Internal Motor Tempo Contributes to the Determination of Preferred Music Tempo Regardless of Music Familiarity.

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Abstract

Humans have long listened to music. However, it is still unclear why people prefer some types of music over others. To investigate how music preference is determined, previous studies have focused on preferred music tempo since tempo can essentially determine music preference. Such studies have reported that external music components as well as internal motor tempo determine tempo preference. Moreover, it has been suggested that familiarity with a piece of music affects the impact of external music components on tempo preference. However, the question of how the contributions of the internal motor tempo and external music components for tempo preference simultaneously change depending on familiarity has not been investigated. Moreover, the issue of which external music components contribute to tempo preference depending on familiarity has not been clarified. Here, we investigate how the preference for music tempo is determined by the internal motor tempo and external music components depending on familiarity with a piece of music. Twenty-three participants adjusted music tempos according to their preferences and rated their music familiarity. In addition, they engaged in finger tapping at their preferred tempo. Music components, such as typically performed tempo or the number of notes, were also analysed. Analysis of the collected data with multiple linear regressions showed that the preferred tapping tempo contributed to the preferred music tempo regardless of familiarity, whereas the contributions of some of the music components changed depending on familiarity. The typically performed tempo that might relate to the memory of a piece of music contributed to the estimation of the preferred music tempo for familiar music, and the number of notes or the pitch that might relate to perceived tempo contributed to the estimation of unfamiliar music. These results suggested that internal motor tempo is constantly involved in tempo preference regardless of music familiarity, whereas the contribution of external music components varies depending on whether a piece of music has been memorized.

Introduction

Human beings have long listened to music, and we still listen to music in everyday life. It has been estimated that a person listens to music as much as 32 hours per week[1]. Music is an essential part of our everyday life; nonetheless, it remains unclear why humans like to listen to music. To investigate why humans listen to music, it has been studied how music preference is determined by individual personality[2,3,4]. In addition, recent studies have revealed that music enhances social communication, for example, in the sharing of one's preferred types of music[5,6] as well in terms of individual listening[7]. Therefore, studies of music preference are now applied to enhance social communication[8,9] as well as to regulate individual moods or states[10,11]. Furthermore, clarifying how music preference is determined should lead to an improved understanding of human diversity, that is, to an understanding of the differences and commonalities among humans.

Music consists of certain elements including melody (the succession of pitches[12]), harmony (the relationship of pitches that sound simultaneously[12]), rhythm (sound pattern[13]), and tempo. Tempo is the time interval between successive beats,[13] and it is known as one of the necessary elements that determine music perception, which affects music preference[14]. Music perception varies when the tempo is changed even if the rhythm, melody, and harmony are constant[15]. In other words, preference for tempo potentially determines the preference for music. In the current study, we aimed to investigate the factors affecting the preference for music tempo.

It has been reported that there are individual differences in tempo preference[16,17,18,19]. Moelants (2002) collected data regarding tempo for over 70,000 pieces of music and indicated that the range of preferred tempo varied widely between 67 bpm to 150 bpm[20]. Moreover, it has been suggested that internal motor tempo, which is the pace of mental activity[13], causes individual differences in tempo preference. Iwanaga (1995) showed that preferred music

tempo correlates with individual heart rate, which reflects internal motor tempo[18]. Additionally, Bauer et al. (2015) conducted an electroencephalography study and reported that preferred music tempo was associated with the frequency of motor beta activity recorded during finger tapping[16]. These studies demonstrated that preference for music tempo is modulated depending on individual difference in internal motor tempo.

While internal motor tempo determines preferred tempo, other studies have shown that external music components also determine preferred tempo. It has been reported that each piece of music has a specific tempo that is commonly preferred[21]. This result indicates that preferred music tempo is regulated using external music components, which are defined by physical parameters such as performed tempo or pitch. In addition, it has been reported that the distributions of preferred music tempo change depending on familiarity with a given piece of music[21]. This means that the external music components that relate to the determination of preferred tempo change according to familiarity with a piece of music. However, it is unclear which external music components are involved in tempo preference depending on familiarity.

Previous studies have shown that internal motor tempo and external music components relate to the determination of tempo preference. However, the question of how the contributions of the internal motor tempo and external music components for tempo preference simultaneously change depending on familiarity has not been investigated. Moreover, the point at issue of which external music components contribute to tempo preference depending on familiarity with a piece of music has not been clarified. Here, we investigate how the contributions of internal motor tempo and external music components to tempo preference are simultaneously changed depending on familiarity and which external music components contribute to tempo preference depending on familiarity. In this study, we conducted a psychological experiment (Figure 1). In the experiment, the participants were required to adjust their preferred tempo for thirty piano music pieces twice with an interval of more than one week to check the stability of music tempo preference. All pieces of music were presented with the same duration and tempo. After that, the participants were asked to judge the familiarity of each piece of music. Last, a tapping task was conducted to assess the participants' internal motor tempo. The correlations between each music component (typically performed tempo, number of notes, pitch, and velocity) and the preferred music tempo were calculated for three music familiarity categories (familiar, neutral familiarity, unfamiliar) to determine which external music components relate to tempo preference depending on familiarity with a piece of music. Moreover, multiple linear regression analyses were conducted to investigate how internal motor tempo and external music components simultaneously contribute to determine the preferred music tempo.

Results

Music components

All music data were prepared in MIDI files with the following information about the music components.

Tempo.

In the current experiment, the tempo specified in the MIDI file is referred to as the typically performed tempo. The music used in this study was made from pieces downloaded from websites[22,23] that provide music data recorded in a common mode of performance, and the music was not performed with a unique tempo. It was confirmed that the performed tempo of the music used in this study followed indications of the music tempo in scores. Typically, the music performances followed the indications of the music tempo. Therefore, the tempos of the music used in this study could be regarded as typically performed tempos. The unit of tempo was beats per minute (bpm) whereby a

certain number of beats was detected for one minute. The average typically performed tempo was 89.7 bpm (*SD*=35.2). The range was from 27 to 200 bpm.

Number of notes.

The number of notes represents how many notes are presented in a music score. The average number of notes was 85.2 (*SD*=32.0). The range was from 38.0 to 156.0.

Pitch.

The pitch represents how high or low each sound is. The larger number represents a higher sound. Middle C (C4) is 60 in MIDI pitch. The average of all pitches presented in this study was 63.3 (*SD*=5.5). The range of the average for each piece of music was from 54.8 to 80.5.

Velocity.

The velocity represents how fast the key of a note is pressed, which relates to the sound volume. The range of MIDI velocity is from 0 to 127. The average of the velocity was 50.2 (*SD*=15.7). The range of the average velocity for each piece of music was from 32.0 to 97.4.

Behavioural results

The adjusted tempo in the tempo preference task.

The average adjusted tempo in the tempo preference task for two trials was calculated for each participant. For the first and the second days, the same pieces of music were presented in random order. The averages of the adjusted tempo were 99.5 bpm (*SD*=13.4) for the first day and 99.1 bpm (*SD*=13.6) for the second day. There was no significant difference between the first day and the second day ($t(22)=0.41$, $p=.69$, $r=.09$). The correlation between the adjusted tempo for the first and the second day was significant ($r=.90$, $N=23$, $p<.001$), implying that the adjusted tempo was robust regarding the time interval. We calculated the average of the adjusted tempo for the first day and the second day for each piece of music and participant (average=99.3 bpm, *SD*=12.7), and those were used as the preferred music tempo in the following analyses. The range of the preferred music tempo was from 35 to 224 bpm.

The familiarity rating for each piece of music.

In the familiarity judgement task, the number of data points rated 1 (extremely novel), 2, 3, 4, 5, 6, and 7 (extremely familiar) and were 231, 91, 57, 46, 63, 71, and 131, respectively.

The tempo in the tapping task.

The tapping task consisted of two trials, and one trial lasted 30 s. The preferred tapping tempo in bpm for each participant was calculated as the sum of the number of taps for two trials. The average of the preferred tapping tempo was 104.6 bpm (*SD*=25.3). The range of the preferred tapping tempo was from 54 to 170 bpm.

Correlations between the preferred tapping tempo / the music components and the preferred music tempo.

At first, all 690 data points (23 participants × 30 music) were divided into three music familiarity categories based on the responses in the familiarity judgement task: familiar, neutral familiarity, and unfamiliar music. The data points rated 6 or 7 were for familiar music (the number of data points was 202). The data points rated 3, 4, or 5 were for neutral familiarity (the number of data points was 166). The data points rated 1 or 2 were for unfamiliar music (the

number of data points was 322). Then, the correlations between the preferred tapping tempo / the music components (typically performed tempo, number of notes, pitch, and velocity) and the preferred music tempo were calculated for each familiarity category (Figure 2).

Regarding the correlation between the preferred tapping tempo and the preferred music tempo, there were significant correlations for the familiar (r=.36, N=202, p<.001), neutral (r=.45, N=166, p<.001) and unfamiliar (r=.52, N=322, p<.001) categories (Figure 2, top row). Regarding the correlation between the typically performed tempo and the preferred music tempo, there was a significant correlation for familiar music (r=.42, N=202, p<.001) but not for the neutral (r=.13, N=166, p=.083) or unfamiliar (r=.09, N=322, p=.105) categories (Figure 2, second row from the top). The correlations between the number of notes and the preferred music tempo were significant for familiar music (r=-.14, N=202, p=.048), neutral (r=-.17, N=166, p=.029), and unfamiliar (r=-.18, N=322, p<.001) categories (Figure 2, middle row). The correlations between the pitch and the preferred music tempo were significant for familiar music (r=.27, N=202, p<.001) and neutral (r=.16, N=166, p=.045) but not for the unfamiliar (r=-.03, N=322, p=.592) category (Figure 2, second row from the bottom). The correlations between the velocity and the preferred music tempo were not significant for familiar music (r=-.07, N=202, p=.313), neutral (r=.08, N=166, p=.328), and unfamiliar (r=-.04, N=322, p=.480) categories (Figure 2,bottom row).

Correlations among music components

The correlations among music components for the thirty pieces of music used in this experiment were calculated. The correlations between the typically performed tempo and the number of notes were not significant (r=-.22, N=30, p=.252). The correlations between the typically performed tempo and the pitch were not significant (r=.28, N=30, p=.135). The correlations between the typically performed tempo and the velocity were not significant (r=.33, N=30, p=.075). The correlations between the number of notes and the pitch were not significant (r=-.20, N=30, p=.299). The correlations between the number of notes and the velocity were not significant (r=.27, N=30, p=.153). The correlations between the pitch and the velocity were not significant (r=-.07, N=30, p=.705). No significant correlation was found for any combinations of music components.

Multiple linear regression analysis

To assess how internal motor tempo and external music components contribute to tempo preference, a multiple linear regression was calculated to predict the preferred music tempo on the preferred tapping tempo, the typically performed tempo, the number of notes, the pitch, and the velocity. All music components analysed in this study were used in the multiple linear regression analysis because there was not significant correlation among the components.

Table 1 (the leftmost) shows the results of the multiple regression analysis. The model was significant and accounted for 26% of the variance in the preferred music tempo, R^2 = .26, R^2 Adjusted = .26, $F(6, 683)$ = 48.58, p = .000, f^2 = .35. The preferred tapping tempo (β = .46, p =.000), the typically performed tempo (β = .15, p =.000), and the number of notes (β = -.13, p =.000) made significant contributions to the preferred music tempo whereas the pitch and the velocity did not make significant contributions (p > .05).

To examine the effect of familiarity with a piece of music on the preferred music tempo, three separate multiple regression analyses were conducted (Table 1, three rows from the right). The data were divided into three categories in the same way as in the calculation of the correlations. For the familiar category, the model was significant and accounted for 29% of the variance in the preferred music tempo, R^2 = .29, R^2 Adjusted = .27, $F(6, 195)$ = 16.04, p = .000, f^2 = .41. The preferred tapping tempo (β = .32, p = .000) and the typically performed tempo (β = .37, p = .000) made significant contributions to the preferred music tempo whereas the number of notes, the pitch, and the velocity did not

make significant contributions ($p > .05$). For the neutral familiarity, the model was significant and accounted for 30% of the variance in the preferred music tempo, $R^2 = .30$, R^2 Adjusted = .28, $F(6, 159) = 13.59$, $p = .000$, $f^2 = .43$. The preferred tapping tempo (β = .51, $p = .000$) and the number of notes (β = -.20, $p = .005$) made significant contributions to the preferred music tempo whereas the typically performed tempo, the pitch, and the velocity did not make significant contributions ($p > .05$). For the unfamiliar category, the model was significant and accounted for 31% of the variance in the preferred music tempo, $R^2 = .31$, R^2 Adjusted = .30, $F(6, 315) = 23.74$, $p = .000$, $f^2 = .45$. The preferred tapping tempo (β = .52, $p = .000$), the number of notes (β = -.19, $p = .001$), and the pitch (β = -.10, $p = .035$) made significant contributions to the preferred music tempo whereas the typically performed tempo and the velocity did not make significant contributions ($p > .05$).

Table 1. The results of multiple regression analyses

	all			familiar			neutral			unfamiliar		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Variable												
preferred tapping tempo	0.36	0.03	**.46*** **	0.26	0.05	**.32*** **	0.38	0.05	**.51*** **	0.41	0.04	**.52*** **
typically performed tempo	0.09	0.02	**.15*** **	0.27	0.06	**.37*** **	0.08	0.05	.16	0.03	0.03	.06
number of notes	-0.08	0.02	**-.13*** **	0.02	0.04	.03	-0.11	0.04	**-.20** **	-0.14	0.04	**-.19** **
pitch	0.13	0.13	.04	0.35	0.27	.10	0.15	0.27	.04	-0.38	0.19	**-.10* **
velocity	0.00	0.05	.00	-0.04	0.08	-.04	0.10	0.10	.09	0.01	0.11	.01
R^2	.26			.29			.30			.31		
$R^{2Adjusted}$	.26			.27			.28			.30		
F	**48.58*** **			**16.04*** **			**13.59*** **			**23.74*** **		

*$p<.05$. **$p<.01$. ***$p<.001$.

All analyses were conducted with forced entry algorithm on R.

Discussion

The aim of this study was to investigate how preference for music tempo is determined by internal motor tempo and external music components depending on familiarity. The obtained results demonstrate two significant aspects:

First, regardless of the music familiarity, the preferred tapping tempo that reflects internal motor tempo significantly correlated with the preferred music tempo and contributed to the prediction of the preferred music tempo. From these results, the current study clearly shows that internal motor tempo affects the determination of tempo preference, regardless of whether a listener is familiar with a piece of music. The internal clock model, in which the internal clock generates time information that affects time perception in various activities, is widely known[24]. Based on this model, a person with a slow internal clock should perceive time quickly, both in the tapping task and the tempo preference task,

whereas a person with a fast internal clock should perceive time slowly in such tasks. Time perception affects tempo perception because the tempo is defined as the time interval between events[13]. As a result, the individual differences in time perception may significantly correlate between the preferred tapping tempo (in the tapping task) and the preferred music tempo (in the tempo preference task) in the current study. Another interpretation is to consider the individual differences in the stage of determination for tempo preference rather than tempo perception. People tend to like others who have the same values as their own[25,26]. Specifically, Laegn et al. (2013) presented a self-morphed face that was one's partner's face with one's face and an other-morphed face that was their partner's face with the same-sex prototype face[27]. The participants were required to judge how they preferred their faces. The self-morphed face was more preferred rather than the other-morphed face. Laegn et al.'s study suggested that people tend to prefer features similar to their own. In addition, it was reported that a finger tapping tempo was robust across time[28] and that a finger tapping tempo correlated to other movement tempos such as stepping in place[29]. This indicates that finger tapping tempo could reflect the features of one's own movement tempo. If that is the case, in the current study, the participants might prefer a music tempo that mixes the typically performed tempo with their own tapping tempo, which reflects the features of their own movement tempo.

Further, for familiar music, the typically performed tempo contributed to an estimation of the preferred music tempo for neutral familiar music, the number of notes contributed the estimation, and for unfamiliar music, the number of notes and the pitch contributed to the estimation. In other words, the external music components that affected the tempo preference changed depending on familiarity. Regarding the typically performed tempo, the significant contribution was found only for familiar music. One of the plausible explanations is that the memory for each piece of music, which is constructed through experiences, might contribute to the tempo preference. Familiarity, which affects our preference, is constructed through experiences of exposure to items[30], and the number of exposures affects the accuracy of one's memory[31]. Moreover, some of the previous studies have shown that there is a significant correlation between the memorized tempo and the typically performed tempo[32,33]. These results indicate that the participants could correctly memorize the typically performed tempo in the current study. If that is the case, it could be concluded that the typically performed tempo contributes to the determination of the preferred music tempo because the memorized tempo for music, which is associated with tempo preference, correlates to the typically performed tempo. In further studies, the relationship among typically performed tempo, memorized tempo, and preferred music tempo must be clarified. With regard to the number of notes, the estimation of the preferred music tempo for neutral and unfamiliar music was a significant contribution. The number of notes relates to the time resolution of auditory perception. The time resolution of auditory perception is approximately 25 to 150 ms[34]. Hence, the ability to distinguish the notes of a piece of music is limited by tempo. In the current study, the limitation of the fastest tempo is dependent on the number of notes, which might affect the estimation of the preferred music tempo for the neutral familiarity category and the unfamiliar music category because the participants who did not know the typically performed tempo judged their auditory preference based on time clarity. With respect to the pitch, the previous research has shown that when the pitch is higher, the tempo is perceived as being faster than when the pitch is lower[35]. Based on the results, in this study, the preferred music tempo for higher pitched music should be slower compared to the tempo for lower pitched music, even though there is no difference in tempo preference. In this way, the perceived tempo affected by pitch might influence the preferred music tempo. Taken together, the findings suggest that tempo preference is determined using the typically performed tempo when a listener has memorized the music, and the music components that relate to tempo perception (the number of notes and the pitch) instead of the typically performed tempo are used when a listener has not memorized the music.

Another interesting finding is that the number of external music components that contributed the estimation of the preferred music tempo increased as the familiarity with a piece of music decreased when the participants had less

familiarity with of a piece of music (neutral and unfamiliar music). For the neutral familiarity category, only the number of notes contributed to the estimation. For the unfamiliar music, the pitch as well as the number of notes contributed to the estimation of the preferred music tempo. Having common preferences with others is effective in facilitating social communication[36,37,38,39]. To share common preferences with others, it should be effective to determine one's own preference considering object features. When a listener remembers a piece of music, the typically performed tempo should contribute to sharing the same tempo preference with others because the typically performed tempo could be memorized by the individual and others. When a listener does not have such a memory, we might share our preferences by taking several external music components other than the typically performed tempo. To clarify the role of music in society, it is important to investigate how external factors are involved in the determination of music preferences.

In the current study, the preferred tapping tempo was collected while the participants were sitting down. It was reported that the preferred tapping tempo after running was faster compared to that before running because the internal motor tempo had changed[40]. Based on our results and the previous study, it is expected that the preferred music tempo is modulated by various situations, for example, during physical training or just before bedtime. In future research, it should be assessed whether the preferred music tempo is changed depending on internal motor tempo. Another limitation is that it was not considered how the participants perceived music elements such as tempo, rhythm or beat. In the current study, the effect of perceived tempo on the preferred music tempo was not assessed. Therefore, there is a possibility that the music tempo perceived by a listener affected the preferred music tempo. In addition, the rhythm or beat perceived by a listener could be changed accompanied by perceived tempo[41]. Therefore, rhythm or beat might affect the preferred music tempo in the current study because it was found that rhythm and beat as well as tempo affect music preference[42]. The interaction among music elements including tempo, rhythm and beat should be considered to investigate how music preference is determined.

The current study showed that internal motor tempo affects the tempo preference regardless of familiarity. Additionally, the typically performed tempo, which might relate to the memory of a piece of music, contributed to the determination of tempo preference only for familiar music, and the number of notes and the pitch contributed to neutral or unfamiliar music. To understand precisely what determines our music preference, we should consider both internal factors and external music factors. Finally, this study might provide us with new intuitions regarding both individual and common music preferences.

Methods

Participants

Twenty-three participants (2 females and 21 males, aged from 20 to 25, mean = 22.0, *SD*=1.3) were recruited for this experiment. All participants had normal hearing and normal or corrected-to-normal vision. Informed consent was obtained from all the participants. All experimental procedures were approved by the Committee for Human Research at Toyohashi University of Technology. All experiments were conducted in accordance with the Declaration of Helsinki.

Music Stimuli

Thirty pieces of music were selected from the Classical Piano Midi Page[22] and mfiles[23]. All music selections were classical pieces performed as piano solos, and there were no changes in tonality or tempo. The recorded tempo of the music was between 27 and 200 bpm, in which one beat was defined as a quarter note (crochet bpm). The initial tempo presented in this experiment was 90 crochet bpm, and the music recordings lasted for durations of 15 s.

Therefore, in this experiment, all presented music recorded in various tempos were presented with the same tempos and durations. These musical data were analysed with MIDI Toolbox[43] running on MATLAB R2018b.

Procedure

Tempo preference task.

The participants were engaged in a tempo preference task. In the tempo preference task, the participants were required to adjust each piece of music to their preferred tempo. The music was performed with a self-build software on a personal computer and presented to the participants over headphones (MDR-10, SONY). A computer keyboard was used to obtain the participants' responses. At first, the participants listened to a piece of music for 15 s. After that, the participants adjusted to their preferred tempo by pushing a key (up/down arrow) while listening to the same music presented just before. The tempo was faster by 2 crochet bpm steps when the up arrow was pushed once, and the tempo was slower by 2 crochet bpm steps when the down arrow was pushed once. When the participants pushed these keys, the presented tempo was immediately changed. The participants pushed an enter key when they identified their preferred tempo. The same music was presented on repeat until the participants pushed the enter key. Thirty pieces of music were presented and adjusted. The order of the presentation was randomized. After at least one week, the participants again performed the tempo preference task. The procedure of the task was identical in the first and second times.

Familiarity judgement task.

After the second tempo preference task, all participants were engaged in a familiarity judgement task. The music presented in the tempo preference task was again presented with 90 crochet bpm in the task. The participants judged the familiarity of the music by rating it on a scale from 1 (extremely novel) to 7 (extremely familiar). The participants wrote down the numbers on an answer sheet. After writing down an answer, the participants pushed the enter key to change to the next trial. The music was presented on repeat until the participants pushed the enter key. The participants entered judgments for all thirty pieces of music, and the order of the presentation was randomized.

Tapping task.

After the familiarity judgment task, a tapping task was conducted. The participants were required to tap with their index finger of their own dominant hand at their preferred tempo. The participants tapped on a screen of iPad (Apple) that recorded the tapped time. The data were collected in two trials continuing for 30 s each. Between the trials, the participants could take a break for as long as they wanted. After the tapping task, the participants were debriefed.

Declarations

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Author Contributions

Kyoko. H., K.A., Y.K., M.S., T.M., and S.N developed the study concept. K.A., Y.K., Katsunobu. H., and T.M prepared the materials. Kyoko. H. and K.A. collected and analysed the behavioural data. Kyoko. H. wrote the manuscript. All the authors discussed the results and commented on the manuscript.

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Figures

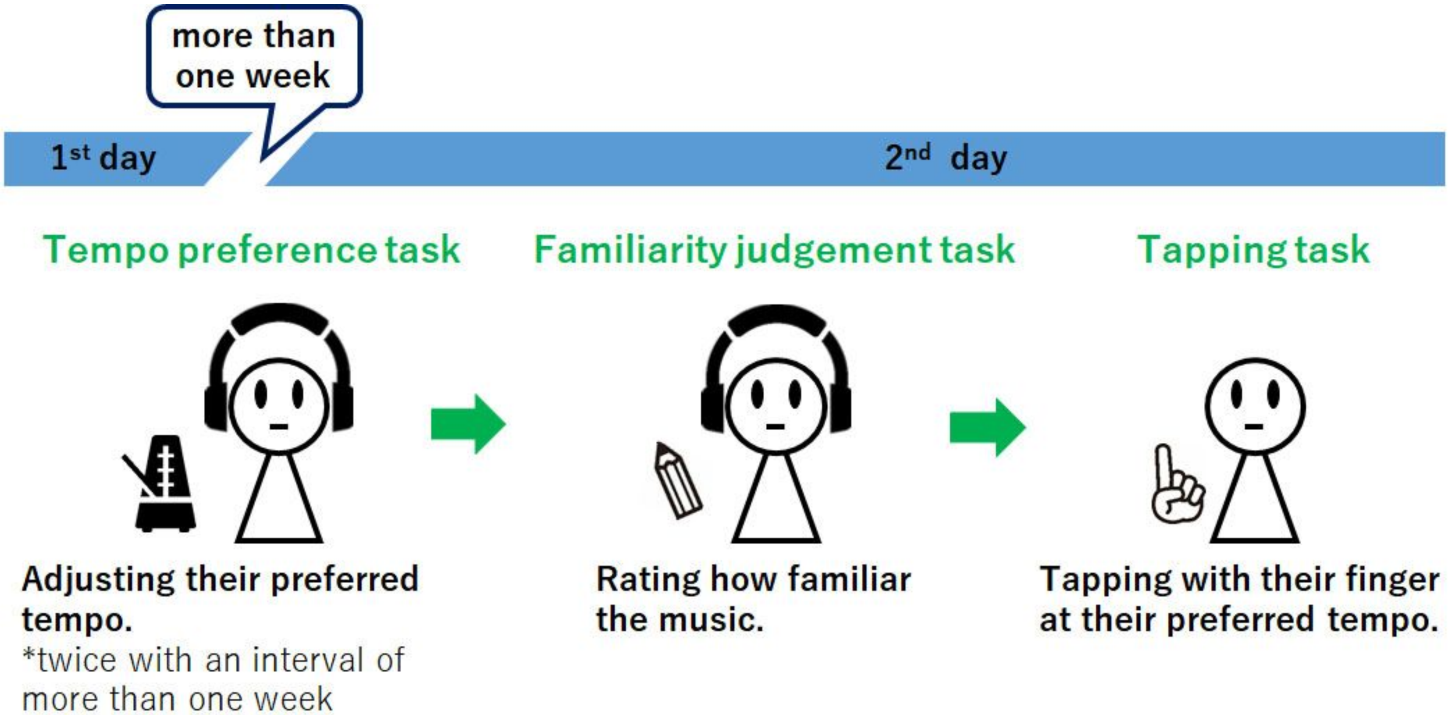

Figure 1

Experimental design. The participants were required to adjust their preferred tempo for the presented music twice with an interval of more than one week. After that, the participants were asked to rate the familiarity of each piece of music. Then, the participants completed the tapping task.

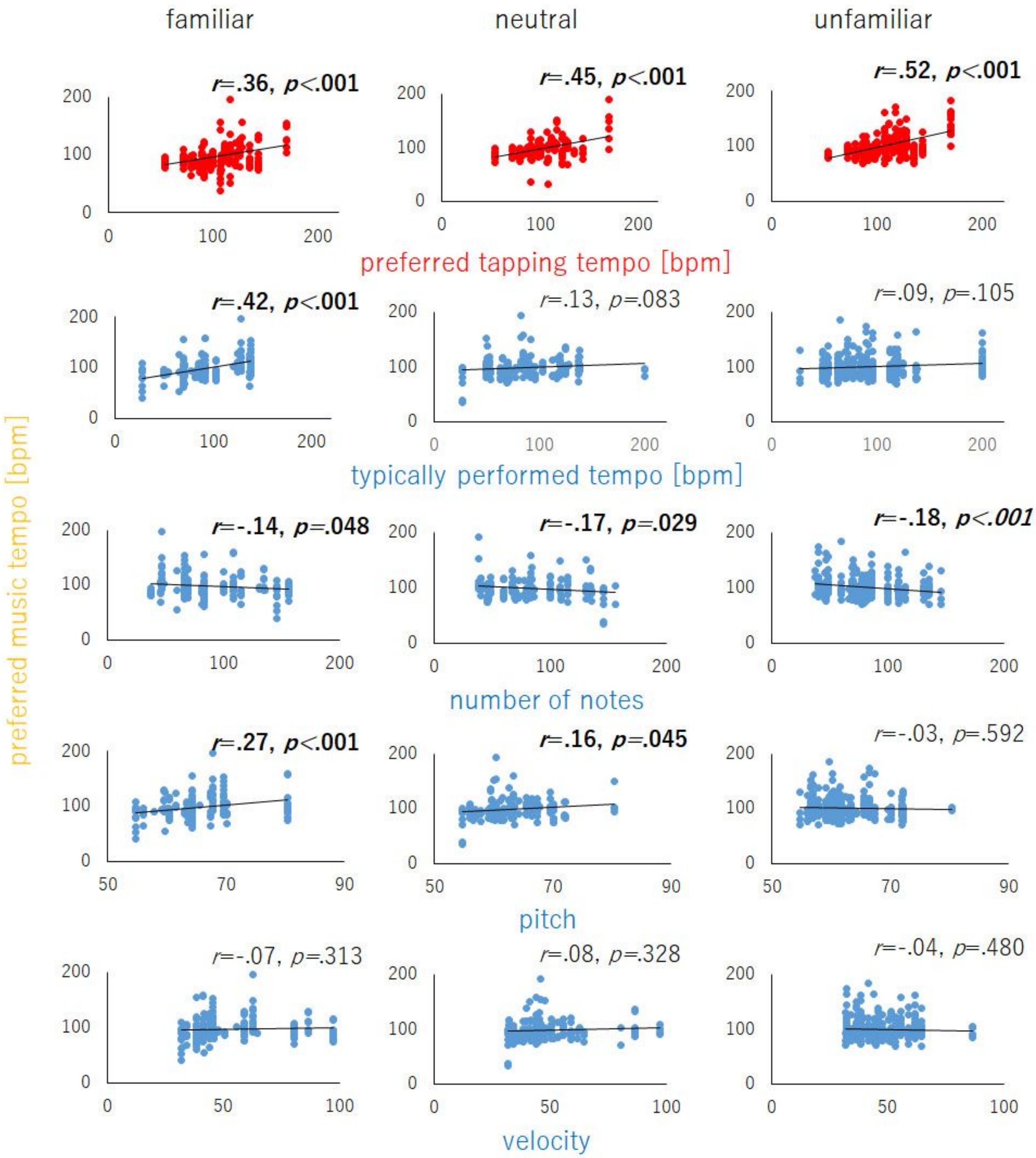

Figure 2

The correlations between the preferred tapping tempo / the music components (typically performed tempo, number of notes, pitch, velocity) and the preferred music tempo for three music familiarity categories (familiar, neutral familiarity, unfamiliar).