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# The Influence of Music and Music Familiarity on Time Perception

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## Abstract

Previous research has shown that secondary tasks sometimes interfere with the perception of time. In this study, we look at the impact of background music, and the familiarity of music on the reproduction of a time interval. We hypothesize that both music listening and attending to time require declarative memory access, and that conflicts between the two can explain why the reproduced intervals are longer when participants listen to music. A cognitive model based on the PRIMs architecture, but built from two existing models can explain the data, including the effect of music familiarity. The model is a combination of two existing models: one of time perception, which requires occasional memory access to check whether the interval is already over, and one of music perception, which tries to predict the next musical phrase based on the one currently perceived. The memory conflict between the two models reproduces the effects found in the data.

**Keywords:** time perception; music; multitasking; declarative memory; cognitive model

## Introduction

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, likability, familiarity, etc. (Bailey & Areni, 2006; Kellaris & Kent, 1992; Baker & Cameron, 1996)

Although many studies have shown that secondary tasks affect time perception, 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 and Areni (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.

The effects of secondary tasks on time perception have traditionally been explained by the *attentional gating theory* (Zakay & Block, 1997). According to this theory, the passage of time is only perceived if it is attended to, which means that if one pays less attention to time, it seems to flow faster. An alternative theory was proposed by Taatgen, van Rijn and Anderson (2007). They found that in many multitasking situations, time perception itself is not affected at all by secondary tasks. However, if time perception is a component of

one of multiple tasks, it needs to be checked occasionally, and this checking step may be affected by competing task components. In other words, time perception is not like an alarm that goes off after the predetermined amount of time has elapsed, but more like a watch that needs to be checked occasionally to see whether the interval has finished. According to Taatgen et al., a “time check” requires a (declarative) memory retrieval followed by a decision. Secondary tasks that have a heavy memory component are therefore expected to have a particularly disruptive effect on time perception.

A part of listening to music is the attempt to predict the next musical phrase based on the current one (Beaudoin et al., 2009). Given that this prediction requires memory, we expect that if we have to produce a certain amount of time (we will use 6 seconds in our experiment), our production will be too long while listening to music, because we check whether the interval is over less often. It is less clear what to predict regarding the difference between familiar and unfamiliar music. On the one hand, unfamiliar music may place higher demands on memory than familiar music, because new information needs to be stored. Hilliard and Tolin (1979), Fontaine and Schwalm (1979), Etaugh and Michals (1975) and Wolf and Weiner (1972) found 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 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 chain of successful predictions of the next music phrases that is harder for the time perception process to interrupt. Consequently, the estimation for familiar music may be longer.

The goal of this research is to investigate the influence of music on time perception in a more controlled laboratory setting, and to construct a cognitive model to explain the results. The model is based on the time estimation model from Taatgen et al. (2007), and an ACT-R model of music perception named SINGER by Beaudoin et al. (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 noise in the model can make the value of associations change. When SINGER needs to recall a melody,

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
	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

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
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

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 between 19 and 29 years old (mean 23) and were mostly students in Groningen

(from University of Groningen) from 13 different countries. The age range was determined to make sure most of them would be familiar with the songs that were designated as familiar. 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.

The music pieces were chosen from Billboard, and they were all English songs. Familiar music pieces were chosen from the top 10 from Hot 100 Songs Year-end Charts in the year 2014, 2015 and 2016. Chart rankings of the Billboard Hot 100 are based on online streaming, radio playing and sales (both physical and digital), which ascertained that the top 10 of recent years year-end charts were probably heard by most young adults 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.) All the music pieces were segmented into one-minute long episodes (start from the beginning) with the code from Tzanetakis, Essl, and Cook (2001). Additionally, they were all set to the same volume before the experiment.

The time duration that participants had to learn and reproduce was 6 seconds. Participants were presented a yellow circle on the screen. During learning, the yellow circle appeared and disappeared automatically after 6 seconds. During reproduction, the yellow circle appeared automatically, and the participants needed to press the spacebar when they thought the 6 seconds were over. The participants were asked not to count during reproduction. Moreover, there was no feedback whether the reproduction was correct.

After the participants heard a piece of music, they were asked to answer two questions: (1) Did you like this song? (2) Have you heard of this song before? Answers had to be given on a scale from 0 to 4: Definitely yes (score zero), Probably yes (score one), Uncertain (score two), Probably not (score three), Definitely not (score four). According to Pereira et al. (2011), likability of music has a strong effect on time perception, so it has been included as a question.

## Procedure

The experiment consisted of a learning part and reproduction part. Music was played only during the reproducing part.

In the learning part, the participants were presented the six-second time interval three times.

There were 60 blocks in reproducing section. Among 60 blocks, 20 were in the control condition, which had no sound, 20 were blocks with unfamiliar music, and the remaining 20

were with familiar music. The 60 blocks were presented in random order.

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 with music present or absent depending on condition. When present, the one-minute music pieces started before the first reproduction, and the music would end after the participants had finished their fourth reproduction. Finally, the two questions about the music they had heard were asked.

## Results

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 outside of 1 to 14 secs were also removed (1.98% of the data). All error bars are standard errors.

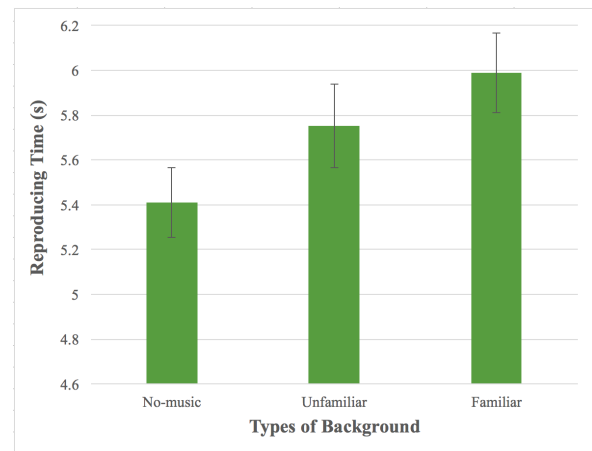


Figure 1: Experiment data results on the influence of different backgrounds on time perception (No-music, unfamiliar music and familiar music background).

Figure 1 shows the experiment results of the different conditions (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 we used linear mixed-effect models (Baayen, Davidson, & Bates, 2008).

Table 3 shows the results of three linear mixed-effect models. Model 1 compares the condition without music to the conditions with music, which are significantly different. The unfamiliar and familiar conditions are not significantly different from each other, despite the difference. However, if we use the familiarity score that subjects have gave to each

Table 3: Results of fitting mixed-effect models.

Data Used	Model Number	Model Name	Factor	Beta(SE)	t
All Data	Model 1	With/Without Music	Intercept(ms)	5419.4 (141.89)	
			With Music	473.26 (48.36)	9.79***
Data Excludes the Control Condition	Model 2	Familiarity	Intercept(ms)	5958.5 (148.14)	
			Familiarity	-40.34 (18.37)	-2.2*
	Model 3	Likability	Intercept(ms)	6055.12 (148.28)	
			Likability	-105.82 (21.43)	-4.94***

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

of the music pieces (presumably a better estimate of familiarity), we do find a significant impact of familiarity (Model 2 in Table 3). Moreover, likability is an even stronger predictor of a longer time estimate (Model 3). Adding both familiarity and likability, with or without interaction, does not improve the model.

### 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). PRIMs is particularly suitable for handling multiple parallel goals. There are two primary goals of the model: reproducing time intervals and listening to music. The two goals compete during a model run. The cognitive model has 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 basic assumption of ACT-R and PRIMs is that modules can operate in parallel, even on multiple tasks, but that a particular module can only do a single thing at a time (Salvucci & Taatgen, 2008).

The reproducing-time-intervals part of the cognitive model is based on Taatgen et al. (2007). The assumption of that model is that we maintain a mental representation of the interval in our declarative memory. This representation can be checked against the currently elapsed (subjective) time. To do this, it has a short procedure that retrieves the representation from memory, compares it to the current time, and decides whether the interval is over or not. Figure 2 illustrates this part of the model.

The listening-to-music part of the model is based on Beaudoin et al. (2009). A music piece is separated into several different phrases of approximately 0.5 seconds. Whenever the model hears a music phrase, it tries to predict the next phrase using declarative memory. It can then test this prediction against the real perceived phrase, and if successful predict the next. If the prediction is unsuccessful, either because the declarative retrieval fails, or it turns up an inaccurate phrase, the process is interrupted, and the model has to pick up the thread again by listening to the next phrase. Figure 3 show the timeline when prediction is successful. In that case,

the music listening part of the model can occupy declarative and procedural memory for longer periods of time, interfering with time perception, and causing delays in response. Figure 4 on the other hand shows the case where the model is not successful in its predictions, opening up more opportunities for the time perception part of the model to check whether the interval is already over.

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.

### Discussion

The experiment confirms the hypothesis that background music indeed leads to longer reproduction times. Moreover, more familiar and likable music leads to even longer reproduction times. The cognitive model is able to capture both main effects, even though the exact fit is not perfect. One of the reasons is that the model has a strict division between unfamiliar and familiar, whereas in participants some of the unfamiliar music may be familiar, and some familiar music is unfamiliar. The model has been constructed by combining two existing models with limited amount parameter estimation (mainly the choice of 0.5 second musical phrases). Even though PRIMs has inherited many parameters from ACT-R, these parameters do not affect the qualitative fit of the model.

An aspect of the data that the model currently does not capture is the effect of likability. This may play a role in a better ability to predict the next phrase. Alternatively, a more likable song can influence the priorities between the two goals: a more likable song may boost the priority of the listening-to-music goal. Even though the PRIMs architecture is capable of modeling such priorities, we refrained from doing so here, because the extra explanatory power is small compared to the added parameters.

The model presented here is based on the time perception model by Taatgen et al. (2007). The data, however, do not explicitly rule out an explanation along the attentional gating theory (Zakay & Block, 1997). However, according to the model presented here, music does not affect time perception directly, but instead how frequent people think about time. The conclusions therefore extend to situation in which peo-

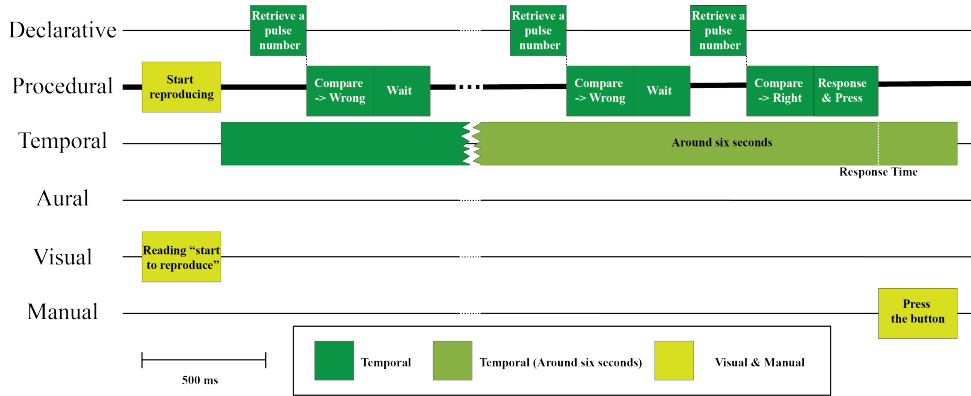


Figure 2: An example process timeline of doing time perception tasks without music as background. Time progresses from left to right in the figure, and each line represents a cognitive module. Boxes on these lines indicate that the module is active, with the label inside the box indicating what it is doing. Note that in this and subsequent Figures procedural steps take less time than suggested (around 50–100 ms), whereas declarative retrievals are typically longer.

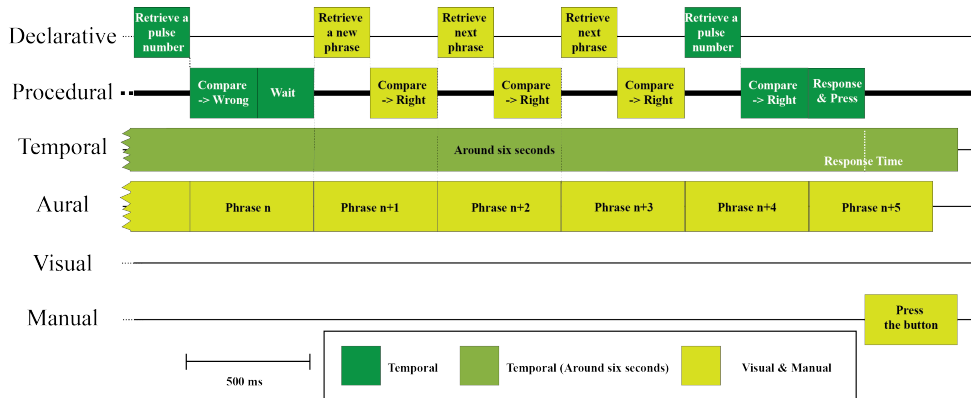


Figure 3: An example process timeline of doing time perception tasks with familiar music as background. Both tasks compete for declarative and procedural memory. The assumption of the model is that a perceived musical phrase can trigger a memory retrieval to predict the next phrase. In this example the familiarity of the music means that predictions are generally successful, making time perception checks less frequent.

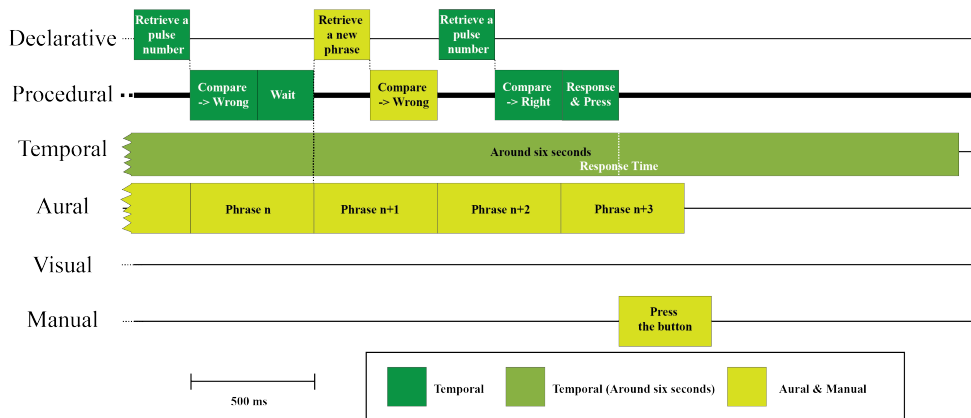


Figure 4: An example process timeline of doing time perception tasks with unfamiliar music as background. If that retrieval fails because the music is unfamiliar, it has to be restarted, but this also gives time perception a chance to check whether the interval is over.

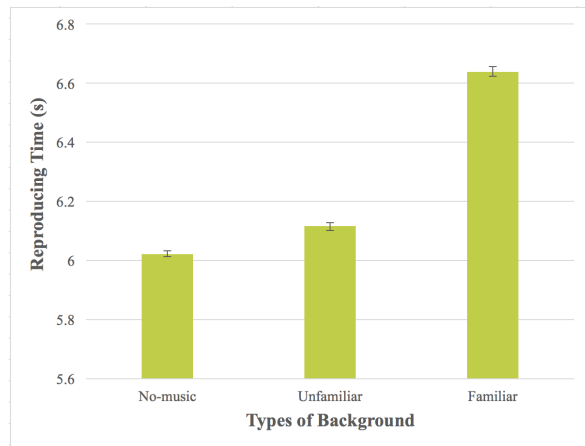


Figure 5: Model results on the influence of different backgrounds on time perception (No-music, unfamiliar music and familiar music backgrounds).

ple listen to music for longer periods of time than what is normally studied in interval time perception (typically intervals not exceeding 30 seconds). This means that in situations where people have to wait for extended periods of time, the presence of music can help diminish the annoyance of having to wait. However, this mainly works when the music is familiar and likable, which is not necessarily true for all “elevator music”.

We have to be a bit careful about drawing conclusions from this study. 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.

A further caveat is that the model has been built after getting the results, even though it is justified by earlier models. The number of data points it can predict 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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