Cognition and Emotion

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pcem20

Music-induced emotions influence intertemporal decision making

Linshu Zhou, Yufang Yang & Shu Li

To cite this article: Linshu Zhou, Yufang Yang & Shu Li (2022) Music-induced emotions influence intertemporal decision making, Cognition and Emotion, 36:2, 211-229, DOI: 10.1080/02699931.2021.1995331

To link to this article: https://doi.org/10.1080/02699931.2021.1995331

COGNITION AND EMOTION
2022, VOL. 36, NO. 2, 211–229
https://doi.org/10.1080/02699931.2021.1995331

Music-induced emotions influence intertemporal decision making

Linshu Zhou [a], Yufang Yang [b] and Shu Li [b,c]

[a]Music College, Shanghai Normal University, Shanghai, People's Republic of China; [b]CAS Key Laboratory of Behavioural Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, People's Republic of China; [c]Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, People's Republic of China

ABSTRACT
People tend to choose smaller, immediate rewards over larger, delayed rewards. This phenomenon is thought to be associated with emotional engagement. However, few studies have demonstrated the real-time impact of incidental emotions on intertemporal choices. This research investigated the effects of music-induced incidental emotions on intertemporal choices, during which happy or sad music was played simultaneously. We found that music-induced happiness made participants prefer smaller-but-sooner rewards (*SS*), whereas music-induced sadness made participants prefer larger-but-later rewards (*LL*). Time perception partially mediated this effect: the greater the perceived temporal difference, the more likely they were to prefer *SS*. Tempo and mode were then manipulated to disentangle the effects of arousal and mood on intertemporal choices. Only tempo-induced arousal, but not mode-induced mood, affected intertemporal choices. These results suggest the role of arousal in intertemporal decision making and provide evidence in support of equate-to-differentiate theory with regard to the non-compensatory mechanism in intertemporal choices.

ARTICLE HISTORY
Received 24 February 2021
Revised 14 October 2021
Accepted 14 October 2021

KEYWORDS
Intertemporal choice; incidental emotions; music; arousal; time perception

1. Introduction

Many important decisions about health, wealth, and happiness involve intertemporal choices (Reeck et al., 2017). However, people tend to forgo larger, delayed rewards in favour of smaller, immediate rewards (Loewenstein, 1996; Loewenstein et al., 2008; Peters & Büchel, 2011). The propensity to devalue delayed rewards, known as temporal discounting, is a basic psychological principle in intertemporal decision making (Green & Myerson, 2004). Dual systems theory suggests that our preference for immediate rewards stems from "hot" emotional responses, whereas patience emerges from more deliberative, "cold" reasoning (Figner et al., 2009; McClure et al., 2004; Metcalfe & Mischel, 1999). The processing of temporal discounting recruits brain regions associated with emotional responses and top-down cognitive control (Frost & McNaughton, 2017; Jimura et al., 2013; Peters & Büchel, 2011), implying that the manipulation of emotions may alter people's intertemporal choices.

Some theories suggest that incidental emotions, which are carried over from one situation to another, can influence intertemporal choices that are unrelated to that incidental emotion (see Engelmann & Hare, 2018 for a review). However, prior studies on the effects of incidental emotions on intertemporal choices have reported mixed results. For example, some studies have demonstrated that negative emotions are more likely to lead to impatience than positive emotions (e.g. Augustine & Larsen, 2011; Liu et al., 2013), whereas other studies have shown that positive emotions lead to impatience (e.g. Hirsh et al., 2010; Luo et al., 2014). These studies usually ask participants to first envision

CONTACT Yufang Yang yangyf@psych.ac.cn; Shu Li lishu@psych.ac.cn CAS Key Laboratory of Behavioural Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, People's Republic of China
Supplemental data for this article can be accessed https://doi.org/10.1080/02699931.2021.1995331.

incidents (e.g. Benoit et al., 2011; Liu et al., 2013), watch pictures (e.g. Augustine & Larsen, 2011; Luo et al., 2014) or read emotional words (e.g. Augustine & Larsen, 2011; Pyone & Isen, 2011) and then engage in intertemporal decision-making tasks. Unfortunately, such emotional manipulations end before decision-making tasks begin, making it difficult for emotions to have a real-time impact during the decision-making process. Furthermore, given that emotional guidance requires conscious attention, such manipulations may not be easily applied to in real life. Understanding the real-time influence of emotions outside the laboratory is crucial to the discussion of the effects of incidental emotions on intertemporal decision making.

Music can serve as a good strategy to continuously arouse emotions (Juslin & Västfjäll, 2008; Konečni, 2008), even during decision-making tasks. The propensity to respond emotionally to music may be innate: newborn infants prefer consonance over dissonance (Trainor & Heinmiller, 1998), and by nine months, they can discriminate between happy and sad music (Flom et al., 2008). Moreover, the social functions of music and the basic emotions it expresses are recognised across cultures (Fritz et al., 2009; Mehr et al., 2018). Most importantly, considering that music can arouse emotions without conscious attention to the stimulus, the use of music as an emotion inducer represents real-life situations (Halko et al., 2015).

To date, no study has examined the influence of music-induced emotions on intertemporal decision making, but some pieces of evidence prove that it affects other decision-making processes, such as prosocial and cooperative behaviours (Greitemeyer, 2009a, 2009b; Kniffin et al., 2017) and risk-taking behaviours (Halko et al., 2015; Schulreich et al., 2014). Unlike other decision-making processes, however, the processing of intertemporal decisions involves the comparison of different options across the dimension of time (e.g. "today" vs. "one year later"). Musical events unfold over time; and the tempo, metre, and rhythm of music are closely related to time. For example, the tempo of a musical piece is usually described in time-related words, such as "fast" and "slow", and is typically measured in beats per minute.

Fast music, associated with high subjective arousal, is perceived to be longer than slow music (e.g. Droit-Volet et al., 2013; Penton-Voak et al., 1996; Treisman et al., 1990, 1992). Therefore, music-induced emotions may affect people's intertemporal choices via an effect on the temporal dimension. Although compensatory theories suggest that people make intertemporal choices by weighting and summing the information from all dimensions and assigning discounted values independently to all options (e.g. Laibson, 1997; Loewenstein & Prelec, 1992; Samuelson, 1937), non-compensatory theories assume that options are not treated independently but rather comparatively (e.g. Jiang et al., 2016; Li, 1994, 2004, 2016; Scholten & Read, 2010; Zhang, Zhou, et al., 2018). For example, equate-to-differentiate (ETD) theory assumes that people tend to compare the difference between the smaller-but-sooner option (*SS*) and the larger-but-later option (*LL*) in the payoff dimension ($\Delta_{payoff\ \mathrm{SS,LL}}$) and the difference in the *delay* dimension ($\Delta_{delay\ \mathrm{SS,LL}}$). Additionally, if $\Delta_{payoff\ \mathrm{SS,LL}} > \Delta_{delay\ \mathrm{SS,LL}}$ ($\Delta_{payoff\ \mathrm{SS,LL}} < \Delta_{delay\ \mathrm{SS,LL}}$), then people will treat the smaller $\Delta_{delay\ \mathrm{SS,LL}}$ ($\Delta_{payoff\ \mathrm{SS,LL}}$) as if no difference exists (i.e. will equate them). In other words, the two options are treated as if they have a weak dominance relationship.[1] Following the weak-dominance principle, people are likely to choose (differentiate) the option with a greater value in the payoff dimension (*LL*) or the option with a smaller delay/time in the delay dimension (*SS*) than other available options (Li, 1994, 2004, 2016). If so, music-induced emotions may influence the perception of temporal differences and thereby affect intertemporal decision making.

The present study thus conducted three experiments to examine the impact of music-induced incidental emotions on intertemporal decision making. First, the influence of music-induced happiness and sadness on intertemporal decision making was investigated in Experiment 1 by using happy (fast major) music, sad (slow minor) music, and white noise (control condition) to induce the corresponding emotions as participants completed an intertemporal decision-making task under money-gain and -loss conditions. To distinguish the effects elicited by arousal and mood, the tempo (fast vs. slow) and mode (major vs. minor) of the background music used in Experiment 1 were selectively manipulated in Experiments 2 and 3, respectively. We predicted that music-induced emotions would influence intertemporal choice under money-gain and -loss conditions, with delay perception playing a mediating role. According to ETD theory (Li, 1994, 2004, 2016), the greater the perceived temporal difference ($\Delta_{delay\ \mathrm{SS,LL}}$), the more likely participants preferred *SS*, whereas the smaller the perceived temporal difference, the more likely participants preferred *LL*. Given the dissociation of mechanisms between intertemporal choices under money-gain and -loss conditions reported in prior studies (e.g. Mitchell & Wilson, 2010; Ohmura et al., 2005; Xu et al., 2009; Zhang, Xu, et al., 2018), the patterns of effect between the two were predicted to be different.

2. Experiment 1: effect of happy and sad music on intertemporal decision making

Happiness and sadness are the most reliable and distinguishable musically induced emotions (Balkwill & Thompson, 1999). In Western tonal music, they rely on two flexible musical features: the tempo (speed of the beat) and the mode (major or minor) (Krumhansl, 1997). Music with a fast tempo and in the major mode evokes a sense of happiness, whereas music with a slow tempo and in the minor mode evokes a sense of sadness (Peretz et al., 1998). The difference between happy and sad emotions can be explained by the two dimensions of arousal and mood: happy emotions involve high arousal and high pleasure, whereas sad emotions involve low arousal and low pleasure (Russell, 1980). Both dimensions may explain the effects of tempo and mode in inducing happiness and sadness because fast music is more arousing than slow music, and major music is more pleasant than minor music.

Experiment 1 used musical excerpts to investigate the effects of music-induced happiness and sadness on intertemporal decision making under money-gain and money-loss conditions. Musical excerpts that express happiness (i.e. fast tempo, major mode) or sadness (i.e. slow tempo, minor mode) were used as background music to induce the corresponding emotions. White noise was used as a control condition because it has relatively neutral emotional characteristics (Nyklíček et al., 1997). According to ETD theory (Li, 1994, 2004, 2016), we predicted that participants in the happy music group (condition) perceived the delay (one year later) to be longer in *LL*. Their perception leads to larger perceived differences in the *delay* dimension ($\Delta_{delay\ \mathrm{SS,LL}} = \Delta_{\mathrm{today,\ one\ year\ later}}$); thus, they were more likely to prefer *SS* than those in the sad music and control conditions. In contrast, participants in the sad music condition were expected to perceive the time delay (one year later) to be shorter in *LL*. Their perception leads to a smaller perceived difference in the *delay* dimension ($\Delta_{\mathrm{today,\ one\ year\ later}}$); thus, they were more likely to prefer *LL* than those in the happy music and control conditions.

2.1. Method

2.1.1. Participants

We applied a between-subjects design, in which participants were randomly assigned to one of three conditions: happy music, sad music, or white noise. *A priori* power analysis with GPower 3.1 (Faul et al., 2009) was conducted. A medium effect size of emotion effect on intertemporal choices was assumed on the basis of previous studies (Bulley et al., 2019; Liu et al., 2013). A minimum of 159 participants were required to detect a medium-sized effect ($f = 0.25$) using one-way ANOVA *F*-tests with 80% power at a 5% α level. A total of 240 participants between 18 and 57 years old were recruited. They were randomly distributed to happy music, sad music, and white noise groups, with 80 participants in each group. Data from six participants were discarded because the data failed to pass the logic check (e.g. one preferred to receive ¥120 now rather than ¥200 one year later, but preferred to receive ¥200 one year later rather than ¥130 now). The final set of participants consisted of 234 participants (140 females, $M_{\mathrm{age}} = 23$ years, Standard Deviation [*SD*] = 1.4). A sensitivity power analysis using GPower 3.1 (Faul et al., 2009), assuming two-tailed $\alpha = 0.05$ and 80% power, revealed a minimum effect size of $f = 0.20$. Table 1 displays the participants' demographic characteristics. The three groups were matched in age, years of education, and years of musical training. All participants signed a written consent form before the experiment and were paid for their participation.

2.1.2. Material

2.1.2.1. Musical stimuli. Twenty-eight musical excerpts, all piano music without lyrics, were used in this experiment. All excerpts were selected from a previous study on music emotion (Peretz et al., 1998), and all were Western tonal music composed during the baroque, classical, romantic or contemporary musical periods from around 1700 to 1900. Half of the excerpts express happiness, and the other half express sadness (Peretz et al., 1998). Happy excerpts were characterised by major mode and fast tempo (between 80 and 255 BPM), whereas sad excerpts

Table 1. Demographic characteristics of participants in the happy music, sad music, and white noise groups.

	Happy music ($n = 77$)	Sad music ($n = 77$)	White noise ($n = 80$)	F	p	Partial η^2
Sex	48F, 29M	46F, 31M	46F, 34M			
Age in years (*SD*)	23.94 (5.42)	24.57 (7.77)	23.93 (5.73)	0.26	.771	0.002
Education in years (*SD*)	15.62 (3.31)	15.26 (3.50)	15.65 (3.57)	0.31	.735	0.003
Music training in years (*SD*)	0.49 (1.21)	0.29 (0.89)	0.50 (1.21)	0.93	.397	0.008

Note: F = female; M = male.

were characterised by minor mode and slow tempo (between 20 and 100 BPM). All excerpts were edited using Adobe Audition CS6 software (Adobe Systems Incorporated, San Jose, CA, USA) with 44.1 kHz and 16-bit resolution; the mean duration was 16 s. The loudness was normalised with Adobe Audition CS6 at an approximate intensity of 68 dB SPL.

2.1.2.2. Intertemporal choice tasks. Two tasks were designed to measure intertemporal decision making under money-gain and money-loss conditions. In the money-gain task, participants were given a series of hypothetical choices between receiving ¥200 one year later and receiving a small amount of money today. In the money-loss task, they were given a series of choices between losing ¥200 one year later and losing a smaller amount of money today. In both tasks, the value of immediate rewards or losses increased from ¥10 to ¥190 in ¥10 increments. In each task, different outcomes (payoffs) were presented in the form of a list. The list consists of 19 rows, and in each row, participants were required to choose between *SS* and *LL*.

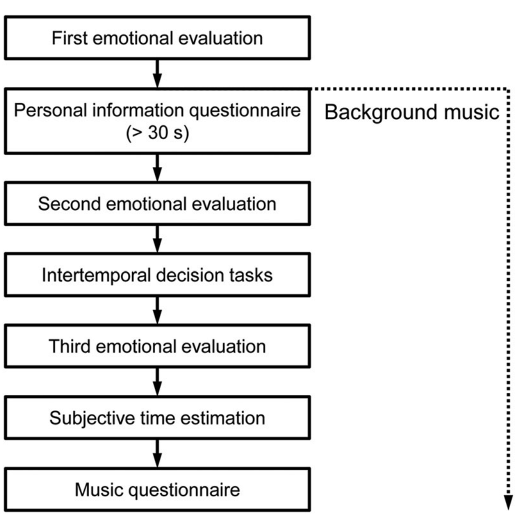

Figure 1. Process of the experimental programme.

The conventional model of intertemporal choice posits that the effect of delay on the subjective value of future outcomes can be captured by a discount function. The discount function is often given as a *discount factor*, which is the proportion of the value that remains after delaying an outcome over a standard period (usually one year).

In this study, the discount factor was computed as follows: The present subjective value was the midpoint value at which participants switched from consistently preferring variable but immediate money to consistently preferring a fixed amount of future money (¥200). This choice-titration procedure made it possible to infer the discount factor. For example, if a participant preferred to receive ¥130 now, rather than ¥200 one year later and preferred to receive ¥200 one year later, rather than ¥120 now, then receiving ¥125 now was assumed to be only as attractive as receiving ¥200 one year later. The subjective value of ¥200 in one year would thus be ¥125 now. The discount factor in this condition would therefore be inferred as 125/200 = 0.625 by definition. If a participant always preferred the alternative "receiving ¥200 one year later", then the subjective value was assumed to be ¥195 now. By contrast, if a participant never preferred the alternative "receiving ¥200 one year later", then the subjective value was assumed to be ¥5 now.

Accordingly, the discount factor in the money-loss task was calculated in the same way. For example, if a participant preferred to lose ¥120 now, rather than ¥200 one year later and preferred to lose ¥200 one year later, rather than ¥130 now, a loss of ¥125 now was assumed to be equal to a loss of ¥200 one year later. The discount factor in this condition would thus be 0.625, according to its definition. If one always preferred the alternative "losing ¥200 one year later", then the subjective value was assumed to be ¥5 now. If one never preferred the alternative "losing ¥200 one year later", then the subjective value was assumed to be ¥195 now.

It should be noted that the discount factor differs from the discount rate, which is another popular index of discounting in intertemporal choices. The discount rate is positively correlated with the degree of discounting or impatience, whereas the discount factor is negatively correlated with it. Specifically, the concept and the calculation indicate that the greater the discount factor, the more likely people prefer *LL* (i.e. less impatient), whereas the smaller the discount factor, the more likely people prefer *SS* (i.e. more impatient). Furthermore, given that our intertemporal tasks involve only two time points (i.e. “today” and “one year later”), the discount factor in the present study reflects only one certainty equivalent, not a curvature over multiple delays as in a typical intertemporal task.

2.1.2.3. Measurement of time perception. To measure participants’ time perception, they were asked to indicate how long or short they considered the duration between today and one day after one year to be on a 100-point scale (where 1 = very short, 100 = very long).

2.1.3. Procedure

Figure 1 illustrates of the experimental programme. Participants were randomly assigned to one of the three different background conditions: (1) happy music, (2) sad music, and (3) white noise conditions. The experiment began with an evaluation of the emotions felt by the participants. They were asked to rate their current happy–sad emotions on a seven-point scale (7 = very happy to 1 = very sad). They were also required to rate the arousal (7 = highest arousal to 1 = lowest arousal) and mood (7 = very pleasant to 1 = very unpleasant) they felt on seven-point scales. Subsequently, background music (or noise) was played until the end of the experiment. In the happy and sad music conditions, excerpts were played continuously in random order. The volume was adjusted to the level that the participant felt comfortable with. Given that previous studies have suggested that 30 s is a reasonable amount of music listening time for emotional induction (Eerola & Vuoskoski, 2013), background music or white noise was played for at least 30 s before the task began. During this time, the participants were asked to fill out a personal information questionnaire to prevent them from knowing the purpose of the manipulation.

To test the success of emotion induction, participants were asked to assess their current emotions a second time after 30 s of background music or white noise. They then performed two intertemporal decision tasks while the music or noise continued to play. The order of the two tasks was counterbalanced across participants. The decision tasks were followed by a third emotional evaluation in which the participants were asked to rate their current emotions again. Finally, they were required to fill out another questionnaire in which they reported on whether and how long they had received any extracurricular training in music, whether they were familiar with the background music or white noise, and how much they liked it (7 = like it very much to 1 = dislike it very much). They were also asked to report whether they had an idea about the purpose of the study, and if they chose “yes”, they were asked to report what they thought the purpose of the study was. To exclude the potential demanding effect, data were reanalysed after exclusion of participants that indicated understanding of the study goal.

2.1.4. Statistical analyses

The differences between the three groups (happy music, sad music, and white noise) were first analysed to determine whether emotional induction was successful. A second analysis was then performed to determine whether differences existed in discount factors among the three groups for each of the two intertemporal decision-making tasks. One-way ANOVAs were followed with multiple comparison analysis tests for the presence of any significant group effect. The Tukey method was adopted for all possible simple contrasts (McHugh, 2011).

To obtain more conservative results and assess the strength of evidence, we ran a Bayesian ANOVA analysis and calculated Bayes factors (*BF*s) using JASP software (van Doorn et al., 2021) with the default priors. The *BF* is the ratio of the probability of one hypothesis over another and can quantify the relative strength of evidence for the alternative (H_1) and null (H_0) hypotheses (Brydges et al., 2020; Love et al., 2019; Wagenmakers et al., 2018). For example, a *BF* of 30 means that the data are 30 times more likely under H_1 than under H_0, providing strong evidence in support of the presence of an effect. Typically, $1 < BF < 3$ is considered *weak* evidence for H_1, $3 < BF < 10$ means *moderate* and $BF > 10$ means *strong*; whereas $0.33 < BF < 1$ indicates *weak* evidence for H_0, $0.10 < BF < 0.33$ means *moderate* and $BF < 0.10$ means *strong* (Jeffreys, 1961; Lee & Wagenmakers, 2014).

As mentioned above, music-induced emotions may affect people’s intertemporal choices via an effect on the temporal dimension. To test this hypothesis, the bootstrapping procedure developed by Hayes and Preacher (2014) was applied to the mediation analysis, with group as an independent variable, discount factor as a dependent variable, and time perception as a mediating variable. The analysis was performed using Model 4 of the PROCESS procedure for SPSS (Hayes & Preacher, 2014). Considering that the independent variable (group) in the present experiment was multicategorical, dummy codes were created for the happy and sad music groups, whereas the white noise group was set as the reference group in each case (Hayes & Preacher, 2014). The bootstrapping process involved 5,000 resamples, and the statistical significance of the indirect paths was determined by 95% confidence intervals (CIs) (Hayes & Preacher, 2014). When zero was not within the 95% CI, the mediation test revealed a significant difference. Familiarity and preference for the music/noise were included in the model as covariables to control for any potential effects of familiarity and preference.

2.2. Results and discussion

The data were reanalysed after exclusion of participants that indicated understanding the purpose of the experiment ($n = 21$). The reanalysis yielded similar results (see Supplemental text for more information).

2.2.1. Effect of music on the emotions of participants

Figure 2 illustrates the participants' rating scores for emotions (happy–sad), arousal, and mood in the three emotional evaluations (before music, with music but before, and after tasks). There was strong evidence against group differences in the first emotional evaluations (all Fs < 0.73, all ps > .481, all partial $\eta^2 < 0.006$, all BFs < 0.09), but strong evidence for differences between the three groups in the second and third evaluations (all Fs > 32.15, all ps < .001, all partial $\eta^2 > 0.21$, all BFs > 1.576e + 10) (Supplemental text, Table S1). Pairwise comparisons revealed significant differences in emotions (happy–sad), arousal, and mood between the three groups at the second and third evaluations (all Fs > 5.84, all ps < .046, all partial $\eta^2 > 0.035$). However, the sad music and white noise groups did not differ in the third evaluation of mood ($F_{(1, 155)} = 1.68$, $p_{corrected} = .407$, partial $\eta^2 = 0.01$) (Supplemental text, Table S1). As displayed in Figure 2, participants in the happy music group experienced higher happiness, higher arousal, and more positive mood. In contrast, participants in the sad music group experienced more sadness, lower arousal, and more negative mood.

2.2.2. Effect of music-induced emotions on intertemporal decision making

Once the successful induction of emotions was established, the effect of music-induced emotions on intertemporal decision making was investigated by analysing the between-group differences in discount factors. Figure 3 shows the mean discount factors for each of the three groups in the intertemporal decision tasks under money-gain and money-loss conditions.

2.2.2.1. Intertemporal decision task under money-gain conditions. One-way ANOVA was performed, taking group as an independent variable and discount factor as a dependent variable. As shown in Figure 3, there was strong evidence for differences between the happy music (*Mean [M]* = 0.28, *SD* = 0.29), sad music (*M* = 0.54, *SD* = 0.30), and white noise (*M* = 0.42, *SD* = 0.32) groups under money-gain conditions ($F_{(2, 231)} = 13.50$, $p < .001$, partial $\eta^2 = 0.11$, $BF = 5519.97$). This result suggests an effect of music-induced emotions on the discount factors under those conditions. Pairwise comparisons revealed that the discount factor for the happy music group was significantly lower than those of the sad music ($F_{(1, 152)} = 28.66$, $p_{corrected} < .001$, partial $\eta^2 = 0.16$) and white noise groups ($F_{(1, 155)} = 7.65$, $p_{corrected} = .016$, partial $\eta^2 = 0.05$), and the discount factor for the sad music group was significantly higher than that for the white noise group ($F_{(1, 155)} = 5.78$, $p_{corrected} = .039$, partial $\eta^2 = 0.04$). These results indicate that participants in the happy music group preferred *SS* in monetary gains, whereas those in the sad music group preferred *LL* in monetary gains.

2.2.2.2. Intertemporal decision task under money-loss conditions. As illustrated in Figure 3, there was strong evidence for differences between the happy music (*M* = 0.53, *SD* = 0.32), sad music (*M* = 0.72, *SD* = 0.28), and white noise (*M* = 0.66, *SD* = 0.34) groups under money-loss conditions ($F_{(2, 231)} = 7.23$, $p < .001$, partial $\eta^2 = 0.06$, $BF = 26.00$). This result suggests an effect of music-induced emotions on the discount factors under those conditions as well. Pairwise comparisons revealed that the discount factor for the

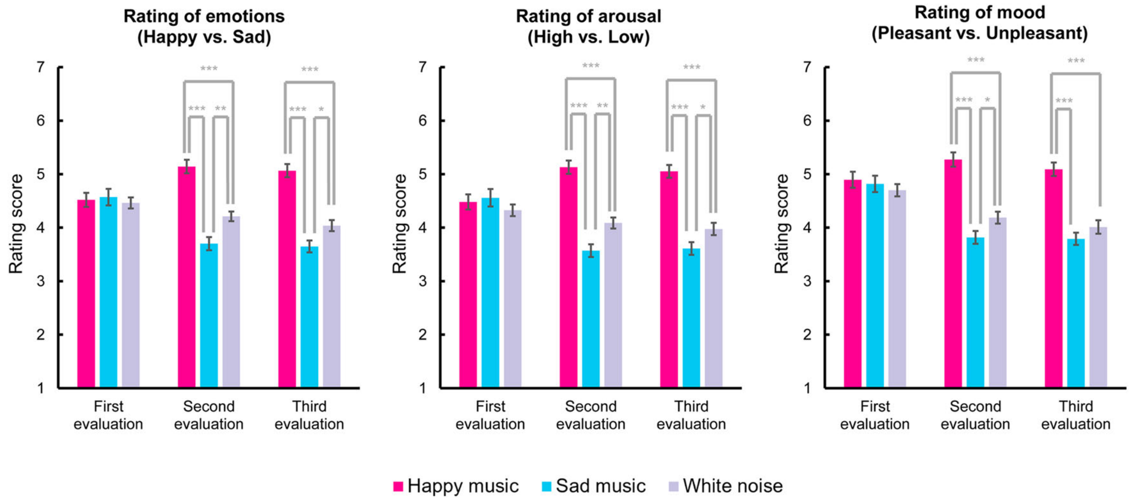

Figure 2. Group differences of the rating scores in the three evaluations of emotions (happy–sad), arousal, and mood. * $p < .05$; ** $p < .01$; *** $p < .001$. Error bars indicate *SE*.

happy music group was significantly lower than those for the sad music ($F_{(1,\ 152)} = 15.21$, $p_{\text{corrected}} = .001$, partial $\eta^2 = 0.09$) and white noise groups ($F_{(1,\ 155)} = 5.86$, $p_{\text{corrected}} = .032$, partial $\eta^2 = 0.04$). These results indicate that participants in the happy music group preferred *SS* in monetary losses more than those in the sad music and white noise groups. No significant difference was observed between the sad music and the white noise groups under money-loss conditions ($F_{(1,\ 155)} = 1.52$, $p_{\text{corrected}} = .440$, partial $\eta^2 = 0.01$).

2.2.3. Mediation effect of time perception

One-way ANOVA showed moderate evidence for a group effect on time perception in subjective time estimation ($F_{(2,\ 231)} = 5.38$, $p = .005$, partial $\eta^2 = 0.05$, $BF = 5.21$), as the duration perceived by the happy music group ($M = 62.79$, $SD = 27.99$) was longer than those perceived by the sad music ($M = 48.62$, $SD = 28.49$, $F_{(1,\ 152)} = 9.69$, $p_{\text{corrected}} = .004$, partial $\eta^2 = 0.06$) and white noise ($M = 53.39$, $SD = 25.33$, $F_{(1,\ 155)} = 4.88$, $p_{\text{corrected}} = .081$, partial $\eta^2 = 0.03$) groups. There was also strong evidence for group differences in familiarity ($F_{(2,\ 231)} = 6.47$, $p = .002$, partial $\eta^2 = 0.05$, $BF = 13.56$) and preference ($F_{(2,\ 231)} = 59.74$, $p < .001$, partial $\eta^2 = 0.34$, $BF = 3.470e + 18$), as participants were more in favour and less familiar with happy and sad music than with white noise (all $Fs > 6.82$, all $ps < .020$, all partial $\eta^2 > 0.04$). Nonetheless, no difference in familiarity or preference existed between the happy and sad music groups (all $Fs < 1.30$, all $ps > .465$, all partial $\eta^2 < 0.009$) (Supplemental text, Table S2).

Figure 4 illustrates the findings from the multicategorical mediation model of intertemporal decision making under money-gain conditions. Compared with the white noise group, the happy music group had a lower discount factor ($B = -.20$, $SE = .06$, $p < .001$), and time perception was found to mediate the relationship between group and discount factor (indirect effect, $B = -.06$, $SE = .03$), 95% CI [−0.12, −0.02]. These results demonstrated a negative correlation between the perceived temporal difference and the discount factor: the greater the perceived temporal difference, the more likely people preferred *SS*. After time perception was controlled for, the 95% CI of the direct effect ($B = -.14$, $SE = .05$, $p = .006$) of the happy music group was [−0.24, −0.04]. This result suggests that time perception played a partial mediating role between group and discount factor for intertemporal decision making under money-gain conditions. A *post-hoc* power analysis was conducted using the application of Monte Carlo Power Analysis for Indirect Effects developed by Schoemann et al. (2017; http://marlab.org/power_mediation). We entered correlation coefficients between X (group) and M (time perception), $r = 0.20$, X (group) and Y (discount factor), $r = -0.29$, and M (time perception) and Y (discount factor), $r = -0.48$, which were obtained from the present experiment. The results indicate that a sample size of 234 participants

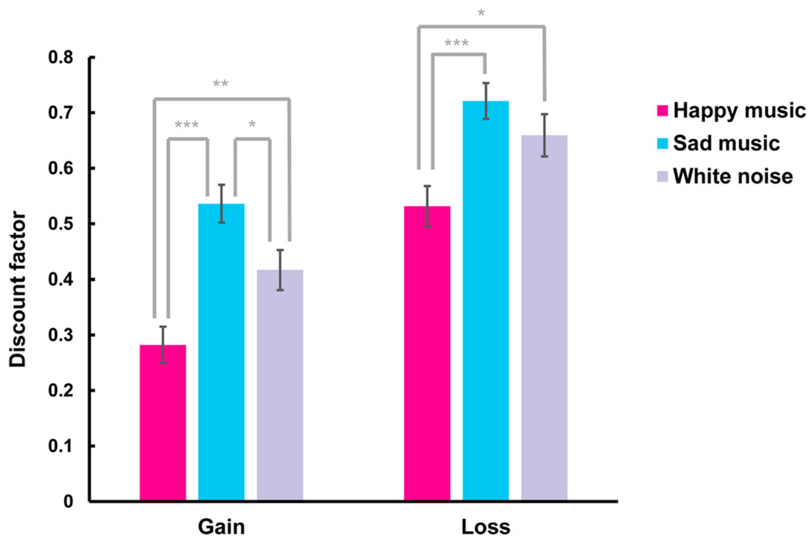

Figure 3. Mean discount factors for the three groups in the intertemporal decision tasks under money-gain and -loss conditions. The greater the discount factor, the more likely people prefer *LL*. * $p < .05$; ** $p < .01$; *** $p < .001$. Error bars indicate *SE*.

reach a power of 86% for the mediation effect of music-induced emotions on intertemporal choices through time perception.

Compared with the white noise group, however, participants in the sad music group did not have a higher discount factor ($B = .04$, $SE = .06$, $p = .518$). Thus, time perception failed to mediate the relationship between the group and discount factor for the sad group (indirect effect, $B = .005$, $SE = .03$), 95% CI [−0.05, 0.06].

In the intertemporal decision-making task under money-loss conditions, the happy music group had a lower discount factor than the white noise group ($B = -.14$, $SE = .06$, $p = .023$). However, time perception failed to mediate the relationship between group and discount factor for the happy group (indirect effect, $B = -.002$, $SE = .01$), 95% CI [−0.03, 0.02]. Given that no significant differences existed between sad music and white noise groups under money-loss conditions ($B = .05$, $SE = .06$, $p = .418$), time perception had no mediating role (indirect effect, $B = .0001$, $SE = .004$), 95% CI [−0.01, 0.01].

In line with previous findings (e.g. Dalla Bella et al., 2001; Khalfa et al., 2005; Peretz & Zatorre, 2005), happy/sad background music can be used to successfully evoke the corresponding emotions. Consistent with existing research (e.g. Hunter et al., 2010), this experiment also confirmed that happy emotional experiences correspond to higher arousal and higher pleasure, whereas sad emotional experiences

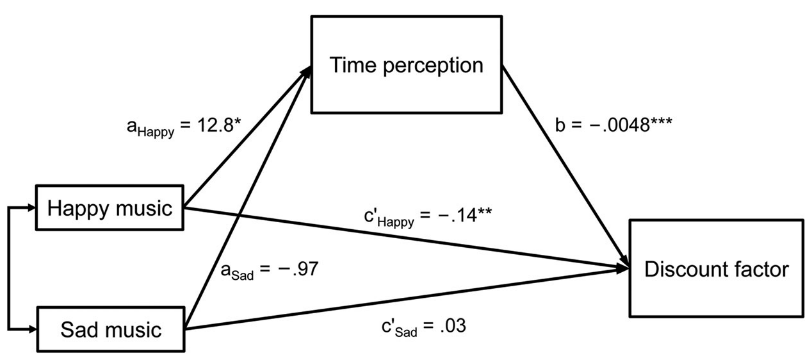

Figure 4. Multicategorical mediation model for happy and sad music on the discount factor in the money-gain intertemporal decision task (unstandardised beta reported). * $p < .05$; ** $p < .01$; *** $p < .001$.

correspond to lower arousal and lower pleasure. Discount factors for the happy music group were found to be significantly lower than those for the sad music and white noise groups, indicating the effects of music-induced emotions on intertemporal decision making. Importantly, the experiment demonstrated a partial mediating role of time perception between group and discount factor for the intertemporal decision making of the happy group under money-gain conditions. Consistent with ETD theory (Li, 1994, 2004, 2016), this finding suggests that participants in the happy music group perceived the delay to be longer in *LL* and thus were more likely to prefer *SS* than the participants in the other groups.

Although Experiment 1 revealed the effect of music-induced incidental emotions on intertemporal decision making, one could ask specifically which features of the music and corresponding emotional effects were responsible for the effect on intertemporal decision making. Specifically, tempo and mode (and their corresponding emotional characteristics) might have different effects on intertemporal decision making. Thus, Experiments 2 and 3 were conducted to distinguish the emotional effects of tempo and mode.

3. Experiment 2: effect of tempo-induced emotions on intertemporal decision making

To investigate the effects of tempo-induced incidental emotions on intertemporal decision making, the mode of all music excerpts in Experiment 1 was reversed; hence, their original emotional characteristics were expressed by tempo, rather than mode. Participants were randomly assigned to one of the two background conditions: fast or slow music. Tempo manipulation has a strong and reliable impact on listeners' changes in arousal, whereas it is not associated with changes in mood (Husain et al., 2002). Tempo manipulation was thus expected to result in variations in arousal, which, in turn, might influence intertemporal decision making under money-gain and money-loss conditions. Time perception was also expected to play a mediating role between tempo-induced emotions and intertemporal decision making.

Table 2. Demographic characteristics of participants in the fast and slow tempo groups.

	Fast tempo ($n = 75$)	Slow tempo ($n = 78$)	t	p	d
Sex	48F, 27M	56F, 22M			
Age in years (*SD*)	20.99 (4.39)	21.68 (5.40)	0.87	.386	0.14
Education in years (*SD*)	14.17 (2.50)	14.31 (2.72)	0.32	.751	0.05
Music training in years (*SD*)	0.74 (1.97)	0.64 (1.54)	0.35	.729	0.05

Note: F = female; M = male.

3.1. Method

3.1.1. Participants

A priori power analysis conducted using GPower 3.1 (Faul et al., 2009) indicated that at least 128 participants were required to detect a medium-sized effect ($d = 0.5$) using independent sample *t*-tests with 80% power at a 5% α level. A total of 160 participants who did not participate in Experiment 1 were recruited. They were randomly distributed to fast and slow tempo conditions, with 80 participants in each condition. Data from seven participants were discarded because the data failed to pass the logic check. The final set of participants thus consisted of 153 individuals (104 females, $M_{age} = 21.34$ years, $SD = 4.92$). A sensitivity power analysis using GPower 3.1 (Faul et al., 2009), assuming two-tailed $\alpha = 0.05$ and 80% power, revealed a minimum effect size of $d = 0.45$. Table 2 shows the participants' demographic characteristics. The two groups were matched in age, years of education, and years of musical training. All participants signed a written consent form before the experiments and were paid for their participation.

3.1.2. Stimuli and procedure

The stimuli for this experiment were 14 musical excerpts played in fast tempi and 14 excerpts played in slow tempi. They were generated by electronically manipulating the 28 musical excerpts used in Experiment 1 to create a mode inversion from major to minor and vice versa (see Peretz et al., 1998 for more details). Although the mode information of the musical excerpts was inverted, their tempo characteristics were retained. That is, the 14 music excerpts that originally expressed happiness were still in fast tempi (between 80 and 255 BPM), whereas the other 14 music excerpts that originally expressed sadness were in slow tempi (between 20 and 100 BPM).

The intertemporal choice tasks, time perception measurements, experimental procedures, and statistical analyses were similar to those of Experiment 1.

3.2. Results and discussion

The data were reanalysed after exclusion of participants that indicated understanding the goal of the experiment ($n = 10$). The reanalysis yielded similar results (see Supplemental text for more information).

3.2.1. Effect of music tempo on the emotions of participants

Figure 5 displays the participants' rating scores for emotions (happy/sad), arousal, and mood in the three emotional evaluations (before music, with music but before, and after tasks). As illustrated in Figure 5, although moderate evidence against the group difference in arousal ratings was observed for the first emotional evaluations ($t_{(151)} = 0.46$, $p = .645$, $d = 0.08$, $BF = 0.19$), there was strong evidence to support that the fast tempo group experienced higher arousal than the slow tempo group on the second ($t_{(151)} = 3.98$, $p < .001$, $d = 0.64$, $BF = 195.95$) and third ($t_{(151)} = 3.20$, $p = .002$, $d = 0.52$, $BF = 17.66$) evaluations (Supplemental text, Table S3). Moreover, moderate evidence against group differences in emotion and mood ratings was observed for each of the three evaluations (all ts < 1, all ps > .322, all ds < 0.17, all BFs < 0.28) (Supplemental text, Table S3). These results suggest that the tempo manipulation of the musical excerpts evoked the predicted changes in emotional arousal without affecting happiness/sadness or mood.

3.2.2. Effect of tempo-induced arousal on intertemporal decision making

Figure 6 presents the mean of the discount factors for both groups in the intertemporal decision making task under money-gain and money-loss conditions. For the money-gain decision task, a Bayesian independent samples t test showed strong evidence for the group difference ($t_{(146.87)} = 3.11$, $p = .002$, $d = 0.50$, $BF = 13.81$), as discount factors were lower for the fast tempo group ($M = 0.35$, $SD = 0.34$) than for the slow tempo group ($M = 0.51$, $SD = 0.30$) (Figure 3). This result indicates that participants in the fast tempo group preferred *SS* in monetary gains more than those in the slow tempo group. For the money-loss decision task, however, there was moderate evidence against the difference between the fast ($M = 0.62$, $SD = 0.34$) and the slow ($M = 0.62$, $SD = 0.33$) tempo groups ($t_{(151)} = 0.03$, $p = .973$, $d = 0.006$, $BF = 0.17$). This finding suggests that tempo-induced arousal did not influence intertemporal decision making under money-loss conditions.

3.2.3. Mediation effect of time perception

Moderate evidence for a group effect on time perception was observed ($t_{(151)} = 2.87$, $p = .005$, $d = 0.46$, $BF = 7.22$), as the average duration perceived by the fast tempo group ($M = 70.01$, $SD = 23.91$) was significantly longer than that for the slow tempo group ($M = 57.94$, $SD = 27.93$). Furthermore, there was moderate and weak evidence against the group differences in music familiarity ($t_{(151)} = 0.76$, $p = .449$, $d = 0.13$, $BF = 0.23$) and music preference ($t_{(144.17)} = 1.55$, $p = .124$, $d = 0.25$, $BF = 0.52$), respectively (Supplemental text, Table S4).

Figure 7 shows the findings from the mediation model of the group effect on discount factors in intertemporal decision making under money-gain conditions. The fast tempo group had a lower average discount factor than the slow tempo group ($B = .15$, $SE = .05$, $p = .004$), and time perception mediated the relationship between music tempo and discount factor (indirect effect, $B = .07$, $SE = .03$), 95% CI [0.02, 0.13]. After time perception was controlled for, the 95% CI of the direct effect ($B = .09$, $SE = .05$, $p = .07$) of the music tempo was [−0.01, 0.18], indicating that time perception played a fully mediating role between music tempo and the discount factor for intertemporal decision making under money-gain conditions. A *post-hoc* power analysis was conducted. Correlation coefficients between X and M, $r = -0.23$, X and Y, $r = 0.25$, and M and Y, $r = -0.48$, were obtained from the present experiment. The results showed that a sample size of 153 participants reach a power of 85% for the mediation effect of tempo-induced arousal on intertemporal choices through time perception.

Consistent with previous studies (e.g. Husain et al., 2002), music tempo manipulation was found to successfully evoke changes in arousal, rather than in mood. Furthermore, participants in the fast tempo group had a stronger preference for *SS* in monetary gains than those in the slow tempo group, suggesting an effect of tempo-induced arousal on intertemporal decision making under money-gain conditions. This effect was attributable to changes in subjective time estimation. These results are consistent with a recent study (Kim & Zauberman, 2019), which have demonstrated that participants who listened to fast (vs. slow) tempo music became more impatient when considering a gift certificate and that this effect was attributable to the change in their temporal distance

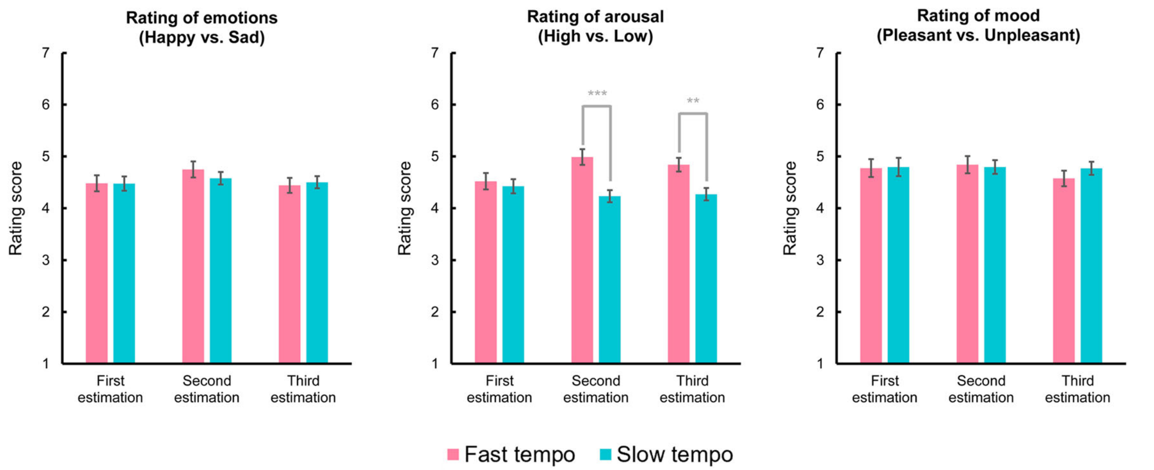

Figure 5. Mean rating scores in the three evaluations of emotions (happy/sad), arousal, and mood for the fast and slow tempo groups. ** $p < 0.01$; *** $p < 0.001$. Error bars indicate *SE*.

judgement. This finding also implies that the influence of music-induced emotions found in Experiment 1 on intertemporal decision making can be partly explained by music tempo and its arousal effect.

4. Experiment 3: effect of mode-induced emotions on intertemporal decision making

The third experiment investigated the effects of mode-induced incidental emotions on intertemporal decision making under money-gain and money-loss conditions. The mode information of the music excerpts in Experiment 1 was retained, but the tempo was altered. Participants were randomly assigned to one of the two background conditions: major or minor music. Mode manipulation has a robust and reliable impact on listeners' mood changes, but it is not associated with changes in arousal (Droit-Volet et al., 2010; Husain et al., 2002). Therefore, mode manipulation was expected to result in changes in mood, which, in turn, could influence intertemporal decision making. Time perception was also expected to play a mediating role between mode-induced emotions and intertemporal decision making.

4.1. Method

4.1.1. Participants

A total of 160 participants who did not participate in Experiments 1 and 2 were recruited. They were randomly distributed to major and minor music conditions, with 80 participants in each condition. Data from one participant were discarded because the data failed to pass the logic check. The final set of participants consisted of 159 individuals (99 females, $M_{age} = 21.32$ years, $SD = 5.13$). A sensitivity power analysis using GPower 3.1 (Faul et al., 2009), assuming two-tailed $\alpha = 0.05$ and 80% power, revealed a minimum effect size of $d = 0.44$. Table 3 presents the participants' demographic characteristics. The major and minor music groups were matched in age, years of education, and years of musical training. All participants signed a written consent form before the experiments and were compensated for their participation.

4.1.2. Stimuli and procedure

The stimuli for this experiment were 14 musical excerpts in the major mode and 14 excerpts in the minor mode. Specifically, the 28 musical excerpts used in Experiment 1 were manipulated electronically to create neutralised tempo versions, which were accomplished by adjusting all tempi to the median (with the quarter note = 84 M.M.) of all original tempi (see Peretz et al., 1998 for more details). Although the tempi of the musical excerpts were normalised, their mode information (major or minor) was retained. That is, the 14 music excerpts that originally expressed happiness were still in a major mode, whereas the other 14 music excerpts that originally expressed sadness were still in a minor mode.

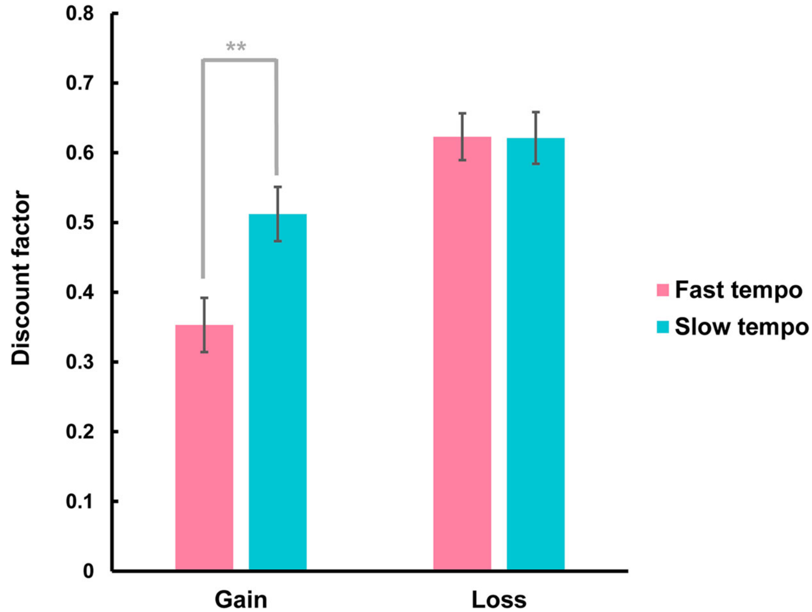

Figure 6. Mean discount factor for the fast and slow tempo groups in the intertemporal decision-making tasks under money-gain and -loss conditions, respectively. ** $p < 0.01$. Error bars indicate *SE*.

The intertemporal choice tasks, time perception measurements, experimental procedures, and statistical analyses were all similar to those of Experiment 1.

4.2. Results and discussion

The data were reanalysed after exclusion of participants that indicated understanding of the study goal ($n = 14$). The reanalysis yielded similar results (see Supplemental text for more information).

4.2.1. Effect of music mode on the emotions of participants

Figure 8 shows the participants' rating scores for emotions (happy/sad), arousal, and mood in the three emotional evaluations (before music, with music but before, and after tasks). As illustrated in Figure 8, although moderate evidence against the group difference in mood ratings was observed for the first emotional evaluations ($t_{(157)} = 0.43$, $p = .67$, $d = 0.07$, $BF = 0.18$), there was strong evidence to

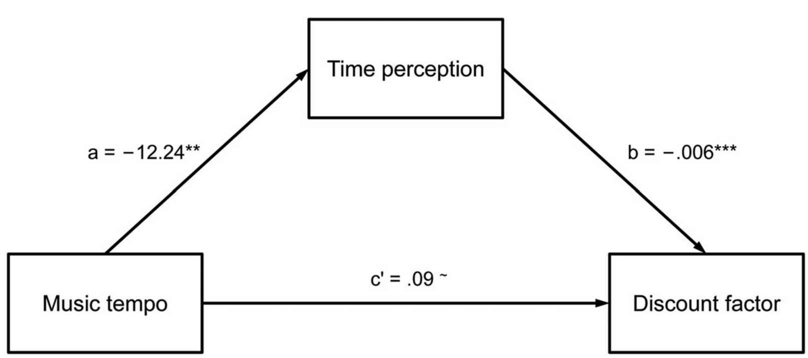

Figure 7. Mediation model for music tempo on the discount factor in the intertemporal decision task under money-gain conditions (unstandardised beta reported). ~ $p < .1$; ** $p < .01$; *** $p < .001$.

Table 3. Demographic characteristics of participants in the major and minor music groups.

	Major (*n* = 80)	Minor (*n* = 79)	*t*	*p*	*d*
Sex	52F, 28M	47F, 32M			
Age in years (*SD*)	20.74 (3.71)	21.91 (6.21)	1.44	.156	0.23
Education in years (*SD*)	14.09 (1.69)	14.24 (2.84)	0.41	.681	0.06
Music training in years (*SD*)	0.52 (1.41)	0.63 (1.64)	0.47	.639	0.07

Note: F = female; M = male.

support that the major group was more pleasant than the minor group on the second ($t_{(157)} = 3.18$, $p = .002$, $d = 0.50$, $BF = 16.42$) and third ($t_{(157)} = 3.02$, $p = .003$, $d = 0.48$, $BF = 10.72$) evaluations (Supplemental text, Table S5). Moreover, no group differences were found in emotion and arousal ratings for each of the three evaluations (all $ts < 1.48$, all $ps > .141$, all $ds < 0.24$, all $BFs < 0.47$) (Supplemental text, Table S5). These results suggest that the mode manipulation of musical excerpts evoked the desired changes in mood.

4.2.2. Effect of mode-induced mood on intertemporal decision making

Figure 9 displays the mean of the discount factor for both groups in the intertemporal decision tasks under money-gain and money-loss conditions. For the money-gain decision task, although the major group ($M = 0.38$, $SD = 0.31$) trended toward lower discount factors than the minor group ($M = 0.46$, $SD = 0.31$), there was weak evidence against a group effect ($t_{(157)} = 1.58$, $p = .116$, $d = 0.26$, $BF = 0.54$). Similarly, for the money-loss decision task, there was weak evidence against the difference between the major ($M = 0.68$, $SD = 0.33$) and the minor ($M = 0.74$, $SD = 0.28$) groups ($t_{(157)} = 1.33$, $p = .184$, $d = 0.20$, $BF = 0.39$). These results suggest that mode-induced mood did not have an influence on intertemporal decision making under either money-gain or money-loss conditions. Furthermore, there was moderate evidence against group differences in subjective time estimation ($t_{(157)} = 0.74$, $p = .463$, $d = 0.12$, $BF = 0.22$), music familiarity ($t_{(157)} = 0.05$, $p = .964$, $d = 0.007$, $BF = 0.17$), and music preference ($t_{(142.74)} = 1.15$, $p = .251$, $d = 0.18$, $BF = 0.31$) (Supplemental Text, Table S6).

Consistent with previous studies (e.g. Droit-Volet et al., 2010; Husain et al., 2002), the mode manipulation in the present experiment successfully evoked changes in mood, rather than in arousal. However, the present experiment found that mode-induced mood did not have an influence on intertemporal decision making. This might be partly due to the fact that music mode has little influence on time perception (e.g. Bueno & Ramos, 2007; Droit-Volet et al., 2010, 2013). These results imply that that mode and the changes in mood it evokes have less influence on intertemporal decisions than do tempo and the associated changes in arousal.

5. General discussion

Experiencing music has a strong emotional component (Sloboda, 1991). The study used different types of background music to investigate the effects of music-induced incidental emotions on intertemporal decision making under money-gain and money-loss conditions. In Experiment 1, happy (fast tempo, major mode) and sad (slow tempo, minor mode) music successfully evoked the predicted emotions of happiness and sadness, which, in turn, affected the discount factors in the intertemporal decision-making tasks via a mediating effect of time perception. Specifically, participants in the happy music group perceived the time delay between immediate and deferred rewards to be longer and thus had a stronger preference for *SS* in monetary gains than did participants in the other groups. For an in-depth understanding of this effect, tempo (Experiment 2) and mode (Experiment 3) were manipulated to further investigate their impact on intertemporal decision making. Tempo manipulations affected arousal but not mood, whereas mode manipulations affected mood but not arousal. However, only tempo and the arousal it induced affected intertemporal choice under money-gain conditions, with a mediating role for time perception. To our knowledge, this study is the first to investigate the effects of music-induced emotions on intertemporal decision making, providing evidence in support of non-compensatory theories in intertemporal choices, such as ETD theory (Li, 1994, 2004, 2016).

The main contribution of this research is to show the real-time impact of music-induced incidental emotions on the discount factors of intertemporal decision making. Consistent with previous studies examining the effects of viewing affective pictures on intertemporal decision making (e.g. Sohn et al., 2015), this study reveals that high arousal induced by music makes people impatient when making

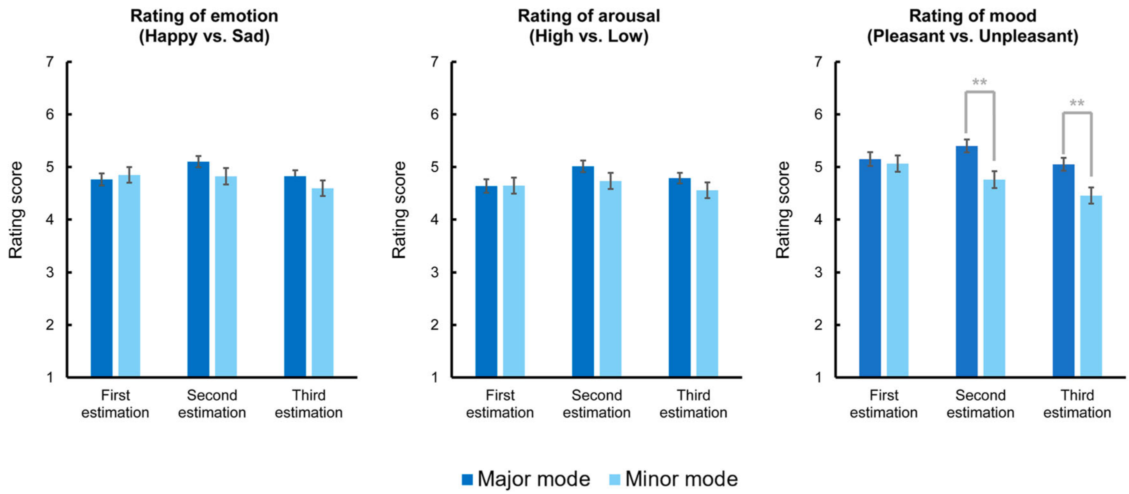

Figure 8. Mean rating scores in the three evaluations of emotions (happy/sad), arousal, and mood for the major and minor groups. ** $p < .01$. Error bars indicate *SE*.

intertemporal choices. Unlike previous studies, the current research also presents the emotional stimulus (i.e. background music) throughout the process of intertemporal decision making, ensuring that music-induced emotions can influence decision making in real time. The results of the emotional evaluations also demonstrated a stable emotional response to music. Therefore, our findings are consistent with those of previous studies (Greitemeyer, 2009a, 2009b; Halko et al., 2015; Kniffin et al., 2017; Schulreich et al., 2014), confirm that music is a reliable emotion-inducing stimulus that can influence decision making.

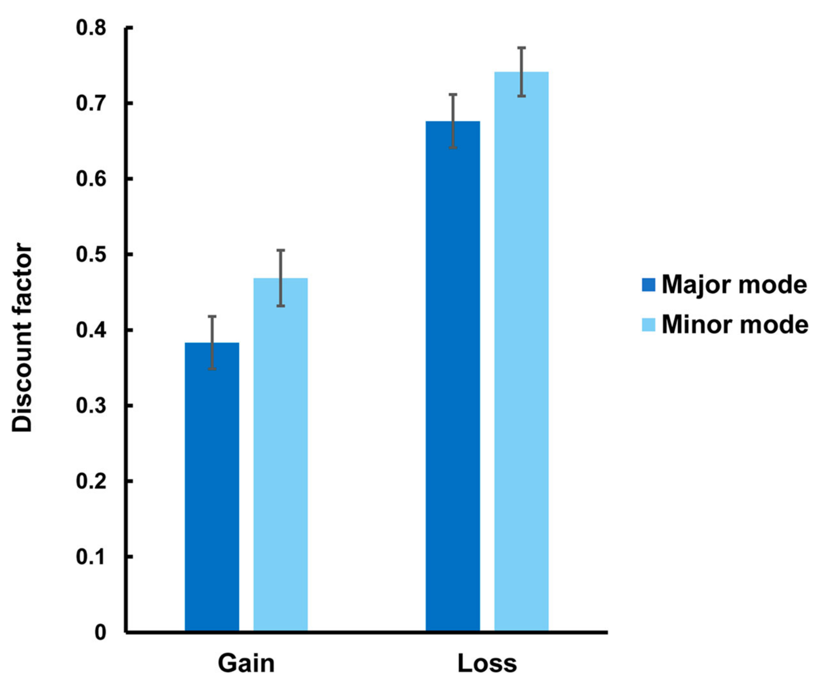

Figure 9. Mean discount factor for the major and minor groups in the intertemporal decision tasks under money-gain and -loss conditions, respectively. Error bars indicate *SE*.

Our results further extend this conclusion to the realm of intertemporal decision making.

Compensatory theories assume that people first weigh and sum the information of all dimensions for each option independently and then compare the discounted values (e.g. Laibson, 1997; Loewenstein & Prelec, 1992; Samuelson, 1937). Based on this assumption, the perception of the time difference between "today" and "one year after" (i.e, $\Delta_{delay\ \mathrm{SS,LL}}$) in the study should not have affected intertemporal choices. However, the greater the difference in time perception, the more likely the participants were to choose *SS*. This finding can be satisfactorily explained by non-compensatory theories. According to EDT theory (Li, 1994, 2004, 2016), when the perceived time differences are enlarged, participants may equate the outcome dimension and leave the temporal dimension as the determinant dimension and then select the superior option (i.e. "today" in the present study) in the determinant dimension. In line with EDT theory, our findings suggest that intertemporal choice may not depend on a weighting-and-adding process, but may be based on a heuristic process that is predicted by non-compensatory theories.

Our findings also support the dual systems theory of intertemporal choice (Figner et al., 2009; McClure et al., 2004; Metcalfe & Mischel, 1999), which predicts that high emotional arousal can increase the engagement of the "hot" system, resulting in steep discounting. Experiments 1 and 2 presented background music with high arousal (resulting from a fast tempo) to make participants impatient when making intertemporal choices. In contrast, when arousal was controlled, the differences in mood were not sufficient to cause changes in intertemporal choices. Therefore, our findings disentangle the effects of arousal and mood with regard to their impact on intertemporal choices.

This study distinguishes the roles of tempo and mode in the effects of happy/sad emotions on intertemporal choices. Given that intertemporal choices were regulated by tempo-induced arousal rather than mode-induced mood, tempo was mainly responsible for the effect found in Experiment 1. This conclusion not only confirms the effect of arousal on intertemporal decision making, but also suggests that tempo exerts a greater effect on emotional changes than mode (Khalfa et al., 2005). Consistent with previous studies (e.g. Bueno & Ramos, 2007; Droit-Volet et al., 2010, 2013), tempo, but not mode, affected time perception in the present study. However, time perception was found to only partially mediate the effect of happy/sad music on intertemporal choices under money-gain conditions, although it fully mediated the effect of tempo. This finding suggests that the effects of happy/sad emotions on intertemporal choices under money-gain conditions cannot be fully attributed to time perception, and that tempo cannot fully explain the effect of happy/sad music. Music has various acoustic and structural characteristics. Future research should focus on other acoustic or structural features of music to fully reveal the mechanisms underlying the effect of music on intertemporal decision making.

The emotional effects of music on intertemporal choices differ in the gain and loss situations. Specifically, in this study, time perception was observed to mediate the effects of happy/sad emotions on intertemporal choices involving gains, but not losses. Given that the investigation of time perception in this research was mainly related to the manipulation of tempo, it should be attributed to the finding that intertemporal choices involving losses are less affected by tempo than those involving gains. Although tempo-induced arousal influenced intertemporal choices involving gains, it did not affect intertemporal choices for the losses. The psychological impact of delayed losses is larger than that of delayed gains of the same size, and the subjective values of losses are less influenced by delay than the values of gains (Frederick et al., 2002; Loewenstein & Prelec, 1992). Consequently, people may be cautious and conservative in choosing to delay their losses, resulting in reduced effects of music-induced emotions on intertemporal choices under money-loss conditions.

Given that some emotional disorders are associated with differences in discounting compared with healthy controls, our findings may help shed light on the mechanisms underlying these atypical decision-making behaviours. For example, individuals with major depressive disorder (Engelmann et al., 2013; Imhoff et al., 2014; Takahashi et al., 2008) and high trait anxiety (Rounds et al., 2007; Xia et al., 2017; Zhao et al., 2015) exhibited greater delay discounting in intertemporal choices, in comparison to healthy controls. Given the suggestive role of emotional arousal in intertemporal choices, as revealed in the present study, the impulsive preferences for *SS* in individuals with emotional disorders may be related to their elevated emotional arousal.

Indeed, people with depression and/or anxiety showed dysfunctional emotional processing and increased arousal experience (e.g. Wenzler et al., 2017), which may be related to their abnormalities in activating arousal-related brain areas such as right hemisphere hyperactivation (Bruder et al., 1997). Future studies may investigate whether the anomaly of discounting in intertemporal choices is related to the abnormal activity of the brain regions involved in emotional arousal.

A potential limitation of this study was that hypothetical scenarios were used in the decision tasks. The participants' involvement might be relatively low because the choices they make have no real consequences for gains or losses. The effect of music-induced emotions on intertemporal choices may be pronounced if there are actual consequences. We cannot rule out this possibility although previous research indicates that hypothetical and actual rewards lead to similar patterns of temporal discounting (Johnson & Bickel, 2002; Madden et al., 2003). Indeed, in the present study, there was weak evidence against the mood effect on the discount factors under money-gain and money-loss conditions. Although strong evidence for the arousal effect was revealed in the same hypothetical scenario, future studies should further examine the role of mode-induced mood on intertemporal choices by using more sensitive experimental designs.

In conclusion, the effects of music-induced incidental emotions on intertemporal decision making were investigated by manipulating musical stimuli and measuring changes in emotional states. Our findings reveal that music-induced happiness or high-arousal emotions make people perceive delays as being longer and thus lead them to prefer smaller but immediate rewards. As one of the major structural determinants of musical emotions, however, tempo and the arousal it induced affected gain-related but not loss-related intertemporal choices. These findings complement previous studies on the influence of incidental emotion on intertemporal decision making, including research on the link between music and human decision-making behaviours. The study also suggests that music can be an effective intervenient variable over intertemporal choices and thus can create a new form of emotional intervention in choice architecture to nudge people toward improved decisions by organising the context in which people make decisions (He et al., 2018; Thaler & Sunstein, 2008).

Note

1. Weak dominance states that if Option A is at least as good as Option B in all dimensions, and Option A is definitely better than Option B in at least one dimension, then Option A will dominate Option B (cf. Lee, 1971; von Winterfeldt & Edwards, 1986).

Acknowledgments

This work was supported by the Open Research Fund of the CAS Key Laboratory of Behavioral Science, Institute of Psychology (No. Y5CX052003), the National Natural Science Foundation of China (No. 71761167001 and No. 31971034), the Major Project of the National Social Science Foundation of China (No. 19ZDA358), the Key Project of National Social Science Foundation of China (No. 16AZD058), and the Key Project of the Chinese Academy of Sciences (No. KFJ-FP-201906). We thank Si-Chu Shen, Yuan-Na Huang, Yi Kuang, Shu-Wen Yang, and Jia-Tao Ma for their helpful comments on an earlier draft of this article. We also thank two anonymous reviewers for their insightful comments and valuable suggestions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Institute of Psychology, Chinese Academy of Sciences (No. Y5CX052003), National Natural Science Foundation of China (No. 71761167001 and No. 31971034), National Social Science Foundation of China (No. 19ZDA358 and No. 16AZD058), and Chinese Academy of Sciences Key Project (No. KFJ-FP-201906).

ORCID

Linshu Zhou http://orcid.org/0000-0003-3134-8635
Shu Li http://orcid.org/0000-0003-4402-1674

References

Augustine, A. A., & Larsen, R. J. (2011). Affect regulation and temporal discounting: Interactions between primed, state, and trait affect. *Emotion*, *11*(2), 403–412. https://doi.org/10.1037/a0021777

Balkwill, L.-L., & Thompson, W. F. (1999). A cross-cultural investigation of the perception of emotion in music: Psychophysical and cultural cues. *Music Perception*, *17*(1), 43–64. https://doi.org/10.2307/40285811

Benoit, R. G., Gilbert, S. J., & Burgess, P. W. (2011). A neural mechanism mediating the impact of episodic prospection on farsighted decisions. *Journal of Neuroscience*, *31*(18), 6771–6779. https://doi.org/10.1523/JNEUROSCI.6559-10.2011

Bruder, G. E., Fong, R., Tenke, C. E., Leite, P., Towey, J. P., Stewart, J. E., McGrath, P. J., & Quitkin, F. M. (1997). Regional brain asymmetries in major depression with or without an anxiety disorder: A quantitative electroencephalographic study. *Biological Psychiatry*, *41*(9), 939–948. https://doi.org/10.1016/S0006-3223(96)00260-0

Brydges, C. R., Bielak, A. A., & Isaacowitz, D. (2020). A Bayesian analysis of evidence in support of the null hypothesis in gerontological psychology (or lack thereof). *The Journals of Gerontology: Series B*, *75*(1), 58–66. https://doi.org/10.1093/geronb/gbz033

Bueno, J. L. O., & Ramos, D. (2007). Musical mode and estimation of time. *Perceptual and Motor Skills*, *105*(3_suppl), 1087–1092. https://doi.org/10.2466/pms.105.4.1087-1092

Bulley, A., Miloyan, B., Pepper, G. V., Gullo, M. J., Henry, J. D., & Suddendorf, T. (2019). Cuing both positive and negative episodic foresight reduces delay discounting but does not affect risk-taking. *Quarterly Journal of Experimental Psychology*, *72*(8), 1998–2017. https://doi.org/10.1177/1747021818819777

Dalla Bella, S., Peretz, I., Rousseau, L., & Gosselin, N. (2001). A developmental study of the affective value of tempo and mode in music. *Cognition*, *80*(3), B1–B10. https://doi.org/10.1016/S0010-0277(00)00136-0

Droit-Volet, S., Bigand, E., Ramos, D., & Bueno, J. L. O. (2010). Time flies with music whatever its emotional valence. *Acta Psychologica*, *135*(2), 226–232. https://doi.org/10.1016/j.actpsy.2010.07.003

Droit-Volet, S., Bueno, L. J., & Bigand, E. (2013). Music, emotion, and time perception: The influence of subjective emotional valence and arousal? *Frontiers in Psychology*, *4*, 417. https://doi.org/10.3389/fpsyg.2013.00417

Eerola, T., & Vuoskoski, J. K. (2013). A review of music and emotion studies: Approaches, emotion models, and stimuli. *Music Perception*, *30*(3), 307–340. https://doi.org/10.1525/mp.2012.30.3.307

Engelmann, J. B., & Hare, T. A. (2018). Emotions can bias decision-making processes by promoting specific behavioral tendencies. In A. S. Fox, R. C. Lapate, A. J. Shackman, & R. J. Davidson (Eds.), *The nature of emotion: Fundamental questions* (pp. 355–359). Oxford University Press.

Engelmann, J. B., Maciuba, B., Vaughan, C., Paulus, M. P., Dunlop, B. W., & Bruce, A. (2013). Posttraumatic stress disorder increases sensitivity to long term losses among patients with major depressive disorder. *PLoS ONE*, *8*(10), e78292. https://doi.org/10.1371/journal.pone.0078292

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. U. (2009). Affective and deliberative processes in risky choice: Age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(3), 709–730. https://doi.org/10.1037/a0014983

Flom, R., Gentile, D. A., & Pick, A. D. (2008). Infants' discrimination of happy and sad music. *Infant Behavior and Development*, *31*(4), 716–728. https://doi.org/10.1016/j.infbeh.2008.04.004

Frederick, S., Loewenstein, G., & O'donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of Economic Literature*, *40*(2), 351–401. https://doi.org/10.1257/jel.40.2.351

Fritz, T., Jentschke, S., Gosselin, N., Sammler, D., Peretz, I., Turner, R., Friederici, A. D., & Koelsch, S. (2009). Universal recognition of three basic emotions in music. *Current Biology*, *19*(7), 573–576. https://doi.org/10.1016/j.cub.2009.02.058

Frost, R., & McNaughton, N. (2017). The neural basis of delay discounting: A review and preliminary model. *Neuroscience & Biobehavioral Reviews*, *79*, 48–65. https://doi.org/10.1016/j.neubiorev.2017.04.022

Green, L., & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin*, *130*(5), 769–792. https://doi.org/10.1037/0033-2909.130.5.769

Greitemeyer, T. (2009a). Effects of songs with prosocial lyrics on prosocial behavior: Further evidence and a mediating mechanism. *Personality and Social Psychology Bulletin*, *35*(11), 1500–1511. https://doi.org/10.1177/0146167209341648

Greitemeyer, T. (2009b). Effects of songs with prosocial lyrics on prosocial thoughts, affect, and behavior. *Journal of Experimental Social Psychology*, *45*(1), 186–190. https://doi.org/10.1016/j.jesp.2008.08.003

Halko, M.-L., Mäkelä, T., Nummenmaa, L., Hlushchuk, Y., & Schürmann, M. (2015). Hedonic context modulates risky choices and reward responses in amygdala and dorsal striatum. *Journal of Neuroscience, Psychology, and Economics*, *8*(2), 100–115. https://doi.org/10.1037/npe0000036

Hayes, A. F., & Preacher, K. J. (2014). Statistical mediation analysis with a multicategorical independent variable. *British Journal of Mathematical and Statistical Psychology*, *67*(3), 451–470. https://doi.org/10.1111/bmsp.12028

He, G.-B., Li, S., & Liang, Z.-Y. (2018). Behavioral decision-making is nudging China toward the overall revitalization. *Acta Psychologica Sinica*, *50*(8), 803–813. https://doi.org/10.3724/SP.J.1041.2018.00803. (何贵兵, 李纾, & 梁竹苑. (2018). 以小拨大: 行为决策助推社会发展. 心理学报, 50(8), 803–813)

Hirsh, J. B., Guindon, A., Morisano, D., & Peterson, J. B. (2010). Positive mood effects on delay discounting. *Emotion*, *10*(5), 717–721. https://doi.org/10.1037/a0019466

Hunter, P. G., Schellenberg, E. G., & Schimmack, U. (2010). Feelings and perceptions of happiness and sadness induced by music: Similarities, differences, and mixed emotions. *Psychology of Aesthetics, Creativity, and the Arts*, *4*(1), 47–56. https://doi.org/10.1037/a0016873

Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of musical tempo and mode on arousal, mood, and spatial abilities. *Music Perception*, *20*(2), 151–171. https://doi.org/10.1525/mp.2002.20.2.151

Imhoff, S., Harris, M., Weiser, J., & Reynolds, B. (2014). Delay discounting by depressed and non-depressed adolescent smokers and non-smokers. *Drug and Alcohol Dependence*, *135*, 152–155. https://doi.org/10.1016/j.drugalcdep.2013.11.014

Jeffreys, H. (1961). *Theory of probability* (3rd ed.). Oxford University Press.

Jiang, C.-M., Liu, H.-Z., Cai, X.-H., & Li, S. (2016). A process test of priority models of intertemporal choice. *Acta Psychologica Sinica*, *48*(1), 59–72. https://doi.org/10.3724/SP.J.1041.2016.00059

Jimura, K., Chushak, M. S., & Braver, T. S. (2013). Impulsivity and self-control during intertemporal decision making linked to the neural dynamics of reward value representation. *Journal of Neuroscience*, *33*(1), 344–357. https://doi.org/10.1523/JNEUROSCI.0919-12.2013

Johnson, M. W., & Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *Journal of the Experimental Analysis of Behavior*, *77*(2), 129–146. https://doi.org/10.1901/jeab.2002.77-129

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences*, *31*(5), 559–575. https://doi.org/10.1017/S0140525X08005293

Khalfa, S., Schon, D., Anton, J.-L., & Liégeois-Chauvel, C. (2005). Brain regions involved in the recognition of happiness and sadness in music. *NeuroReport*, *16*(18), 1981–1984. https://doi.org/10.1097/00001756-200512190-00002

Kim, K., & Zauberman, G. (2019). The effect of music tempo on consumer impatience in intertemporal decisions. *European Journal of Marketing*, *53*(3), 504–523. https://doi.org/10.1108/EJM-10-2017-0696

Kniffin, K. M., Yan, J., Wansink, B., & Schulze, W. D. (2017). The sound of cooperation: Musical influences on cooperative behavior. *Journal of Organizational Behavior*, *38*(3), 372–390. https://doi.org/10.1002/job.2128

Konečni, V. J. (2008). Does music induce emotion? A theoretical and methodological analysis. *Psychology of Aesthetics, Creativity, and the Arts*, *2*(2), 115–129. https://doi.org/10.1037/1931-3896.2.2.115

Krumhansl, C. L. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, *51*(4), 336–353. https://doi.org/10.1037/1196-1961.51.4.336

Laibson, D. (1997). Golden eggs and hyperbolic discounting. *The Quarterly Journal of Economics*, *112*(2), 443–478. https://doi.org/10.1162/003355397555253

Lee, M. D., & Wagenmakers, E.-J. (2014). *Bayesian cognitive modeling: A practical course*. Cambridge University Press.

Lee, W. (1971). *Decision theory and human behavior*. John Wiley & Sons Inc.

Li, S. (1994). *Equate-to-differentiate theory: A coherent bi-choice model across certainty, uncertainty and risk* [Doctoral dissertation, University of New South Wales].

Li, S. (2004). Equate-to-differentiate approach: An application in binary choice under uncertainty. *Central European Journal of Operations Research*, *12*(3), 269–294.

Li, S. (2016). *An equate-to-differentiate way of decision making*. East China Normal University Press. (李纾. (2016). 决策心理: 齐当别之道. 上海: 华东师范大学出版社).

Liu, L., Feng, T., Chen, J., & Li, H. (2013). The value of emotion: How does episodic prospection modulate delay discounting? *PLoS ONE*, *8*(11), e81717. https://doi.org/10.1371/journal.pone.0081717

Loewenstein, G. (1996). Out of control: Visceral influences on behavior. *Organizational Behavior and Human Decision Processes*, *65*(3), 272–292. https://doi.org/10.1006/obhd.1996.0028

Loewenstein, G., & Prelec, D. (1992). Anomalies in intertemporal choice: Evidence and an interpretation. *The Quarterly Journal of Economics*, *107*(2), 573–597. https://doi.org/10.2307/2118482

Loewenstein, G., Rick, S., & Cohen, J. D. (2008). Neuroeconomics. *Annual Review of Psychology*, *59*(1), 647–672. https://doi.org/10.1146/annurev.psych.59.103006.093710

Love, J., Selker, R., Marsman, M., Jamil, T., Dropmann, D., Verhagen, J., Ly, A., Gronau, Q. F., Smira, M., Epskamp, S., Matzke, D., Wild, A., Knight, P., Rouder, J. N., Morey, R. D., & Wagenmakers, E.-J. (2019). JASP: Graphical statistical software for common statistical designs. *Journal of Statistical Software*, *88*(2), 1–17. https://doi.org/10.18637/jss.v088.i02

Luo, S., Ainslie, G., & Monterosso, J. (2014). The behavioral and neural effect of emotional primes on intertemporal decisions. *Social Cognitive and Affective Neuroscience*, *9*(3), 283–291. https://doi.org/10.1093/scan/nss132

Madden, G. J., Begotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology*, *11*(2), 139–145. https://doi.org/10.1037/1064-1297.11.2.139

McClure, S. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science*, *306*(5695), 503–507. https://doi.org/10.1126/science.1100907

McHugh, M. L. (2011). Multiple comparison analysis testing in ANOVA. *Biochemia Medica*, *21*(3), 203–209. https://doi.org/10.11613/BM.2011.029

Mehr, S. A., Singh, M., York, H., Glowacki, L., & Krasnow, M. M. (2018). Form and function in human song. *Current Biology*, *28*(3), 356–368.e5. https://doi.org/10.1016/j.cub.2017.12.042

Metcalfe, J., & Mischel, W. (1999). A hot/cool-system analysis of delay of gratification: Dynamics of willpower. *Psychological Review*, *106*(1), 3–19. https://doi.org/10.1037/0033-295X.106.1.3

Mitchell, S. H., & Wilson, V. B. (2010). The subjective value of delayed and probabilistic outcomes: Outcome size matters for gains but not for losses. *Behavioural Processes*, *83*(1), 36–40. https://doi.org/10.1016/j.beproc.2009.09.003

Nyklíček, I., Thayer, J. F., & Van Doornen, L. J. (1997). Cardiorespiratory differentiation of musically-induced emotions. *Journal of Psychophysiology*, *11*(4), 304–321.

Ohmura, Y., Takahashi, T., & Kitamura, N. (2005). Discounting delayed and probabilistic monetary gains and losses by smokers of cigarettes. *Psychopharmacology*, *182*(4), 508–515. https://doi.org/10.1007/s00213-005-0110-8

Penton-Voak, I. S., Edwards, H., Percival, A., & Wearden, J. H. (1996). Speeding up an internal clock in humans? Effects of click trains on subjective duration. *Journal of Experimental Psychology: Animal Behavior Processes*, *22*(3), 307–320. https://doi.org/10.1037/0097-7403.22.3.307

Peretz, I., Gagnon, L., & Bouchard, B. (1998). Music and emotion: Perceptual determinants, immediacy, and isolation after brain damage. *Cognition*, *68*(2), 111–141. https://doi.org/10.1016/S0010-0277(98)00043-2

Peretz, I., & Zatorre, R. J. (2005). Brain organization for music processing. *Annual Review of Psychology*, *56*(1), 89–114. https://doi.org/10.1146/annurev.psych.56.091103.070225

Peters, J., & Büchel, C. (2011). The neural mechanisms of intertemporal decision-making: Understanding variability. *Trends in Cognitive Sciences*, *15*(5), 227–239. https://doi.org/10.1016/j.tics.2011.03.002

Pyone, J. S., & Isen, A. M. (2011). Positive affect, intertemporal choice, and levels of thinking: Increasing consumers' willingness to wait. *Journal of Marketing Research*, *48*(3), 532–543. https://doi.org/10.1509/jmkr.48.3.532

Reeck, C., Wall, D., & Johnson, E. J. (2017). Search predicts and changes patience in intertemporal choice. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(45), 11890–11895. https://doi.org/10.1073/pnas.1707040114

Rounds, J. S., Beck, J. G., & Grant, D. M. (2007). Is the delay discounting paradigm useful in understanding social anxiety? *Behaviour Research and Therapy*, *45*(4), 729–735. https://doi.org/10.1016/j.brat.2006.06.007

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 1161–1178. https://doi.org/10.1037/h0077714

Samuelson, P. A. (1937). A note on measurement of utility. *The Review of Economic Studies*, *4*(2), 155–161. https://doi.org/10.2307/2967612

Schoemann, A. M., Boulton, A. J., & Short, S. D. (2017). Determining power and sample size for simple and complex mediation models. *Social Psychological and Personality Science*, *8*(4), 379–386. https://doi.org/10.1177/1948550617715068

Scholten, M., & Read, D. (2010). The psychology of intertemporal tradeoffs. *Psychological Review*, *117*(3), 925–944. https://doi.org/10.1037/a0019619

Schulreich, S., Heussen, Y. G., Gerhardt, H., Mohr, P. N., Binkofski, F. C., Koelsch, S., & Heekeren, H. R. (2014). Music-evoked incidental happiness modulates probability weighting during risky lottery choices. *Frontiers in Psychology*, *4*, 981. https://doi.org/10.3389/fpsyg.2013.00981

Sloboda, J. A. (1991). Music structure and emotional response: Some empirical findings. *Psychology of Music*, *19*(2), 110–120. https://doi.org/10.1177/0305735691192002

Sohn, J.-H., Kim, H.-E., Sohn, S., Seok, J.-W., Choi, D., & Watanuki, S. (2015). Effect of emotional arousal on inter-temporal decision-making: An fMRI study. *Journal of Physiological Anthropology*, *34*(1), 1–8. https://doi.org/10.1186/s40101-015-0041-y

Takahashi, T., Oono, H., Inoue, T., Boku, S., Kako, Y., Kitaichi, Y., Kusumi, I., Masui, T., Nakagawa, S., & Suzuki, K. (2008). Depressive patients are more impulsive and inconsistent in intertemporal choice behavior for monetary gain and loss than healthy subjects – an analysis based on Tsallis' statistics. *Neuroendocrinology Letters*, *29*(3), 351–358.

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. Yale University Press.

Trainor, L. J., & Heinmiller, B. M. (1998). The development of evaluative responses to music: Infants prefer to listen to consonance over dissonance. *Infant Behavior and Development*, *21*(1), 77–88. https://doi.org/10.1016/S0163-6383(98)90055-8

Treisman, M., Faulkner, A., & Naish, P. L. (1992). On the relation between time perception and the timing of motor action: Evidence for a temporal oscillator controlling the timing of movement. *The Quarterly Journal of Experimental Psychology Section A*, *45*(2), 235–263. https://doi.org/10.1080/14640749208401326

Treisman, M., Faulkner, A., Naish, P. L., & Brogan, D. (1990). The internal clock: Evidence for a temporal oscillator underlying time perception with some estimates of its characteristic frequency. *Perception*, *19*(6), 705–742. https://doi.org/10.1068/p190705

van Doorn, J., van den Bergh, D., Böhm, U., Dablander, F., Derks, K., Draws, T., Etz, A., Evans, N. J., Gronau, Q. F., Haaf, J. M., Hinne, M., Kucharský, Š., Ly, A., Marsman, M., Matzke, D., Gupta, A. R. K. N., Sarafoglou, A., Stefan, A., Voelkel, J. G., & Wagenmakers, E.-J. (2021). The JASP guidelines for conducting and reporting a Bayesian analysis. *Psychonomic Bulletin & Review*, *28*(3), 813–826. https://doi.org/10.3758/s13423-020-01798-5

von Winterfeldt, D., & Edwards, W. (1986). *Decision analysis and behavioral research*. Cambridge University Press.

Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., Selker, R., Gronau, Q. F., Šmíra, M., Epskamp, S., Matzke, D., Rouder, J. N., & Morey, R. D. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin & Review*, *25*(1), 35–57. https://doi.org/10.3758/s13423-017-1343-3

Wenzler, S., Hagen, M., Tarvainen, M. P., Hilke, M., Ghirmai, N., Huthmacher, A.-C., Trettin, M., van Dick, R., Reif, A., & Oertel-Knöchel, V. (2017). Intensified emotion perception in depression: Differences in physiological arousal and subjective perceptions. *Psychiatry Research*, *253*, 303–310. https://doi.org/10.1016/j.psychres.2017.03.040

Xia, L., Gu, R., Zhang, D., & Luo, Y. (2017). Anxious individuals are impulsive decision-makers in the delay discounting task: An ERP study. *Frontiers in Behavioral Neuroscience*, *11*, 5. https://doi.org/10.3389/fnbeh.2017.00005

Xu, L., Liang, Z.-Y., Wang, K., Li, S., & Jiang, T. (2009). Neural mechanism of intertemporal choice: From discounting future gains to future losses. *Brain Research*, *1261*, 65–74. https://doi.org/10.1016/j.brainres.2008.12.061

Zhang, Y.-Y., Xu, L., Liang, Z.-Y., Wang, K., Hou, B., Zhou, Y., Li, S., & Jiang, T. (2018). Separate neural networks for gains and losses in intertemporal choice. *Neuroscience Bulletin*, *34*(5), 725–735. https://doi.org/10.1007/s12264-018-0267-x

Zhang, Y.-Y., Zhou, L., You, X., Li, S., & Liang, Z.-Y. (2018). Is intertemporal decision-making based on a temporal discounting process? Evidence from double-dissociation paradigm. *Scientia Sinica Vitae*, *48*(5), 592–608. https://doi.org/10.1360/N052017-00104

Zhao, J., Cheng, J., Harris, M., & Vigo, R. (2015). Anxiety and intertemporal decision making: The effect of the behavioral inhibition system and the moderation effects of trait anxiety on both state anxiety and socioeconomic status. *Personality and Individual Differences*, *87*, 236–241. https://doi.org/10.1016/j.paid.2015.08.018