Influence of Music Familiarity on Time Perception

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Abstract

Previous research has shown that time perception relies on working memory processes, other parallel cognitive tasks can also be carried out in working memory system and therefore interfere with time perception. In particular, listening to music may lead to working memory use, which may be different for familiar music than for unfamiliar music. Thus, it is expected that the familiarity of music might have an effect on time perception. A more controlled behavioral experiment than previous research has been conducted. The results show that when familiar music is playing in the background, participants tend to reproduce the same time duration longer than in the unfamiliar music background. In addition, participants reproduce the same time duration much shorter in the background without music than with music. A PRIMs model has been built to explain the primary results, and the model fits the data finally.

Keywords: time perception, music, familiarity, working memory, cognitive model

Influence of Music Familiarity on Time Perception

Music is surrounding our daily life: it plays in shopping malls, in computer games, in movies, etc. There is no doubt that different aspects of music can influence our perception of time durations. These influential factors include several elements of music ranging from volume, genre, pitch, presence and absence, likeability, familiarity, etc. (Bailey & Areni, 2006; Kellaris & Kent, 1992; Baker & Cameron, 1996).

Previous studies on the effects of music familiarity on time estimation have yielded mixed results. Yalch and Spangenberg (2000) found evidence that relative to unfamiliar music, familiar music causes people to perceive certain time intervals as being longer. However, Bailey et al. (2006) found that when respondents were waiting idly, a particular interval was reported to be shorter when familiar as opposed to unfamiliar music was played. Nevertheless, these studies investigated the effects of ambient music in retail settings rather than controlled laboratories.

Prospective time interval estimation refers to the ability of predictions about attention and learning. This ability is thought to rely on the working memory processes (Taatgen, Van Rijn & Anderson, 2007). Furthermore, studies on the neural mechanisms of time estimation suggest that time may be encoded by firing patterns, with "time-stamp" neurons emitting spikes after an event of a specified time interval. These "time-stamps" can be used to track the duration of new stimuli (Dehaene, Meyniel, Wacongne, Wang & Pallier, 2015), including music stimuli.

On the one hand, unfamiliar music may place higher demands on working memory than familiar music. This is indicated by Hilliard and Tolin (1979), Foutaine and Schwalm (1979), Etaugh and Michals (1975) and Wolf and Weiner (1972) that performance of cognitive tasks in the presence of familiar background music is better than in unfamiliar background music. Considering that unfamiliar background music may have stronger working memory demand, and

it will in such a way interfere with time perception, which causes less frequent checking of time. Thus, the estimation for unfamiliar music may be longer. On the other hand, familiar music may lead to a successful prediction of the next music phrase, and may, therefore, interfere with the time perception decision process. Consequently, the estimation for familiar music may be longer.

Therefore, it is expected that familiarity of music also affects time perception, and the time perception in the background of familiar pieces of music is different from in the unfamiliar pieces. Apart from investigating the effect of music, this paper aims to provide insight into the link between time perception, working memory and familiarity (of music). Furthermore, previous studies were not set in laboratories, so another objective of this paper is to provide a more controlled test in the laboratory of the influence of music familiarity on time perception.

Finally, a cognitive model has been built based on hypothesis explaining the behavioral experiment results. Chikhaoui has made an ACT-R model of music named SINGER with his colleagues (2009). SINGER can learn a song and recall the learned melody, which separates music pieces into phrases with a certain length of duration. There are strong associations between every two adjacent phrases, while the associations between any other two phrases are weak, but noises in the model can make the value of associations change. When SINGER needs to recall a melody, it will retrieve the phrase which has the highest association with the current phrase, and this phrase-retrieving cycle will continue during the recalling process. What's more, auditory representation for each item typically lasts for 0.5 sec to 2 secs (Baddeley, 2000), which is the reason why SINGER sets all the music phrases with the same time duration.

Methods

Participants

There were 28 participants (21 female) in total taking part in this experiment. All the participants were aged from 19 to 29 years old (mean 23) and were mostly students in Groningen (from University of Groningen) from 13 different countries. The range of age (18-30) was determined to make sure most of them should be familiar with the familiar songs designed. All participants had normal hearing and normal visual acuity. Informed consent forms have been filled in before the experiment.

Design

During the test, participants were asked to reproduce a specified time duration for several times while listening to various music pieces which they are either familiar with or unfamiliar with.

Table 1 List of Familiar Music

Year	Rank at the Year	Title	Artist(s)
2016	1	Love Yourself	Justin Bieber
	2	Sorry	Justin Bieber
	3	One Dance	Drake featuring Wizkid and Kyla
	4	Work	Rihanna featuring Drake
	5	Stressed Out	Twenty One Pilots
	6	Panda	Desiigner
	7	Hello	Adele
	8	Don't Let Me Down	The Chainsmokers featuring Daya
	10	Closer	The Chainsmokers featuring Halsey
2015	1	Uptown Funk	Mark Ronson featuring Bruno Mars
	2	Thinking Out Loud	Ed Sheeran
	3	See You Again	Wiz Khalifa featuring Charlie Puth
	4	Trap Queen	Fetty Wap
	5	Sugar	Maroon 5
	6	Shut Up and Dance	Walk the Moon
2014	1	Happy	Pharrell Williams

Year	Rank at the Year	Title	Artist(s)
	2	Dark Horse	Katy Perry featuring Juicy J
	3	All of Me	John Legend
	4	Fancy	Iggy Azalea featuring Charli XCX
	5	Counting Stars	OneRepublic

The music pieces were chosen from Billboard, and they were all English songs. Familiar music pieces were chosen are top 10 from Hot 100 Songs Year-end Charts in the year 2014, 2015 and 2016. Chart rankings of Billboard Hot 100 are based on online streaming, radio playing and sales (both physical and digital), which ascertained that top 10 of recent years' year-end charts were probably heard by most young adults (18-30 years old) from diverse countries. (See Table 1.) Unfamiliar music pieces were selected from The Hot 100 weekly charts. These unfamiliar songs were ranked 99 or 100 on charts from the year 2010 to 2016, and merely on the charts for one or two weeks, which were possibly the songs not disliked by young adults and unfamiliar to them while having similar genres and types as the familiar music pieces. (See Table 2.) What's more, all the music pieces were segmented into one-minute long (start from the beginning) with the code from Tzanetakis, Essl & Cook (2001). Additionally, they were all set to the same volume before the experiment.

Table 2   List of Unfamiliar Music

Week(s) on Chart	Top Rank	Title	Artist(s)
5-Dec-15	100	Never Enough	One Direction
15-May-10	100	New Morning	Alpha Rev
25-Jun-11	100	Teenage Daughters	Martina McBride
10-Jan-15	100	Title	Meghan Trainor
3-Dec-11	100	Shot For Me	Drake
31-Oct-15	100	Love Me	The 1975
1-Mar-14	100	Explosions	Ellie Goulding
17-Mar-12	100	Thank You	Estelle

Week(s) on Chart	Top Rank	Title	Artist(s)
29-Aug-15	100	100 Grandkids	Mac Miller
22-May-10	99	All Or Nothing	Theory Of A Deadman
19-Mar-11	99	21st Century Girl	Willow
10-Oct-15, 24-Oct-15	99	Hold Each Other	A Great Big World featuring Futuristic
7-May-16	99	Let Me Love You	Ariana Grande featuring Lil Wayne
11-Jul-15, 15-Aug-15	99	Like I Can	Sam Smith
25-Feb-12	99	La Isla Bonita	Glee Cast featuring Ricky Martin
13-Feb-10	99	Hurry Home	Jason Michael Carroll
29-Oct-11	99	Lost In Paradise	Evanescence
24-Jul-10	99	Up On The Ridge	Dierks Bentley
26-Dec-15	98	Drifting	G-Eazy featuring Chris Brown & Tory Lanez
10-Sep-16	98	Nights	Frank Ocean

The time duration participants learning and reproducing was fixed to six secs. Participants were presented a yellow round on the screen, and the length of which was the particular time interval participants learning and reproducing. During learning, the yellow dot appeared and disappeared automatically; while during reproducing, the yellow round appeared automatically, and the participants needed to press the spacebar when they thought it was six secs in order to make the yellow dot disappear. The participants were asked not to count in mind during reproducing in case the reproduced time durations were too precise to be influenced by the background music. Moreover, there was no feedback on whether the reproduction is correct or not.

Two questions about the music were needed to be answered after the participants heard a piece of music: (1) Do you like this song? (2) Have you heard of this song? Answers had five scales to each question: "Definitely yes (score zero)", "Probably yes (score one)", "Uncertain (score two)", "Probably no (score three)", "Definitely no (score four)". According to Pereira,

Teixeira, Figueiredo, Xavier, Castro & Brattico (2011), likeability of music has a strong effect on

time perception, so it has been included as a question. Besides, the five scales which are from

"Definitely yes" to "Definitely no" were equaled to score zero, one, two, three and four in order

to be simply analyzed.

Before the formal experiment, a pilot experiment had been done. After the pilot

experiment, the behavioral experiment's program has been optimized. Moreover, the music

selections had been improved based on the feedback. The pilot data was not included in the

pivotal study.

Procedure

Learning section and reproducing section were formed as the whole experiment for each

participant. Music was played only in the reproducing part.

In the learning section, the participants were presented the six-second time interval for

three times with no sound in the background.

There were 60 blocks in reproducing section. Among 60 blocks, 20 were in control

group, which had no sound in the background, 20 were blocks with unfamiliar music in the

background, and the rest were with familiar music in the background. However, all the 60 blocks

were randomly presented to the participants.

In each block, participants first learned the six-second duration once again, in order not to

drift away from the effects of music they previously heard. Then, they were asked to produce the

time interval they had learned for four times while listening to a particular piece of music, which

was the only situation that had various background stimuli. The one-minute music pieces started

earlier than the first reproduction concerning to exert enough influence on the first reproduction,

and the music would end after the participants had finished the fourth reproduction. Finally, two

questions about the music they had heard were asked in the questions section.

<div align="center">Results</div>

Two participants who had not adhered to instructions of the task were removed from the

dataset. Data with no reproducing time or no answers to the questions were discarded (0.14% of

the data). Outliers in reproducing times exceeding 1 to 14 secs were also removed (1.98% of the

data). All error bars are standard errors.
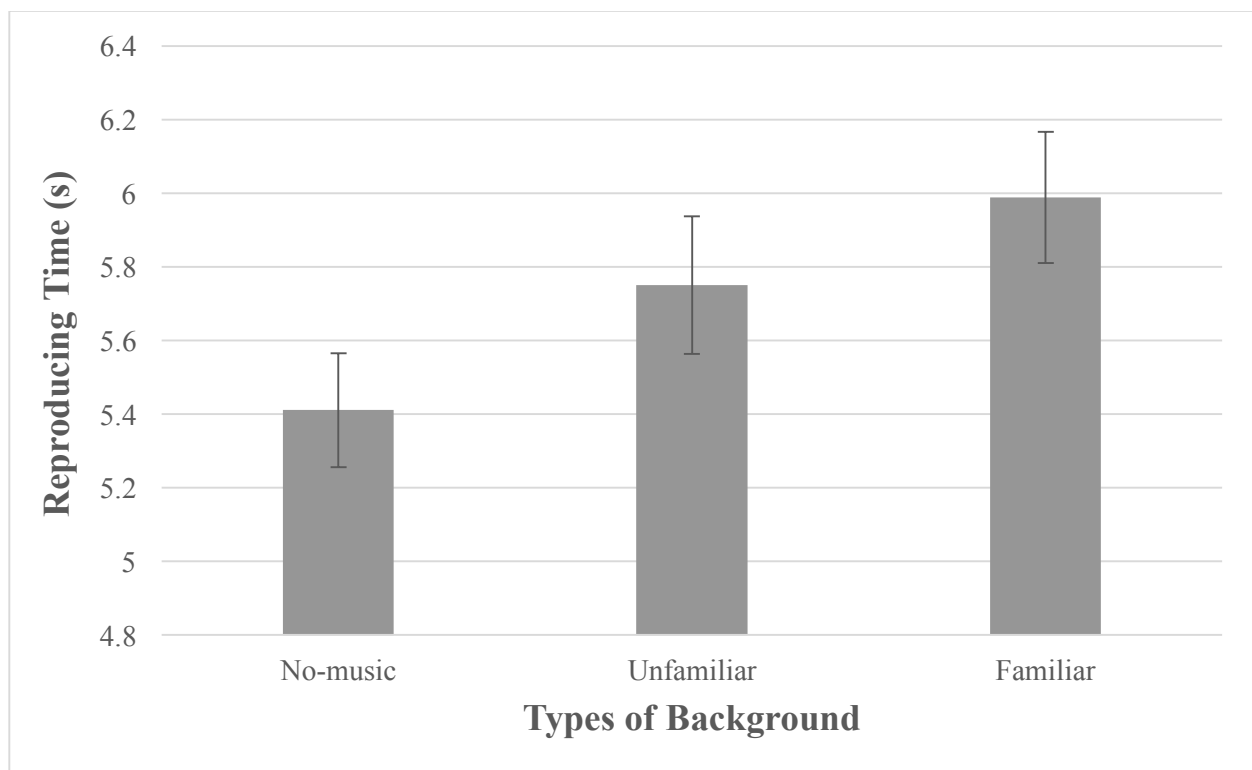
Figure 1. Experiment data results on the influence of different backgrounds on time perception

(No-music, unfamiliar music and familiar music backgrounds).

Figure 1 shows the experiment results of different backgrounds' effects on time

perception including no music (scale "uncertain"), unfamiliar music (scale "Probably no" and

"Definitely no") and familiar music (scale "Probably yes" and "Definitely yes") backgrounds. It

is clear that when there was no music in the background, participants tended to reproduce much shorter time durations. Moreover, familiar background music tended to make people reproduce longer time durations than unfamiliar background music.

In order to analyze the effects in more detail, linear mixed-effect models had been fit to each time intervals (Baayen, Davidson & Bates, 2008). The contribution of single factors to one dependent variable can be tested from linear mixed-effect models as well as the estimates.

Table 3   Results of fitting mixed-effect models

Data used	Model name	Factor	Beta (SE)	t
All Data	With/Without music	intercept(ms)	5419.4 (141.89)	38.19***
		with music	473.26 (48.36)	9.79***
Data Excludes the Control Condition	Familiarity	intercept(ms)	5958.5 (148.14)	40.22*
		familiarity	-40.34 (18.37)	-2.2*
	Likeability	intercept(ms)	6055.12 (148.28)	40.84***
		likeability	-105.82 (21.43)	-4.94***

Note: * p < .05, ** p < .01, *** p < .001

Table 3 demonstrated the results for linear mixed-effect models. The first model showed in Table 3 which was the model of with/without music had used all data; nevertheless, the model of familiarity and the model of likeability had used the data excluding the no background music condition.

Take familiarity model as an example, the predicted reproducing time includes a fixed intercept of 5958.5 ms, because from "definitely familiar" to "definitely unfamiliar" were set to zero to four, namely five scales answers. For the factor familiarity, the estimate was -40.34, which meant that the more unfamiliar the music was, the shorter the reproducing time was compared with the intercept, i.e. participants tended to reproduce longer time durations for more familiar music. As for likeability, it had the same scale setting as familiarity's, so the more unenjoyable the background music was, the less reproducing time duration it would be.

Similarly, it can be significantly stated that with music in the background, the reproducing time

would be 473.26 ms longer than without music, which was the same as shown in Figure 1.

Finally, the influence of likeability and familiarity were compared together in one model;

however, the combined model did not fit the data better than the models with just one of the two

fixed effects (i.e., familiarity or likeability).

Generally, subjects were apt to reproduce the same time duration longer in the

background with music than without music. They were also likely to reproduce the time interval

longer in the background with familiar music than unfamiliar music.

Model

Based on the results we obtained from the experiment, a cognitive model has been made

to explain the results.

This cognitive model is built with PRIMs, which is a cognitive architecture evolved from

the ACT-R cognitive architecture (Taatgen, 2013). There are two primary goals of the model:

reproducing time intervals and listening to music. The two goals compete during the working of

the cognitive model. The cognitive model had six modules to work within this time reproducing

task ranging from the declarative memory module, procedural module, temporal module, aural

module, visual module and manual module. (See Figure 2.) The declarative memory buffer in

PRIMs corresponds to the working memory, which has been raised before.

The reproducing-time-intervals part of the cognitive model is based on Taatgen, Van Rijn

& Anderson (2007), and the listening-to-music part of the model relies on Chikhaoui et al.

(2009). One hypothesis of the model to explain the results in Figure 1 is that the two goals both

are doing retrieving and comparing work. A music piece is separated into several different

phrases with the same time duration. The fixed duration is 0.5 sec in this case that is tested as the

best fitted one in the model, i.e. the duration which is not too short to let the model pursue, either not too long to have any interference of music. Therefore, if the declarative memory buffer is available, it will retrieve or predict a new phrase, then this phrase will be compared with the phrase which has merely been "heard" by the aural module. If the result of the comparison is positive, which is the condition when the background music is familiar, the listening to music goal might have higher activation to continue this retrieve-compare cycle. However, if the background music is unfamiliar, then the result might be negative, then the cycle might stop.
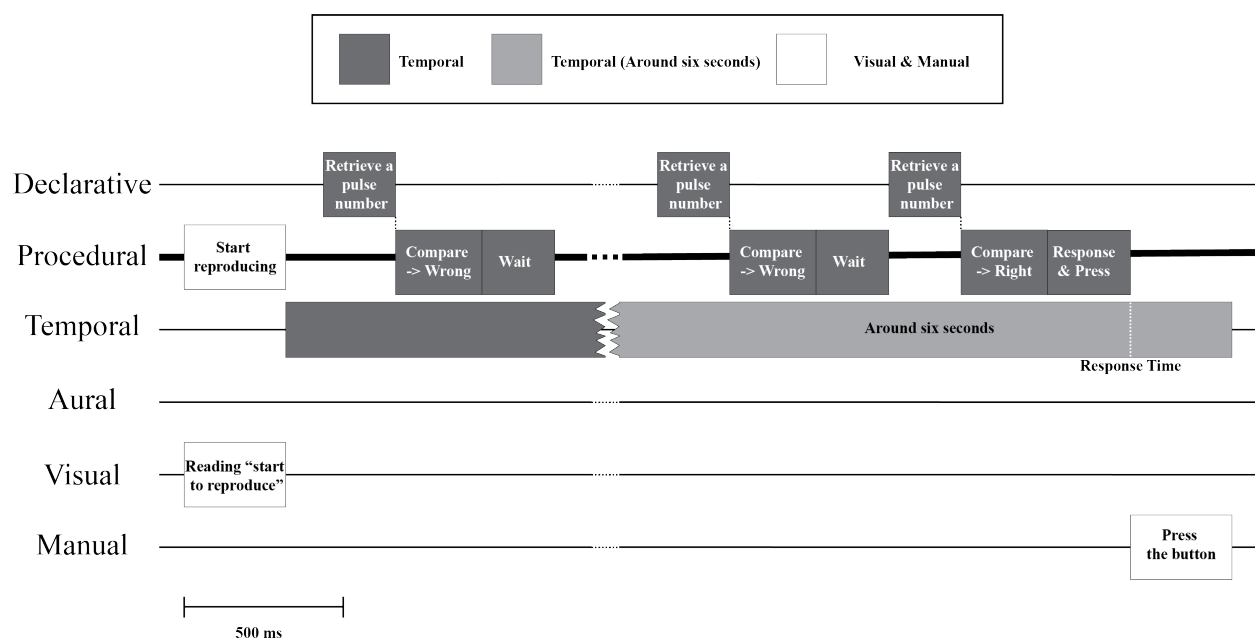
Figure 2. An example process timeline of doing time perception tasks without music as background.

The example process timelines in Figure 2, 3 and 4 illustrate how the cognitive model works while the two goals are competing with each other. Figure 2, 3 and 4 are the models doing time reproducing tasks with no music, with unfamiliar music and with familiar music in the background. Three figures all provide examples with the same beginning, it "reads" the instruction "start to reproduce", and launch the temporal module to count the pulse.
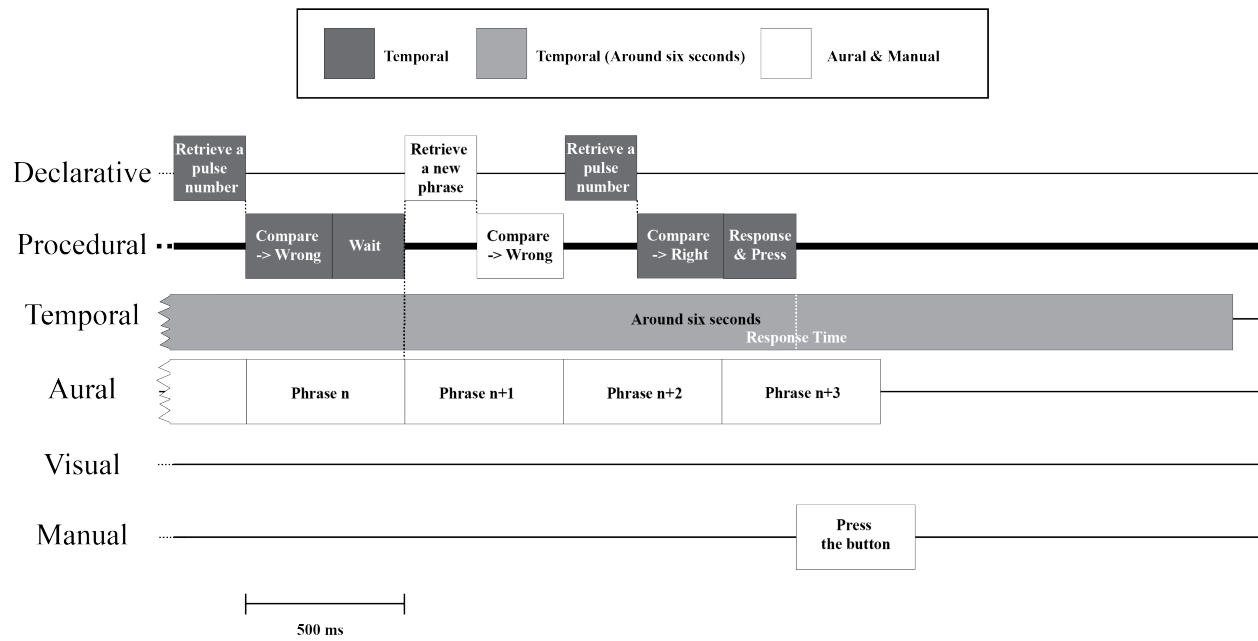
Figure 3. An example process timeline of doing time perception tasks with unfamiliar music as background.
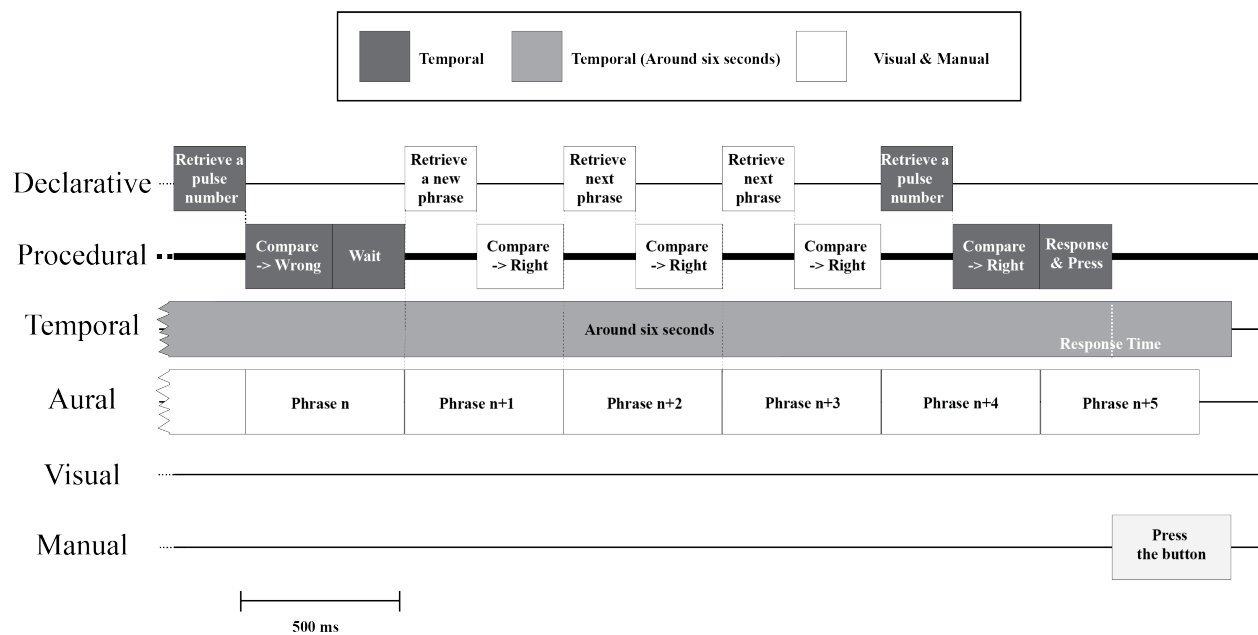

Figure 4. An example process timeline of doing time perception tasks with familiar music as background.

In the condition when there is no music in the background (See Figure 2), the only thing the model does is checking the time and waiting. Firstly, the model retrieves a pulse number which is most activated at that moment. Then, it compares the pulse they have retrieved just now with the pulse they have counted in the temporal module. If the two pulse numbers are the same, or the pulse they have counted is larger than the retrieved one, then the model will stop counting and response with pressing the button; if the retrieved pulse number is greater than the pulse they are counting, they will continue the retrieve-compare cycle.

In the unfamiliar and familiar music conditions (See Figure 3 & 4), the examples in the figures merely show what happens around six secs, which is the end of time reproducing, but also the point that matters how long the time it reproduces. One of the reproducing-time-intervals goal and listening-to-music goal is active when it has a higher activation than the other one in the model. Once the temporal module has accounted the pulses around six secs, any time when the model retrieves a pulse from declarative memory may cause the model stop and press the button to react the end of the reproduction. However, if the listening to music goal is active, and the music is familiar, which causing positive result after comparison, it might continue its retrieve-compare cycle because of its high activation. Consequently, the declarative memory is occupied by the phrase it retrieves, and no longer available for retrieving any pulses. On the other hand, when the music is unfamiliar, the model has more chance to retrieve and compare a pulse number, and it is more likely to end the reproduction on time.

The results of the model are displayed in Figure 5. It demonstrates that the model is reproducing much shorter time durations when there is no music in the background. Besides, when the background music is familiar other than unfamiliar, the model tends to reproduce longer time intervals.
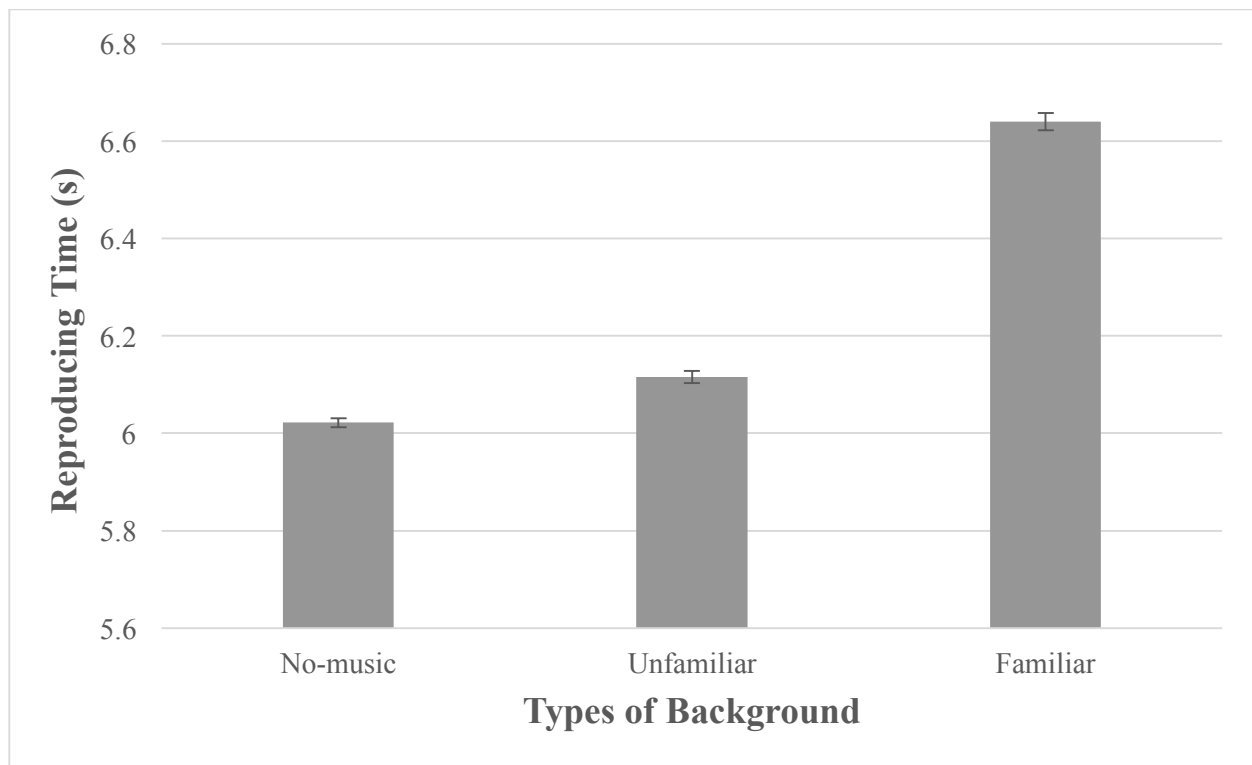
Figure 5. Model results on the influence of different backgrounds on time perception (No-music, unfamiliar music and familiar music backgrounds).

Discussion

In the results we have obtained, the familiarity of music significantly affects time perception, and the time perception in the familiar background music is different from in the unfamiliar background music. It proves that the hypothesis of the influence of familiarity music on time perception is correct, and people tend to reproduce longer time intervals in familiar background music because their attention is consistently captured by the music. The significant result that time perception is different in the background with music than without music, which also supports the hypothesis that there is a tight link between time perception and background music. Furthermore, it is clear that likeability has a strong effect on the reproducing time results. If the hypothesis of the effect of familiarity is right, it can also hypothesize that the music people

like is similar to the music people familiar with, it can make people pay more attention to the music than reproducing time, and even more compared to familiar music.

Comparing Figure 1 and Figure 5, it indicates that the model has the same tendency on time durations of three conditions: from no background music to unfamiliar background music, then to familiar music, same time intervals are reproduced longer. Notwithstanding, the distinction in the model between with music in the background and without music in the background is not as sharp as the experiment data.

Tentatively, the prediction theory, which states that there is an interaction between the familiarity of music and time perception, may be right but requires further empirical confirmation.

The model is built after getting the results. The interference between time perception and music listening should be working memory as it has mentioned before. Nevertheless, working memory is not explicitly defined in ACT-R and PRIMs. The conflict between time reproducing and music listening in the model is mainly a declarative memory aspect. In fact, most models of typical working memory tasks use declarative memory to store items to be memorized. Therefore, maintaining the correct number of pulses for the six sec interval is apparently a working memory aspect. Familiar music is not directly a working memory element but does use declarative memory to produce the interference. Moreover, familiar music has a working memory aspect, in which the prediction of the next phrase is held until it actually arrives.

The number of data points the cognitive model can predict now is limited. Therefore, it would be good to let the model make a prediction that we can then test. For example, the model can predict doing other tasks instead of time perception tasks while listening to familiar and unfamiliar music. These tasks can include visual perception tasks, memory tasks, etc. Then

behavioral experiments are designed and conducted to prove if the prediction is right. There are

also other factors can contribute to the length of reproducing time, including other musical

elements and factors not concerned with music. Further research can test these factors and

combine them together in one implemented cognitive model. Therefore, it may predict more

reliable and fitting results.

We feel that the time flies when we listen to the music which is more familiar to us.

Environments, where there are long queues, can play hot music in the background, which may be

familiar to most people, to make people feel the waiting time shorter.

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