Although the emotional valence of the musical pieces used in the present studies had already been tested by Peretz et al. (1998), we nevertheless decided to pretest them with 50 additional students in order to make sure that the major and the minor music did indeed elicit the expected emotional response (sad vs. happy). We also measured arousal when the participants listened to each stimulus. Using the Self-Assessment Manikin scale (SAM) (Lang, 1980), the participants were told to indicate how they felt while listening to the music: from happy (1) to sad (9) for the valence dimension, and from calm (1) to excited (9) for the arousal dimension. Each piece of music was presented for 500 ms and 1700 ms and the task order was counterbalanced across the participants. The ANOVA performed on emotional valence (see the Appendix A) confirmed that the major and the minor musical pieces elicited different emotion, happiness (3.49) for the former and sadness for the latter (5.77). The non-musical sine wave stimuli were also judged sad (5.47). The ANOVA performed on the arousal rating showed no effect of mode for the musical pieces (except for one musical piece M2, see the Appendix A), suggesting that the minor and the major mode and its matched sine wave version were judged to be similarly arousing.

1.1.3. Procedure

Each participant performed two temporal bisection tasks as a function of the duration range used: 0.5/1.7 s and 2.0/6.8 s. In the shorter duration range, the short anchor duration was 0.5 s and the long anchor duration 1.7 s. The comparison durations were 0.5, 0.7, 0.9, 1.1, 1.3, 1.5 and 1.7 s. In the longer duration range, the short and the long anchor durations were 2.0 and 6.8 s and the comparison durations 2, 2.8, 3.6, 4.4, 5.6, 6 and 6.8 s. The task presentation order was counterbalanced across subjects, with each task being separated by 24 h. The bisection task consisted of two phases: a training and a test phase. In the training phase, the participants were presented with the 2 anchor durations in the form of a control sound (sine wave music). In each trial, the music was randomly selected from a set of 4 different control sounds. There were 10 trials, 5 for each anchor duration, presented in a random order. The inter-trial interval was randomly selected between 1 and 3 s in order to avoid rhythmic regularity between trials. In the training phase, the participants were trained to press one key in response to the short anchor duration, and the other key in response to the long anchor duration. The button press order was counterbalanced across subjects. In the test phase, the procedure was the same as during training, except that the participants were presented with the 3 types of music, i.e., control (sine wave music), major and minor. The test phase consisted of 10 blocks of 21 trials each, i.e., 7 trials for each comparison duration and this for the 3 types of music. This resulted in a total of 210 trials. The trials within each block were randomly presented and the type of music was randomly selected from the associated set. In addition, the subjects were instructed not to count and were told why this was important.

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1.2. Results and discussion

Q5 Fig. 1 indicates the proportion of long responses (p(long)) plotted against the comparison durations for the three types of music in the 0.5/1.7 s (upper panel) and the 2/6.8 s (lower panel) anchor duration conditions. An examination of Fig. 1 suggests that, whatever the type of music—major or minor—it shifted the bisection function toward the right compared to the sine wave music, thus causing the durations to be judged shorter. An overall analysis of variance (ANOVA) was performed on p(long) with the anchor durations, music and comparison duration as within-subjects factors. The ANOVA revealed no significant effect of anchor duration, $F(1, 24) = 2.54$, $p > .05$. However, there was a significant main effect of comparison duration, $F(6, 144) = 410.84$, $p < .05$, as well as a significant anchor duration × comparison duration interaction, $F(6, 144) = 3.94$, $p < .05$. This indicates that the proportion of long responses increased with the comparison duration value, thus indicating good temporal discrimination. However, temporal discrimination appeared to be lower for the short (ms) than for the long (s) anchor durations. More interestingly here, there was a significant main effect of music, $F(2, 48) = 198.70$, $p < .05$. This indicates that the proportion of long responses was lower for both the major (.36) and the minor (.35) music than for the sine wave music (.56) (post-hoc Bonferroni tests, both $p = .0001$) while no significant difference was found between the music played in the major and minor modes ($p > .05$). However, there was also a significant music × anchor duration interaction, $F(2, 48) = 5.24$, $p < .05$, as well as a significant music × comparison duration interaction, $F(12, 288) = 22.62$, $p < .05$. No other interaction was significant.

To investigate the significant music × comparison duration interaction, we performed pairwise comparisons for each music type, with the music and the comparison duration as within-subject factors. In all cases, a comparison of the major or the minor music with the sine wave music revealed a significant effect of comparison duration ($F(6, 144) = 431.60$, $F(6, 144) = 413.58$, respectively, both $p < .05$), and of music ($F(1, 24) = 211.49$, $F(1, 24) = 280.96$, $p < .05$), as well as a significant comparison duration × music interaction ($F(6, 144) = 26.26$, $F(6, 144) = 28.21$, $p < .05$). This shows that the bisection function was shifted to the right for the major and the minor music compared to the control stimulus. The comparison of the major and the minor music also revealed a significant comparison duration effect, $F(6, 144) = 262.8$, $p < .05$. In this case, however, there was neither a significant main effect of music, $F(1, 24) = 1.96$, $p > .05$, nor a significant music × comparison duration interaction, $F(6, 144) = 2.13$, $p > .05$. The bisection function was therefore similar for both the major and the minor music irrespective of duration range.

The decomposition of the significant interaction between the music and the anchor durations revealed that for both the long and the short anchor durations, the duration of the music played in the major and minor modes was systematically underestimated compared to the sine wave music (2.0/6.8 s, .34 vs. .53, $t(24) = 11.55$, .34 vs. 53, $t(24) = 14.28$, respectively, 0.5/1.7 s, .38 vs. .53, $t(24) = 12.86$, .36 vs. 60, $t(24) = 13.73$, all $p < .05$). In contrast, the duration of the music played in the major and the minor modalities was judged to be similar, although it tended to be underestimated in the minor compared to the major mode in the short anchor duration condition (2.0/6.8 s, .34 vs. .34, $t(24) = 0.11$, $p > .05$; 0.5–1.7 s, .36 vs. .38, $t(24) = 1.96$, $p = .06$).

To further investigate the significant differences between the music modalities, we calculated two more indexes, the Bisection Point (BP) and the Weber Ratio (WR). The BP is the point of subjective equality, i.e., the comparison duration giving rise to p(long) = .50. The WR is an index of temporal sensitivity. It is the Difference Limen ((p(long) = .75-p(long) = .25)/2) divided by the BP. The regression method originally used by Church and Deluty (1977) and subsequently employed by other authors (e.g., Droit-Volet & Wearden, 2001; Wearden & Ferrara, 1996) was used in the present experiment. More precisely, we performed a linear regression on the steepest part of the individual bisection functions in order to derive the slope and the intercept parameters which make it possible to identify the BP and the DL. The regression was not significant for one subject, who was excluded from the subsequent analysis. Table 1 illustrates the obtained BP and the WR values.

The ANOVA run on the BP with the musical mode and the anchor duration as factors revealed a significant main effect of anchor duration, $F(1, 23) = 790.71$, $p < .05$. As one might well expect, the BP value was higher for the 2.0/6.8-s than for the 0.5/6.8-s anchor durations (4.81 vs. 1.16). There was also a significant main effect of music, $F(2, 46) = 82.86$, $p < .05$, and a significant interaction between music and the anchor durations, $F(2, 46) = 32.21$, $p < .05$. In the 0.5/1.7-s and the 2.0/6.8-s condition, the BP value was always higher for the major and the minor music than for the control sound, thus

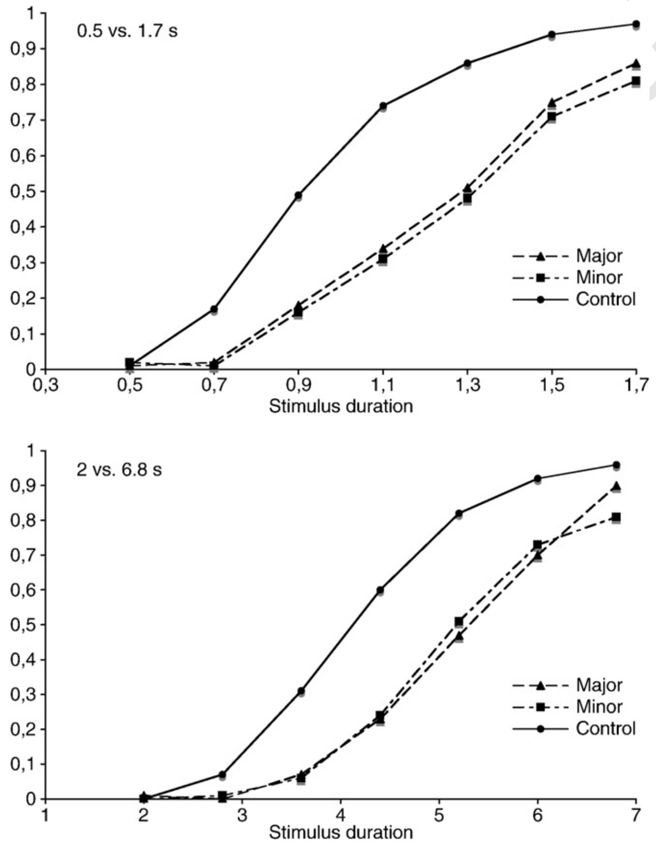

Fig. 1. Proportion of long responses plotted against stimulus durations for the major, minor and the sine wave (control) music in the 0.5–1.7 s and the 2 s–6.8 s anchor duration conditions.

Table 1
Bisection Point (BP) and Weber Ratio (WR) for the major, minor and matched sine wave stimuli in the 0.5/1.7-s and the 2/6.8-s duration range.

	BP		WR	
	M	*SD*	*M*	*SD*
0.5/1.7 s				
Sine wave	0.92	0.14	0.19	0.05
Major	1.24	0.21	0.20	0.06
Minor	1.31	0.23	0.20	0.07
2.0/6.8 s				
Sine wave	4.04	0.57	0.18	0.05
Major	5.16	0.71	0.17	0.03
Minor	5.22	0.77	0.19	0.06

Arithmetic mean for 0.5/1.7 = 0.6 and for 2.0/6.8 = 4.4.

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indicating that the duration of the music was underestimated (Post-hoc Bonferroni tests, all $p = .001$). Furthermore, the magnitude of the difference in the BP between the major or minor music and the sine wave music was not the same for the two sets of anchor durations, but was instead found to be larger for the long than for the shorter anchor durations ($t(23) = 7.28$, $t(23)$ 6,47, respectively, both $p < .05$). As discussed below, this suggests that the music effect was not due to a simple switch-closure latency effect, but to an attention-related switch flickering effect that occurred during the passage of time. Unlike in the case of the difference between the modal and the sine wave music, the BP values for the major and the minor music were similar in the 2.0/6.8-s anchor duration conditions (Bonferroni test, $p > .05$). It was only in the shorter anchor duration condition (0.5/1.7-s) that the BP was significantly higher for the minor than for the major music, $p = .02$, an observation that is consistent with the tendency observed for p(long). Therefore, for the durations in the milliseconds range, the duration of the music was underestimated more when it was presented in a minor than in a major key.

The ANOVA performed on the WR did not reveal any significant effect. The non-significant main effect of anchor durations, $F(1, 23) = 3.46$, $p > .05$, indicated that temporal sensitivity remained constant whatever the anchor duration. This finding is consistent with the scalar property of time perception (for a review, see Wearden & Lejeune, 2008). The non-significant effect of music, $F(2, 46) = 0.69$, $p > .05$, and the non-significant music × anchor duration interaction, $F(2, 46) = 0.52$, $p > .05$, indicate that temporal sensitivity remained similar whatever the musical key.

The fact that the proportion of long responses was lower and that the BP values observed for the major and the minor music were higher than for the sine wave stimulus indicates that the durations were underestimated in the presence of music compared to the sine wave stimulus. In addition, the duration of the minor key music was judged shorter than that of the music played in a major, but only for the anchor durations less than one second. The lack of any systematic difference between the major and the minor music may be due to a perceptual contrast effect related to the presence of the control stimulus in the test phase. Therefore, to investigate whether a minor–major difference occurs when no sine wave music is presented, we conducted a second experiment in which only the major and the minor music were presented in the test phase.

2. Experiment 2

2.1. Method

2.1.1. Participants

The sample consisted of 25 new students at Clermont University (15 women and 10 men, mean age = 26.88, $SD = 5.13$) who were paid 10 euros for their participation.

2.1.2. Materials and procedure

The material and the procedure were the same as those used in Experiment 1, except that, in the bisection test phase, the participants were presented with only the major and the minor music. This led to a total of 140 trials, 10 trials for the 7 comparison durations and the 2 music modalities: major and minor.

2.2. Results and discussion

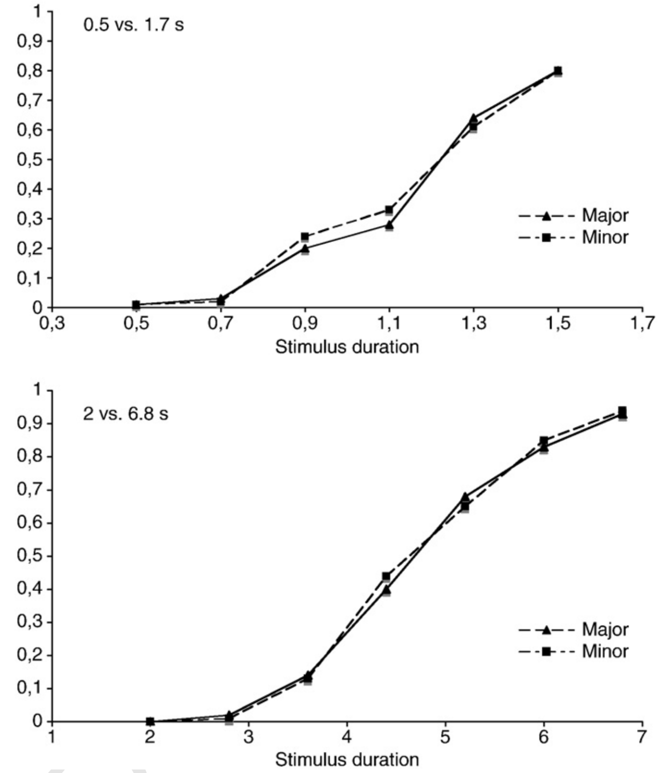

Fig. 2. Proportion of long responses plotted against stimulus durations for the major and the minor music in the 0.5–1.7 s and the 2 s–6.8 s anchor duration conditions.

Fig. 2 presents the bisection function for the major and the minor music in the 0.5/1.7-s and the 2/6.8-s anchor durations. The ANOVA run on the proportion of long responses revealed a significant main effect of comparison duration, $F(6, 144) = 400.13$, $p < .05$, and a significant interaction between the comparison duration and the anchor durations, $F(6, 144) = 3.21$, $p < .05$, which subsumed no significant main effect of anchor duration, $F(1, 24) = .75$, $p > .05$. In line with the results found in Experiment 1, this significant interaction indicated that, although the bisection data was orderly for all the anchor duration conditions, temporal discrimination appeared to be lower in the milliseconds duration condition. In addition, the ANOVA indicated neither a significant main effect of music, $F(1, 24) = .14$, $p > .05$, nor any significant interaction involving this factor (music × duration range, music × comparison durations, music × duration range × comparison duration, all $p > .05$). As clearly shown in Fig. 2, the bisection functions were similar for the major and the minor music whatever the duration values. Consequently, we did not calculate BP and WR values in order to further investigate the bisection data.

These results reveal that, in a bisection task, the participants estimated the duration of music accurately, without any difference in temporal estimates being observed as a function of musical key. However, it is nevertheless possible that a major–minor difference might be observed in a bisection task which uses longer durations than those employed in Experiments 1 and 2 which, to a considerable extent, relied on memory processes. To test this possibility, we ran a third experiment with longer durations. We have not tested shorter durations (<500 ms) because a certain amount of time is required in order to detect the musical mode. Consequently, reducing the duration of the piece of music below 500 ms would have made the manipulation of the musical mode pointless, since it is usually necessary to listen to several notes in order to identify the mode of a piece.

3. Experiment 3

3.1. Method

3.1.1. Participants

Seventeen new students (11 women and 6 men, mean age = 21.75, $SD = 2.57$) took part in this study in return for a payment of 10 euros.

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3.1.2. Materials and procedure

Both the material and the procedure were similar to those used in Experiment 2, with two types of music being presented in the test phase (major vs. minor). The only difference was that the participants were presented with longer duration values. The short and the long anchor durations were 8 and 27.2 s., respectively, and the comparison durations 8, 11.2, 14.4, 17.6, 20.8, 24 and 27.3 s.

3.2. Results and discussion

The ANOVA performed on *p*(long) revealed neither a significant main effect of music, $F(1, 16)=.05$, $p>.05$, nor any significant interaction between music and the comparison durations, $F(6, 96)=1.54$, $p>.05$. As shown in Fig. 3, there was only a significant effect of comparison durations, $F(6, 96)=193.34$, $p<.05$. This indicates that the proportion of long responses increased with the duration value. To summarize, even with longer durations than those used in Experiments 1 and 2, there was no difference between the perceived duration of the major and minor music. In sum, our various experiments demonstrated that, in the specific case of music, emotional valence did not affect the perception of time.

3.3. General discussion

The present study is the first to investigate the influence of musical stimuli and their emotional valence on the perception of time by means of a temporal bisection task using different ranges of durations. The main finding was that sensitivity to time (i.e., WR) was high (0.18–0.20), with a value close to those found in other bisection studies using auditory stimuli (e.g., Allan & Gibbon, 1991; Droit-Volet & Izaute, 2009; Wearden, 2001; Wearden & Ferrara, 1996). Moreover, this sensitivity to time did not differ as a function of the type of auditory stimulus used (musical vs. pseudo-musical sine wave sound). However, whereas the music did not affect temporal sensitivity, it did result in a distortion of time. Compared to the sine wave control music, the music presented in a major or a minor key shifted the bisection function toward the right, thus increasing the BP value. This rightward shift of the bisection function reveals that the duration of a melody is judged shorter than that of a non-melodic stimulus. This finding is consistent with the results of studies indicating that musical stimuli reduce time estimates compared to less musical stimuli (e.g., Bailey & Areni, 2006; North & Hargreaves, 1999). All of these studies confirm that “time flies” when we listen to music.

As suggested by most studies of music and time perception (for a review, see Bailey & Areni, 2006), this shortening effect may be interpreted in the light of attention-based theories on time (for reviews, see Lejeune, 1998; Zakay, 2005). According to these theories, there are two processors, one for temporal information and the other for non-temporal information, that compete for attentional resources taken from a common pool of limited capacity. When more attention is directed toward the processing of non-temporal information, fewer units of time are accumulated and the time is judged shorter. The attentional models based on a pacemaker–accumulator clock system (Zakay & Block, 1996) explain this shortening effect in terms of an attentional switch that gates the temporal units (pulses) emitted by a pacemaker into an accumulator by closing and opening at the beginning and the end of the stimulus duration, respectively. In these models, an attention-shortening effect may be produced by a longer switch-closure latency or by a flickering of the switch during the passage of time (alternating closure–opening phases) (Lejeune, 1998; Penney, 2003). In both cases, some pulses are lost and the duration is perceived as shorter. However, only in the former case is the shortening effect constant irrespective of duration value (Burle & Casini, 2001). The results of the present study, which indicate a greater shortening effect for the long than for the short anchor durations, are thus more consistent with a music-related attentional effect which occurs throughout the stimulus duration than with a simple effect relating only to the triggering of temporal processing. An alternative hypothesis is that the music decreases the internal clock speed. Certain studies have also demonstrated a temporal shortening effect linked to a decrease in clock speed in response to the administration of antipsychotic medication such as haloperiodol which reduces the level of dopamine in the brain (e.g., Maricq & Church, 1983; Meck, 1983). In the present study, the participants might have felt more relaxed when listening to music because it was a pleasurable experience for them. In the present study, it is difficult to dissociate between an attention-related and an arousal-related effect. However, our pretest of musical stimuli did not demonstrate that the pieces of music used in the present study were less arousing than the neutral stimuli. All the musical pieces presented in a major or minor key or in the form of a sine wave control version were judged similarly arousing, with only one exception (M2). It is thus now important to investigate in more detail the effect of music as a function of emotional dimensions other than valence—such as arousal level.

The second main aim of the present study was to assess whether the emotions induced by musical stimuli affect time estimation. Kellaris and Kent (1992) found that music played in a major mode lengthened time estimates compared to minor and atonal music. In contrast, Bueno and Ramos (2007) did not find any significant effect of major versus minor mode, and reported that the locrian mode (less tonal) results in a lengthening of the experience of time compared to the major and minor modes. The present data confirm Peretz et al.'s (1998) finding by showing that the major and the minor music did indeed elicit two different emotions, i.e. happiness and sadness, respectively. However, although we conducted a series of experiments using different methodological conditions (i.e., different ranges of durations from a few milliseconds to several seconds, presence or absence of a control stimulus), our results did not reveal any temporal difference between the major and the minor music. Only a tendency toward a minor–major difference for the short anchor durations (0.5/1.7 s) was observed in Experiment 1, with the duration being estimated shorter for the minor than for the major music. However, this observation was not replicated in either Experiment 2 or 3. Our results are thus consistent with those found by Bueno and Ramos (2007) who, however, used a retrospective and not a prospective paradigm as in our study. To summarize, although the duration of an auditory stimulus was perceived as shorter when the stimulus took the form of music, the musical valence (happy or sad) did not significantly change the perception of time.

Studies of the effect of emotion on time perception have used emotional stimuli other than musical pieces. They have used emotional faces (e.g., Droit-Volet, Brunot, & Niedenthal, 2004; Droit-Volet & Meck, 2007;

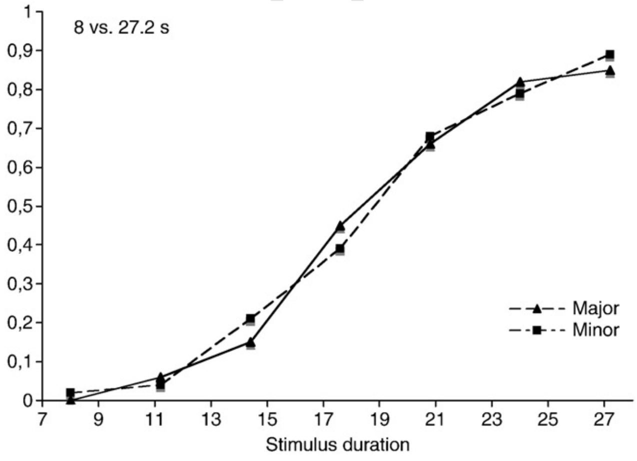

Fig. 3. Proportion of long responses plotted against stimulus duration for the major and the minor music in the 8–27.2 anchor durations condition.

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Gil, Niedenthal & Droit-Volet, 2007), and emotional pictures from the International Affective Pictures System (IAPS) (Angrilli, Cherubini, Pavese, & Manfredini, 1997). Recently, Noulhiane, Mella, Samson, Ragot and Pouthas (2007) conducted an experiment using sounds from the International Affective Digital Sounds (IADS, Bradley & Lang, 1999.). They found that emotional sounds were judged longer than neutral sounds and that this temporal overestimation was greater for sounds with a negative than with a positive valence. The authors explained this lengthening effect in terms of the arousing dimension of their emotional sounds which speeded up the internal clock. When the internal clock runs faster, more pulses are accumulated, and time is judged longer. Noulhiane et al. (2007) concluded that "the activation seems to be the predominant aspect of the influence of emotions on time perception, as all emotional stimuli regardless of their self-assessed valence and arousal are perceived as being longer than neutral ones" (p. 702). However, each emotional stimulus organizes and motivates specific aspects of behavior as a function of its meaning in a specific context (Izard, 2007; Mikels et al., 2005).

In our study, the absence of any effect of emotional valence on time perception in the presence of music emphasizes the specificity of music compared to other emotional sounds. Recently, Zentner, Grandjean and Scherer (2008) suggested that music is an emotional stimulus that differs from other types of emotional stimuli. Consequently, a sad sound (individual crying) or a sad picture from the IAPS (people in distress) may involve cognitive mechanisms that are different from those involved when we listen to sad music in that the former directly activate a readiness to act as quickly as possible to stop the other person from feeling sad (Droit-Volet & Gil, 2009). The urgency of the timing of action thus makes the clock run faster and the faster the clock runs, the sooner we are ready to act. In contrast, although sad music is also considered to induce a negative emotion (sadness), it is infrequently followed by a direct goal-oriented action (Zentner et al., 2008). Consequently, when music is rated as sad or happy (minor vs. major key), it may have an effect on time perception which is different from that of other emotional stimuli which are also considered to be negative or positive. In addition, one main difference between music and other emotional stimuli lies in the fact that musical pieces can be judged as pleasant independently of their negative or positive valence (Bigand et al., 2005). It is well known that the subjects spontaneously listen to music for pleasure and well-being, whatever the modality of the music, i.e., sad or happy. Although a piece of music may be judged as negative, subjects take pleasure in listening to this music as much as they do to happy music. In contrast, it is unlikely that perceiving a sad face, i.e., an individual crying, is a pleasant experience. This may therefore explain why, contrary to the results found with other emotional stimuli, the effect of music on time perception does not differ as a function of its positive or negative valence.

In conclusion, our results show that time flies in the presence of music because it distracts our attention away from the processing of time, probably due to music's rich structure or the pleasure produced by listening to it. However, the emotional valence of music (sad vs. happy) is not enough to modulate the perception of time. It is still necessary to determine whether time perception is modulated by pleasant versus unpleasant music and the specific role of the arousal dimension of music.

4. Uncited reference

Droit-Volet & Wearden, 2002

Appendix A

The ANOVA performed on emotional valence with mode (major, minor, sine wave music), duration and musical piece as factors revealed a significant main effect of mode, $F(2, 96)=70.94$, $p<.05$. The major and minor music thus elicited different emotions, i.e. happiness for the former (3.49) and sadness for the latter (5.77) (post-hoc Bonferroni test, $p=.0001$) (Fig. 4). The non-musical sine wave stimuli were also judged sad (5.47). They were rated as being equally sad as the music played in a minor key ($p=.43$), and, consequently, as being sadder than the major music ($p=.0001$). There was neither a significant main effect of duration, $F(1, 48)=0.42$, $p>.05$, nor any significant interaction involving this effect (all $p>.05$), thus indicating that the emotional valence of the music was identified whatever its presentation duration. The ANOVA on the valence rating also showed a main effect of the musical pieces, $F(3, 144)=10.30$, $p>.05$, as well as an interaction between musical pieces and mode, $F(6, 288)=4.82$, $p>.05$. For each musical piece, the minor version was always judged to be sadder than the major version (M1: 5.13 vs. 3.04; M2: 6.49 vs. 4.10; M3: 5.57 vs. 3.24; M4: 5.95 vs. 3.48, post-hoc Bonferroni test, all $p=.0001$). The major music was also judged happier than the matched sine wave stimulus (M1: 5.51; M2: 5.31; M3: 5.61; M4: 5.48, all $p=.001$). Finally, only for one specific musical piece (M2) was the sine wave music judged to be less sad than the corresponding minor version (5.31 vs. 6.49, $p=.0001$). These results confirmed that the minor and the major musical pieces elicited the expected emotions, namely sadness and happiness respectively.

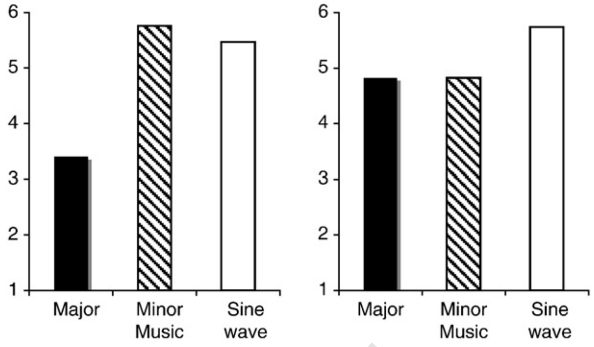

Fig. 4. Subjective valence and arousal ratings for the major, minor and the sine wave (control) music used in the present experiment.

The ANOVA performed on the arousal rating revealed a significant three-way interaction between mode, duration and musical piece, $F(6, 282)=6.77$, $p<.05$, which suggested a variation in the assessment of arousal as a function of the stimulus used. The fact that no effect of mode was observed for most of the musical pieces and presentation durations suggests that the minor and the major mode and its matched sine wave version were judged to be similarly arousing (M1–500 ms, $F(2, 98)=0.73$; M3–500 ms, $F(2, 98)=1.05$; M3–1700 ms, $F(2, 98)=0.84$; M4–500 ms, $F(2, 98)=2.96$; M4–1700 ms, $F(2, 98)=2.06$, all $p>.05$). There was only one musical piece (M2) for which the effect of mode was significant for both the 500-ms and the 1700-ms presentation duration ($F(2, 98)=12.29$, $F(2, 98)=45.11$, respectively, both $p<.05$). The post-hoc comparisons performed using Bonferroni tests suggested that for the 500 and 1700 ms presentation durations, the major (4.12, 3.16, respectively) and the minor music (4.9, 3.26) were judged to be more relaxing that the associated sine wave stimulus (6.06, 6.38) (all $p<.05$), while no significant difference was found between the major and the minor music (all $p>.05$). In the case of the 1700-ms presentation of musical piece M1, an effect of mode was also found, $F(2, 98)=3.78$, $p<.05$. This was due to the sine wave stimulus (5.84) and the minor music (5.34) which were both judged to be more arousing that the major music (4.68), whereas there was no difference between the first two stimuli ($p>.05$).

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